SPICES AND AROMATIC PLANTS

Challenges and Opportunities in the New Century

Contributory Papers

Centennial Conference on Spices and Aromatic Plants

September 20 - 23, 2000
Calicut, Kerala

Indian Society for Spices

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CONTRIBUTORY PAPERS

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FOREWORD

India, is often called as the spice bowl of the world. The richness and diversity of spices and aromatic crops found in India are really amazing. India is also the center of diversity for major spices like black pepper, cardamom, large cardamom and possibly for ginger and turmeric. It was that attracted foreign traders to the Indian sub continent in ancient times, which culminated in the landing of Vasco-da-Gama near Calicut on May 20, 1498.

Spices and aromatic crops constitute a major part of the medicinal plant wealth of India and vast majority of the people of our country depend on traditional and tribal medicines. The role played by spices and aromatic crops is remarkable in the history of healthcare of Indian people from time immemorial. As we begin a new century and a new millennium, it is quite appropriate to take stock of the achievements that we have made in the Indian Society for Spices and the Indian Institute of Spices Research for taking the timely lead in organizing the Centennial Conference on Spices and Aromatic Crops at Calicut during 20-23 September 2000. This publication comprises of 75 contributory papers that are to be presented during the Conference. These papers cover different areas of research and throw light into the present status of spices and aromatic crops research in our country. Needless to say that this timely effort will go a long way in realizing our achievements, in pin-pointing the gaps existing in our understanding and giving a direction for the future.

I take this opportunity to congratulate the Indian Society for Spices who has championed the cause of spices research and development in the country, for their endeavour in organizing this important conference and for bringing out this useful publication. I deem it my proud privilege to present this volume before the spice workers of the country.

S. P. Ghosh

(S. P. Ghosh)
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ICAR, New Delhi

PREFACE

The Indian Society for Spices (ISS) has completed a decade of its existence. During this period, the Society could carve a niche of its own, and could effectively provide a forum for the benefit of research and development workers in the area of Spices and Aromatic crops. Among the various professional societies in India the ISS is recognized as a vibrant one. During the past one decade of its existence the Society organized six seminars/symposia on various theme areas. The Centennial Conference on Spices and Aromatic Plants (CC - SAP) is the seventh in the series.This publication is a compilation of the scientific papers accepted for presentation in the conference during 20-23 September 2000. Unlike in previous seminars, this time full text of all contributory papers are brought out as a book before the conduct of the conference to ensure better interactions and deliberations, and also to avoid any possible delay in publication of the papers.

The contributory papers, 75 altogether, are arranged theme-wise 1. Crop Improvement & Biotechnology (22), 2. Crop Production (33), 3. Economics & Marketing (3), 4. Crop Protection (8) and 5. Post Harvest Technology (9). Among various crops, issues related seed spices are addressed in 20 papers while 13 are on aromatic plants. Major spice crops that are covered are black pepper, cardamom, ginger, turmeric, chillies and tree spices.

The invited papers, theme addresses (plenary lectures), recommendations and report on the conference will be brought out as Proceedings.

The opinions expressed in the papers contained in this volume are that of the authors and need not represent the views of the ISS. Due to paucity of time, none of the papers could be edited fully except for formatting them uniformly.

The financial assistance provided by National Horticulture Board, Ministry of Agriculture, Government of India for publication of this volume is gratefully acknowledged.

Publication Committee.

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Session I

Crop Improvement & Biotechnology

In vitro microrhizome production in four cultivars of turmeric (*Curcuma longa* L.) as regulated by different factors

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Abstract

Microrhizomes were produced from tissue culture derived shoots of four cultivars of turmeric (*Curcuma longa* L.) by transferring them to the liquid medium of Murashige and Skoog (MS) supplemented with 6-benzyl adenine (BA) (1-5 mg/l), enhanced concnetration of sucrose (50-100 g/l) and with reduced photoperiod (0-8 hrs). BA (3 mg/l), Sucrose (60 g/l) and photoperiod (4 hrs) was found to be most effective for induction of microrhizome in all four varieties of turmeric (*Ranga, Rashmi, Roma & Surama*). Microrhizomes were formed at the base of the shoots grown on the medium after 30 days of incubation at 25±1°C. Number of buds per microrhizomes varied from 1-4 in number and the weight varied from 40 mg to 700 mg. Interactions of different factors such as BA, sucrose and photoperiod had significant effect in the induction of microrhizome. Concentration of sucrose was most effective in rhizome formation followed by photoperiod and BA in the medium. Microrhizomes were harvested after 120 days of culture. These microrhizomes could be stored in MS media with low concentration of BA (0.01 mg/l) and in moist sand at room temperature. Microrhizomes were produced *in vitro* independent of seasonal fluctuation and sprouted with roots and shoots in potted soil during planting seasons which were then transferred to the field. These microrhizomes, since produced *in vitro* can be used as disease free seed rhizomes. Storage of microrhizome *in vitro* would facilitate continental and intercontinental germ plasm exchange programme.

Key words : *Curcuma longa*, microrhizome, tissue culture

Abbreviation:

BA = 6 benzyladenine

MS = Murashige and Skoog medium

Introduction

Microrhizomes can be produced *in vitro* independent of seasonal fluctuation like induction of tubers and bulbs in culture. (Abbott & Belcher 1986, Sharma & Singh 1995, Nayak & Sen 1995, Hoque *et al.* 1996, Nayak 1998). These organs serve as planting material, stored and sown like seeds (Bhat *et al.* 1994). Microrhizomes are very useful for transport, field delivery and help in improved field establishment of plants and hence, can be profitable from commercial point of view as has been seen in the application of potato minitubers in germplasm storage, conservation and exchange programme. Therefore, experiments were conducted to induce rhizome formation in tissue culture of four cultivars of turmeric (*Curcuma longa* L.).

Turmeric is a tropical spice and well known as condiment and colouring agent since time immemorial (Wealth of India 1950). In Indian system of medicine, turmeric is used as stomachic, tonic and blood purifier. Turmeric has got the unique combination of its properties like antioxidant, heptatoreactive and anticancer effect (Hasmeda & Polya 1996). Oil of turmeric has got antifungal antiinflammatory and antiarthritic activity and acts as an antacid, carminative and appetiser (Wealth of India 1950, Asolkar *et al.* 1992). Though India leads in production of these species, there is severe shortage of healthy planting material due to low multiplication rate (6x-8x per annum) and high incidence of fungal diseases such as leaf spot and rhizome root. Because of this germplasm collection in clonal repositories are also threatened seriously. So there is distinct need to investigate potential of turmeric for *in vitro* rhozime formation which can alleviate both propagation problem and maintain disease free germplasm bank. Tissue culture studies done so far include only *in vitro* clonal multiplication of turmeric (Nadguda *et al.* 1978, Yasuda *et al.* 1987).

This communication reports successful *in vitro* production of microrhizome in the species of *Curcuma* as effected by different factors. Microrhizome induction has been reported earlier in *Curcuma aromatica* (Nayak 1999).

Materials and methods

Four varieties of *Curcuma longa* namely Ranga, Rashmi, Roma and Suroma were used in the present investigation.

In vitro *shoot culture*

Rhizomes of 4 varieties of *Curcuma* were collected from High Altitude Research Station, Pottangi and planted in sand beds in the garden of Regional Research Laboratory, Bhubaneswar and they sprouted at the onset of monsoon. Turmeric sprouts measuring 1-2 cm in length were cut from the rhozimes and washed with distilled water. After washing the sprouts were surface sterilized with 0.1 per cent mercuric chloride solution for 10-12 min. Surface sterilized sprouts were washed five to six times with sterile distilled water. These sprouts were then transferred to a sterile petridish and sprout cuttings (explants) of about 0.7 cm long were incoculated aseptically into agar-solidified Muraslige & Skoog's (MS)(1962) medium containing various hormone supplements. A single explant was placed in culture tube. Varying concentrations of BA (1,3,5 and 7 mg/l) or a combination of BA (1,3, & 5 mg/l) with either kinetins (0.5 & 1 mg/l) or naphthalene acetic acid (NAA) (0.5 & 1 mg/l) were used for shoot bud multiplication. Subculturing of shoots was done on the same media after 30 days of growth. *In vitro* grown shoots of about 4 cm long were then transferred to MS liquid media and maintained by regular subculturing. Shoots were associated with formation of roots in same media giving rise to complete plantlets.

Induction of microrhizome

For induction of microrhizome, young plantlets (ca 4 cm long) were taken out of the culture tubes aseptically and transferred to MS liquid medium supplemented with Benzyl adenine (BA) alone at different concentration (1, 3, 5 and 7 mg/l) or a combination of BA (1,3,5 & 7 mg/l) and NAA (0.1 & 0.5 mg/l). Sucrose (30, 60 and 90 g/l) and photoperiod (0 hr, 4 hr, 8 hr & 16 hr) were tested in different combinations to study their effect on microrhizome formation. Results obtained in 16 different media mentioned below are studied in details.

M1 - BA (1 mg/l) + Sucrose (30 g/l) + Photoperiod (16 hr light)

M2 - BA (1 mg/l) + Sucrose (60 g/l) + Photoperiod (16 hr light)

M3 - BA (1 mg/l) + Sucrose (60 g/l) + Photoperiod (4 hr light)

M4 - BA (3 mg/l) + Sucrose (30 g/l) + Photoperiod (4 hr light)

M5 - BA (3 mg/l) + Sucrose (60 g/l) + Photoperiod (16 hr light)

M6 - BA (4 mg/l) + Sucrose (60 g/l) + Photoperiod (8 hr light)

M7 - BA (3 mg/l) + Sucrose (60 g/l) + Photoperiod (4hr light)

M8 - BA (3 mg/l) + Sucrose (60 g/l) + Photoperiod (0 hr light)

M9 - BA (3 mg/l) + Sucrose (90 g/l) + Photoperiod (8 hr light)

M10 - BA (5 mg/l) + Sucrose (90 g/l) + Photoperiod (4hr light)

M11 - BA (5 mg/l) + Sucrose (30 g/l) + Photoperiod (4 hr light)

M12 - BA (5 mg/l) + Sucrose (60 g/l) + Photoperiod (16 hr light)

M13 - BA (5 mg/l) + Sucrose (60 g/l) + Photoperiod (8 hr light)

M14 - BA (5 mg/l) + Sucrose (60 g/l) + Photoperiod (4 hr light)

M15 - BA (5 mg/l) + Sucrose (60 g/l) + Photoperiod (0 hr dark)

M16 - BA (5 mg/l) + Sucrose (90 g/l) + Photoperiod (4 hr light)

For solidification of media 0.8% bactoagar was used.

Media were autoclaved at 121°C, 1.05 kg/cm^2 for 20 min and pH was adjusted to 5.7. Cultures were incubated at 25±2°C and grown under white fluorescent light with 55 μ mole m^{-2}s^{-1} light intensity. 15 replications for each treatment was used. The experiment was repeated three times. Periodic observations on percentage of shoots forming microrhizomes, weight and number of buds per microrhizome were noted.

Harvesting, storage and germination of rhizomes

In vitro produced rhizomes were repeatedly washed in tap water, air dried and sown in sterile soil in pot and kept in a nethouse. Rate of germination of microrhizome for each cultivars was recorded. For storage *in vitro* microrhizomes were transferred to fresh MS solid medium containing low amount of BA (0.01-0.1 mg/l).

Statistical analysis of data

Date were subjected to analyse the variance for a factorial experiment.

Results and discussion

In vitro *shoot culture and plant regeneration*

Freshly sprouted shoot buds obtained from the field grown rhizomes of different varieties of *Curuma longa* were cultured on MS based medium supplemented with BA alone or with different combinations of BA and kinetics or BA and NAA. 3-5 lateral shoots were originated from the basal region of the bud explanted on the MS basal medium supplemented with 3 mg/l BA within 30 days of culture. BA (3 mg/l) which was found to be optimum for shoot multiplication in all four varieties of *Curcuma* investigated was also most effective for multiplication of shoots in other species of *Curcuma* (Balachandran *et al.* 1990). Each shoot when subcultured in fresh MS basal media, the rate of multiplication was enhanced giving rise to 6-10 lateral shoots within 30 days. Roots were simultaneously formed on shoots on the same medium and regenerated plants with shoots and roots grew vigorously when they were transferred to MS liquid medium.

Microrhizome induction

For inductio of microrhizome *in vitro* grown shoots of different varieties of *Curcuma longa* were cultured on MS liquid medium containing varying concentrations of BA and sucrose under different photoperiod regimes and result obtained in different media are mentioned in Table 1. All the media tested excepting M1, M2 & M11 were effective in formation of microrhizome *in vitro* (Fig.1) the media (M7) containing 3 mg/BA, 60 g/l sucrose and grown under 4 hr photoperiod was found to be optimum (Table 1). Percentage of explant forming rhizomes in 4 varieties ranged from 77.6-86.2 (Table 1) swelling of shoot bases observed within 25 days of explantation was accompanied by formation of 4-6 adventitious buds and microrhizome. Microrhizome formation (Fig.2) could be clearly visualized after 60 days of incubation. Cultures were transferred to fresh microrhizome induction media at monthly intervals. Microrhizomes harvested (Fig.3) after 120 days of culture were of varying sizes ranging from 40-700 mg in weight in all 4 varieties of *Curcuma longa.*

Number of buds per microrhizome in different treatments varied from 1-4 in number and mean number of buds in media for each variety were given in Table (1). Mean weight of microrhizome in 4 varieties of *C. longa* viz., 'Ranga', 'Rashmi', 'Rossa' and 'Suroma' in different media were tabulated (Table 1). The mean weight of microrhizomes in media (M7) showing optimal response were 320.3 mg, 295.6 mg, 326.3 mg and 308.3 mg, rspectively (Table 1). Factors such as sucrose concentration, growth regulations and photoperiod which have been reported to play important role in *in vitro* induction of bubls, cormus and tubers have also been analysed in this study (Abbott & Belcher 1986. Nayak & Sen 1995. Arora *et al.* 1996).

Role of sucrose, BA and photoperiod and their interaction in microrhizome formation

Rhizome formation *in vitro* in different varieties of *Curcuma longa* was significantly influenced by level of sucrose in the medium. Swelling of shoot bases followed by induction of microrhizome was observed in all the BA supplemented media when concentration of sucrose was enhanced from 30 g/l to 60 g/l. Effect of sucrose on other storage organs (corms and tubes) formation has been reported earlier (Abbott & Belcher 1986, Arrora *et al.* 1996). Rhizome could not be induced *in vitro* in the MS medium containing normal amount of sucrose, *i.e.* 30 g/l. With further increase of sucrose from 60 g/l to 90 g/l, there was marked decrease in percentage of response showing rhizome formation (Table 1). Requirement of enhanced level of sucrose for *in vitro* formation of rhizome may be attributed to the presence of high carbon energy in sucrose since rhizomes contain mostly carbohydrates and sucrose. This assumption has been explained by Bhat

Table 1. Effect of different media on microrhizome formation in 4 varieties of *Curcula longa*

Media	Explant forming rhizome (%)				Mean wt. of rhizome (mg)*				Mean no. of buds/rhizome**			
	Ranga	Rashmi	Roma	Surima	Ranga	Rashmi	Roma	Surima	Ranga	Rashmi	Roma	Surima
M1	-	-	-	-	-	-	-	-	-	-	-	-
M2	8.5	10.2	8.8	11.2	52.2	55.6	48.7	51.3	1.2	1.3	1.2	1.1
M3	24.2	28.5	27.3	23.8	110.5	108.2	120.5	106.3	1.5	1.3	1.6	1.5
M4	-	-	-	-	-	-	-	-	-	-	-	-
M5	30.3	33.5	37.4	32.5	220.3	230.5	205.7	208.6	2.3	2.5	2.6	2.6
M6	72.6	70.3	75.0	71.6	300.5	290.6	290.3	300.6	2.2	2.0	2.0	1.8
M7	80.5	83.2	78.2	77.6	320.3	295.6	326.3	308.3	2.8	2.6	2.5	2.3
M8	36.3	33.3	35.2	32.8	105.3	110.5	96.3	98.2	1.0	1.3	1.1	1.5
M9	43.2	45.5	40.2	38.7	207.5	200.6	215.3	205.5	1.8	2.0	1.6	2.1
M10	45.0	42.5	41.6	46.2	230.2	235.5	240.6	241.3	2.1	2.3	2.0	1.9
M11	-	-	-	-	-	-	-	-	-	-	-	-
M12	16.5	18.3	15.6	18.2	205.5	215.3	195.6	212.2	2.3	2.3	2.5	2.2
M13	56.2	50.5	58.2	52.8	280.3	275.5	290.3	285.6	2.0	1.8	1.9	1.6
M14	60.3	62.3	58.6	60.5	310.3	300.6	318.5	321.2	2.5	2.4	2.2	2.0
M15	23.6	25.1	27.2	25.6	97.6	105.3	115.2	102.2	1.2	1.1	1.0	1.3
M16	40.5	38.2	40.6	36.3	186.3	203.6	196.5	190.7	1.5	1.6	1.5	1.6

Data represents average of 15 replicators per treatment. No response obtained in media No.1, 4 & 11.
*SD in different treatments varies from 20.6-58.5 **SD in different treatment varies from 0.3-0.8

et al. (1994) during microrhizome fomation in ginger.

BA (3 mg/l) was found to be most effective in *in vitro* induction of microrhizome in all the four varieties of *C. longa* studied at enhanced concentration of sucrose (60 g/l) in the medium and with relatively reduced photoperiod (4 hr). No marketed difference in size of microrhizomes was noted by increasing concentration of BA from 3 mg/l to 5 mg/l in medium (Table 1). Amount of BA (3 mg/l) required for microrhizome induction and shoot multiplication was same in *C. longa* unlike in *Zingiber officinale* where microrhizomes were induced in media by enhancing the amount of BA from 1 mg/l to 8 mg/l (Sharma & Singh 1995). Microrhizome formation did not occur *in vitro* in absence of BA in the medium.

Effect of various duration of photoperiods, i.e. 16 hrs, 8 hrs, 4 hrs, and 0 hr (dark) on formation of microrhizome in all the four varieties viz., Ranga, Rashmi, Roma and Surama revealed that microrhizomes wre best initiated in the MS medium grown with reduced photoperiod of 4 hrs, 60 g/l sucrose and BA 3 mg/l. It was observed that microrhizome formation in varieties of *C. longa* was better when cultures were grown with relatively reduced photoperiod (8-4 hr) than grown in dark (0 hr) (Table 1). Cultures grown in dark become etiolated with thin upright stem and rudimentary leaves. Microrhizomes produced in dark had relatively lower number of eyes (1-2) than those produced in light containing 1-5 eyes. This was in close agreement with report of Gopal *et al.* (1998) showing relatively lower number of eye formation in dark during microtuberization in potato. Requirement of relatively reduced photoperiod (8-4 hrs) for improved microrhizome formation in varieties of *C. longa* can be compared with the result obtained during microcuberisation in potato (Abbott & Belcher 1986).

Analysis of variance (ANOVA) for the number of explant forming microrhizome in 4 varieties of *Curcuma longa* by factors such as BA (A), sucrose (B) and photoperiod (C) revealed that sucrose was most effective followed by photoperiod and growth regularities (Table 2). Interactions between BA and sucrose (AxB), sucrose and photoperiod (BxC) as well as BA and photoperiod (AxC) were highly significant as shown in the Table (Table 2). Interactions among BA, sucrose and photoperiod (AxBxC) were also highly significant (P=0.01) for *in vitro* formation of microrhizomes.

Harvesting, storage and germination of microrhizome

Microrhizomes induced in all four varieties of *C. longa* were harvested after 120 days of growth in the medium. These microrhizomes were thoroughly washed with running tap water and air dried in shade. Microrhizomes were produced throughout the year

Table 2. Analysis of variance (ANOVA) for the number of explant forming microrhizome in 4 varieties of turmeric on the media with different combination of BA, sucrose and photoperiods

Source of variation	Degree of	F values observed in different turmeric varieties			
		Ranga	Rashmi	Roma	Surama
Replication (D)	2	0.09*	0.13*	0.08*	0.17*
BA (A)	2	165.13**	218.35**	181.16**	196.21**
Sucrose (B)	2	720.75**	640.36**	686.33**	746.38**
AXB	4	72.26**	58.75**	61.32**	75.25**
Photoperiod (C)	3	325.27**	286.33**	262.72**	250.55**
AXC	6	35.34**	30.27**	27.32**	36.22**
BXC	6	107.25**	92.21**	96.75**	98.12**
AXBXC	12	9.62**	8.94**	8.65**	10.15**

* Not significant ** Significant at P=0.01%

Fig.1. : *In vitro* grown shoot of *Curcuma longa* showing microrhizome formation at the basal region after 90 days of culture.

Fig.2. : Shoot base of *C. longa* plantlet showing clear view of formation of microrhizome after 60 days of culture.

Fig.3. : Harvested microrhizomes of *C. longa* after 120 days of culture.

Fig.4. : Germinating microrhizomes with shoots and roots.

Fig.5. : Microrhizome germinated plants grown in pots.

irrespecrtive of any seasonal fluctuation. Microrhizomes could be stored *in vitro* in the MS basal media supplemented with low concentration of BA (0.01 mg/l) upto 8 months. *In vitro* storage facilitates germplasm conservation and exchange programme at national and international levels. Microrhizomes were also stored *ex vitro* in polybags filled with sand. These microrhizomes which were produced *in vitro* could be used as disease free planting materials. Microrhizomes germinated (Fig.4) in potted soil at the onset of monsoon producing shoots and roots. Plants germinated from microrhizomes showed normal morphology. The freshly sprouted plantlets were grown in potato (Fig.5) and were subsequently transferred to the field for further study.

The present study thus, provides efficient prottocol for *in vitro* microrhizome production in forur varieties of *C. longa.*

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References

Abbott A J & Belcher A R 1986. Potato tuber formation *in vitro* in : Plant tissue culture and its agricultural application (Withers, L.a. and Alderson, P.G. eds.), Butterworths, London, pp.113-122.

Anonymous 1950. In : The Wealth of India. Raw Materials Vol.II, pp.401-402, CSIR, New Delhi.

Arora J S I, Singh K, Grewat H S, Gosal S S & Chanana Y R 1996. *In vitro* Cormel Production from nodal buds and cormel tips in gladiolus, In : Plant Tissue Culture (A.S Islamedt) pp.50-53., Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.

Asolkar L V, Karkkar K K & Charkre O J 1992. In : Second supplement to Glossary of Indian Medicinal Plants with active principles, Part 1, pp.246-248, Publication and Information Directorates, CSIR, New Delhi.

Balachandran S M, Bhat S R & Chandel K P S 1990. *In vitro* clonal multiplication of turmeric (*Curcuma* spp.) and ginger (*Zingiber officinale* Rosc). Plant Cell Rep. 8 : 521-524.

Bhat S R, Chandel K P S & Kackar A 1994. *In vitro* induction of rhizome in ginger *Zingiber officianale* Rosc. Indian J. Exp. Biol. 32 : 340-344.

Gopal J, Minocha J L & Dhaliwal H S 1998. Microtuberization in potato (*Solanum tuberosum* L.). Plant Cell Rep. 17 : 794-798.

Hasmeda M & Polya G M 1996. Inhibition of cyclic AMP dependent protein kinase by *Curcumin.* Phytochemistry 42(3) : 599-605.

Hoque M I, Islam M A, Sarkar R H & Islam A S 1996. *In vitro* microtuber formation in potato (*Solanum tuberosum* L.) In : Plant tissue culture (Edt. A.S. Islam), pp.221-228, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Murashige T & Skoog F 1962. A revised medium for rapid growth and bioassay with tobacco tissue culture. Physiol. Plant 15 : 473-497.

Nadguada R S, Mascarenhas A F, Hendre R R & Jagannathan V 1978. Rapid clonal multiplication of turmeric *Curcuma longa* L. plants by tissue culture. Indian J. Exp. Biol. 16 : 120-122.

Nayak S & Sen S 1995. Rapid and stable propagationof *Ornith-galum umbellatum* L. in long term culture. Plant cell Rep. 15 : 150-153.

Nayak 1999. High frequency *in vitro* multiplication and microrhizome induction in *Curcuma aromatica.* Abstract published in Proceedings of National conference Plant Biotechnology towards strategic agriculture and drug improvement, March 15-17, CIMAP, Lucknow, pp.31.

Sharma T R & Singh B M 1995. *In vitro* microrhizome production in *Zingiber officinale* Rosc. Plant Cell Rep. 15 : 274-277.

Yasuda K, Tsuda T, Shimizu H & Sugaya A 1987. Multiplication of *Curcuma* species by tissue culture. Plant a Media 54 : 75-79.

Performance of different turmeric varieties in high altitude area of Andhra Pradesh

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Abstract

Seven turmeric (*Curcuma longa*) varieties were evaluated under rainfed conditions for three crop seasons in the high altitude area of Chintapalle in the Visakhapatnam district of Andhra Pradesh. The varieties differed in their production potential and growth characters (plant height, number of tillers per plant, leaves per tiller, leaf length and leaf breadth). Among varieties tested, BSR-1 exhibited maximum productivity of fresh rhizome 34.84 t/ha (1996-97), 32.23 t/ha (1997-98) and 36.5 t/ha (1998-99) and it was at par with the productivity of the selection PTS-62 (32.72 t/ha, 34.43 t/ha and 27.36 t/ha during 1996-97, 1997-98 and 1998-99, respectively). These two varieties, BSR-1 and PTS-62 were significantly superior to other varieties during all the three seasons and are suitable for cultivation in the agency areas of Visakhapatnam district of Andhra Pradesh.

Introduction

Turmeric is one of the important spices and a dye of moderate importance which has good demand in India and other oriental countries. India is the largest producer and exporter of turmeric in the world. In India it is grown mainly in the states of Andhra Pradesh, Tamil Nadu, Kerala, Bihar, Orissa and Maharastra. However, Andhra Pradesh and Tamil Naidu contribute nearly 50% of the production. Crop improvement studies undertaken at various research organisations have resulted in the release of twelve improved varieties (Edison *et al.* 1991). Systematic efforts on introduction and evaluation of improved varieties of turmeric were not undertaken in the high ranges of Visakhapatnam district of Andhra Pradesh where inferior local clones are under cultivation resulting in low productivity thus making turmeric cultivation less remunerative. Hence the present study was carried out to evaluate the performance of different varieties of turmeric, so as to find out the best variety suitable for this area.

Materials and methods

The field experiment was carried out under rainfed conditions at the Regional Agricultural Research Station, Chintapalle of Visakhapatnam district, Andhra Pradesh (17° 19' N 80° 22' E Alt 900m). The trial was laidout in RBD with three replications using four varieties and three selections of turmeric viz., IISR Prabha, IISR Prathibha, PTS-12, PTS-43, PTS-62, Rajendra Sonia and BSR-1 proeured from various research organisations during 1996-97 and repeated in 1997-98 and 1998-99 crop seasons. The net plot size was 3 x 1m and a spacing of 30 x 20 cm was adopted. Standard package of practices recommended by Indian Institute of Spices Research, Calicut was followed. Observations on plant height, number of tillers per plant, number of leaves per plant, leaf length, leaf breadth and yield attributes were recorded.

Results and discussion

The mean performance of the varieties in relation to growth characters is presented in Table 1. Results indicated that there is significant variation among the turmeric varieties in respect of growth characters such as plant height, number of tillers per plant, number of leaves per plant, leaf length and leaf breadth. BSR-1 was found to be the tallest (70.4 cm) with more number of tillers per plant among the varieties studied. The number of leaves per plant were maximum in IISR Prathibha (15.2) whereas maximum leaf length and leaf breadth were recorded in PTS-62. Rajendra Sonia showed poor growth in terms of plant height, leaf length and leaf breadth. Similar variation in the growth paramters among different cultivars were reported by Shah *et al.* (1982), Reddy *et al.* (1989) and Cholke (1993) under different agro-climatic conditions.

Significant variation in fresh yield of rhizomes was noticed among varieties (Table 2). Significantly higher rhizome weight per clump was recorded by BSR-1

(350.5 g) followed by PTS-43 (299 g), PTS-62 (284.4 g) and IISR Prabha (277.7 g) which were on par with each other. BSR-1 exhibited maximum productivity of fresh rhizome

34.84 t/ha (1996-97), 32.23 t/ha (1997-98) and 36.5 t/ha (1998-99) and it was on par with PTS-62 which recorded 32.72 t/ha 34.43 t/ha and 27.36 t/ha during 1996-97, 1997-98 and 1998-99 respectively. Maximum yield in BSR-1 variety was also reported by Patil (1995). The higher yields in BSR-1 and PTS-62 could be attributed to higher number of tillers per plant and large size of mother rhizomes. These two varieties are characterised by bigger sized mother rhizomes and medium sized fingers with bright yellow colour. Positive and significant association of rhizome yield with height of preudostem, number of tillers and weight of rhizome were reported by Nambiar (1979).

The variation in yield and growth attributes among tur-

Table 1. Morphological and yield attributing characters of turmeric varieties

Variety	Plant height (cm)	Tillers/ plant	No. of leaves/ plant	Leaf length (cm)	Leaf breadth (cm)	Rhizome weight/ clump
IISR Prabha	51.50	2.80	15.00	29.73	11.20	277.70
IISR Prathibha	43.40	2.93	15.20	32.30	12.33	239.80
PTS-12	40.50	1.93	10.26	31.33	14.53	232.30
PTS-43	48.40	2.00	11.20	33.66	14.20	299.30
PTS-62	52.35	3.26	14.73	43.86	16.40	284.40
Rajendra Sonia	25.30	2.86	11.80	24.13	8.60	241.50
BSR-1	70.40	3.50	9.80	31.60	14.53	350.50
CD at 5%	6.75	0.54	1.87	4.55	1.11	30.13

Table 2. Fresh rhizome yield (t/ha) of turmeric varieties

Variety	Source	Fresh rhizome yield in tonnes/hectare		
		1996-97	1997-98	1998-99
IISR Prabha	IISR, Calicut	19.47	26.76	26.60
IISR Prathibha	IISR, Calicut	26.77	28.56	19.61
PTS-12	HARS, Pottangi	17.67	33.56	25.99
PTS-43	HARS, Pottangi	23.32	33.33	24.88
PTS-62	HARS, Pottangi	32.72	34.43	27.36
Rajendra Sonia	Dholi, Bihar	19.16	27.23	14.10
BSR-1	RARS, Bhavani Sagar	34.84	32.23	36.50
CD at 5%		5.93	3.59	9.89

meric varieties grown under same agroecological conditions can be attributed to the genetic factors. (Aiyadurai 1966, Subbarayadu *et al.* 1976 and Jalgaonker *et al.* 1988). It is suggested that BSR-1 and PTS-62 are suitable for cultivation in the high altitude areas of Visakhapatnam district of Andhra Pradesh and the same can be cultivated extensively to enhance the production and productivity of the crop in this region.

References

Aiyadurai S G 1966. Curing quality in turmeric. A Review of Research on Spices and Cashewnut Cholke S M 1993. Performance of turmeric (*Curcuma longa* L.) Cultivars. M.Sc., (Agril.) thesis Univ. Agric. Sci. Dharwad.

Edison S, Jhony A K, Nirmal Babu K & Ramadasan A 1991. Spices varieties. A compendium of morphological and agronomic characters of improved varieties of spices in India. NRCS, Kerala.

Jalgaonkar R, Patil M M & Rajput J C 1988. Performance of different varieties of turmeric (*Curcuma longa.* L) under Konkan conditions of Maharastra. In: Proc. National Seminar on Chillies, Ginger and turmeric (p.102-105) Andhra Pradesh Agricultural University, Hyderabad and Spices Board, Cochin.

Patil D V 1995. Performance of turmeric (*Curcuma longa.* L.) varieties in lower Pulney hills of Tamil Nadu, India. Journal of Spices and Aromatic crops 4(2) : 156-158.

Reddy M L N, Rao D V R & Reddy S A 1989. Sreening of short duration turmeric varieties suitable for Andhra Pradesh. Indian Cocoa, Arecanut and Spices J. 12(3) : 87-89.

Shah H A, Seemanthini R, Arumagam R, Muthuswamy S & Khadar J B M 1982. Co-1 turmeric-A high yielding mutant. South Indian Horti. 30 (4) : 276-277.

Subbarayudu M, Reddy R K & Rao M R 1976. Studies on varietal performance of turmeric. Andhra Agric. J. 23 (588) : 195-198.

Nambiar M C 1979. Morphological and cytological investigations in the genus *Curcuma* Linn. Ph.D. thesis. University of Bombay. p.95.

Effect of pollen load on growth and development of vanilla (*Vanilla planifolia* Andr.) fruits

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Abstract

The effect of pollen load on growth and development of vanilla (*Vanilla planifolia* Andr.) - an economically important spice crop was studied at Indian Cardamom Research Institute, Spices Board, Sakleshpur, Karnataka during 1999-2000. Hand pollination was made using different quantities of pollen (12.5 to 100%) and the growth and development of fruits were studied at fortnightly intervals. Higher growth was observed with higher pollen load. The importance of this observation is discussed.

Key words: fruit growth, pollen load, vanilla, *Vanilla planifolia*

Introduction

Vanilla planifolia Andr. is an epiphytic orchid originating from tropical central America and Mexico. This spice crop is being grown for its pleasant flavour. The genus *Vanilla* belongs to the family Orchidaceae and it comprises of over 100 species but only three species are important as the natural source of vanillin. The most commercially preferred species viz. *Vanilla planifolia* Andr. is widely cultivated and other species *Vanilla pompona* Schiede. and *Vanilla tahitensis*. J.W. More also yield vanillin but of poor quality. Annual world production is estimated to be 3,000 to 4,000 MT.

Vanilla is obtained primarily from the fully grown but unripened fruits or 'beans' of a climbing orchid *Vanilla planifolia* Andr. that have been subjected to fermentation curing process to produce the characteristic aroma. The substance chiefly responsible for the peculiar fragrance and flavour of vanilla bean is vanillin (C8 H8 03).

Due to the absence of natural pollinators and the morphology of the flowers, there is no natural self/cross pollination. Hence in vanilla each flower is to be hand pollinated. It has been observed that the bean size varies in different vanilla gardens and to some extent between vines in the same vanilla garden.

A study was conducted at Indian Cardamom Research Institute, Regional Station, Spices Board, Sakleshpur, Karnataka to study the role of pollen load on the growth and development of the fruits where in 100%, 75%, 50%, 25% and 12.5% of the pollen were transferred to stigma and the results were recorded.

Materials and methods

The experiment was initiated with five year old vanilla (*Vanilla planifolia* Andr.) plants trained on the support tree *Glyricidia* growing under silver oak shade.

Twenty plants were selected and one inflorescence from each plant was labelled during March/April 1999. To get different pollen load, the pollinia was removed from the opened flower and the specific quantity of pollen mass was transferred to the stigmatic surface of the same flower. The average weight of pollinia was 2.25 mg (2 to 2.5 mg) with about 3,76,476 (2,32,916 to 3,90,416) pollen grains (counted using haemocytometer). When the full mass of pollen was used for pollination then it was considered 100 per cent. Based on this, pollinia were cut to get 75%, 50%, 25% and 12.5% pollen mass. Pre-determined load of pollen was used to pollinate all the flowers of a selected inflorescence. Pollination was done between 9 am and 10 am which was the ideal time for pollination. All the flowers in an inflorescence was pollinated by a specific quantity (12.5 to 100%) of pollen load. This was repeated in four different inflorescences per treatment.

Length and girth of the ovary was measured on the day of flower opening and there after every fortnight till the fruit attained complete growth. In each inflorescence though all the flowers were pollinated, only first 10 fruits were retained for further growth observations and the remaining fruits were removed after completion of the pollination (15 to 20 days required to complete the pollination in an inflorescence) to ensure the similar bean load in all the inflorescences. Data were statistically analysed using completely randomized design.

Results and discussion

At the time of pollination, the length and girth of the inferior ovary was 5.0 cm and 1.46 cm, respectively (Table 1). After pollination, the fruit showed fast growth in the early days of development upto 30 days and then the rate of growth reduced till 75 days. No increase in the length and the girth of beans were observed beyond 75 days. These results are in agreement with our earlier findings (Bhat & Sudharshan 1998).

Growth (length) in 30, 45, 60 and 75 days of observations showed that there was significant difference between the treatments. Length of a bean was maximum when the pollen load was 100 per cent and attained 17.18 cm length in 75 days followed by 16.43 cm and 16.07 cm in 75 and 50 per cent pollen load, respectively as against 12.77 cm, 14.22 cm length in 12.5 and 25% pollen load, respectively (Table 2). It was observed that higher the pollen load on the flower recorded higher growth rate in each and every fortnight.

Maximum growth (length) of 3.88 cm and 4.17 cm was observed in 12.5 and 25 per cent pollen load in the first fortnight. In the subsequent fortnights the growth rate reduced till 75 days after the pollination. But where the pollen load was 50, 75 and 100 per cent, the maximum growth (length) of 4.83, 5.0 and 5.02 cm was observed in the second fortnight (Table 3).

Table 1. Effect of pollen load on length of vanilla beans

Pollen load	Length of beans							Total gro-
(%)	Poll. day	15th	30th	45th	60th	70th	90th	wth (cm)
T1 - 12.5	5.11	8.99	12.05	12.49	12.74	12.77	12.77	7.66
T2 - 25	4.96	9.13	12.75	13.57	14.12	14.22	14.22	9..26
T3 - 50	5.00	9.39	14.22	15.43	15.98	16.07	16.07	11.07
T4 - 75	4.95	9.43	14.43	15.88	16.40	16.43	16.43	11.48
T5 - 100	5.00	9.80	14.82	16.32	17.07	17.18	17.18	12.18
Mean	5.00	9.35	13.65	14.74	15.26	15.33	15.33	10.33
CD (0.05)	NS	NS	1.78	1.83	1.73	1.72	1.72	-

Table 2. Effect of pollen load on girth of vanilla beans

Pollen load	Girth of beans							Total gro-
(%)	Poll. day	15th	30th	45th	60th	70th	90th	wth (cm)
T1 - 12.5	1.46	2.28	2.92	3.16	3.24	3.26	3.26	1.80
T2 - 25	1.46	2.34	2.97	3.17	3.33	3.36	3.36	1.90
T3 - 50	1.46	2.35	3.19	3.52	3.64	3.67	3.67	2.21
T4 - 75	1.46	2.36	3.20	3.53	3.74	3.77	3.77	2.32
T5 - 100	1.45	2.41	3.24	3.56	3.75	3.79	3.79	2.34
Mean	1.46	2.35	3.10	3.39	3.54	3.57	3.57	2.11
CD (0.05)	NS	NS	NS	0.29	0.30	0.31	0.31	-

Girth also showed the similar growth pattern as of length. Growth (girth) in 45, 60 and 75 days showed significant differences among treatments. The girth in 50, 75 100 per cent pollen load were on par and they showed significantly higher growth rate than that of 12.5 and 25 per cent pollen load. Maximum girth was attained in 75 days and it was 3.79, 3.77, 3.67, 3.36 and 3.26 cm when the pollen load was 100, 75, 50, 25 and 12.5 per cent respectively (Table 2).

Maximum growth (girth) of 0.82, 0.88, 0.89, 0.90 and 0.96 cm was observed in the first fortnight in 12.5, 25, 50, 75 and 100 per cent pollen load. In the subsequent fortnights the growth rate was reduced till 75 days and beyond that no growth has been observed (Table 4).

In vanilla large sized fruits, fetch premium prices in the market. Number of seeds/fruit may contribute in determining the size of the fruit. Hence complete pollination is essential to get maximum number of seeds. In many fruits like blue berry, grape, pear and several species of prunus marked correlations exist between seed number and ultimate fruit size and also between seed distribution and fruit shape (Crane 1964).

To get best growth of fruits, more than 50% of the pollen grains have to be transferred to stigma. Below 50% pollen load produce only small and inferior quality beans which will not fetch premium in the market. From the present study, it is observed that the pollinators need to be trained to carry out pollination effectively by trans-

Table 3. Effect of pollen load on rate of growth (length) of beans.

Growth observations (Days after pollination)	Growth (length - cm) under different pollen load				
	12.5	25	50	75	100
Initial length	5.11	4.96	5.0	4.95	5.0
15th	3.88 (50.6)	4.17 (45.0)	4.39 (39.6)	4.48 (39.0)	4.80 (39.4)
30th	3.06 (39.9)	3.62 (39.1)	4.83 (43.6)	5.00 (43.6)	5.02 (41.2)
45th	0.44 (5.70)	0.82 (8.80)	1.21 (10.9)	1.45 (12.6)	1.50 (12.3)
60th	0.25 (3.30)	0.55 (5.90)	0.55 (4.90)	0.52 (4.50)	0.75 (6.10)
75th	0.03 (0.40)	0.10 (1.10)	0.09 (0.80)	0.03 (0.30)	0.11 (0.90)
Total growth (cm)	7.66	9.26	11.07	11.48	12.18

The figures within parenthesis show percentage growth rate/fortnight.

Table 4. Effect of pollen load on rate of growth (girth) of beans.

Growth observations (Days after pollination)	Growth (length - cm) under different pollen load				
	12.5	25	50	75	100
Initial length	1.46	1.46	1.46	1.46	1.45
15th	0.82 (44.8)	0.88 (4.70)	0.89 (38.5)	0.90 (37.9)	0.96 (36.8)
30th	0.64 (34.9)	0.63 (33.7)	0.84 (36.4)	0.84 (35.4)	0.83 (31.8)
45th	0.24 (13.1)	0.20 (10.7)	0.33 (14.3)	0.34 (14.3)	0.32 (12.3)
60th	0.08 (4.40)	0.16 (8.50)	0.12 (5.20)	0.21 (8.90)	0.20 (7.70)
75th	0.02 (1.10)	0.03 (1.60)	0.03 (1.30)	0.03 (1.30)	0.03 (1.10)
Total growth (cm)	1.8	1.9	2.21	2.32	2.34

The figures within parenthesis show percentage growth rate/fortnight.

ferring complete pollinia to the stigmatic surface to get maximum growth. The failure to transfer complete pollen mass to stigmatic surface during hand pollination could be one of the main reason for the differences observed in size of beans between vanilla gardens and to some extent between the different vines within the same garden. Thus the technique used in hand pollination by pollinators is an important factor in determining fruit size in vanilla.

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References

Bhat S K & Sudharshan M R 1998. Floral biology and fruit growth in vanilla (*Vanilla planifolia* Andr.) In: plantation Crops Symposium XIII (PLACROSYM XIII), December 16-19, 1996. Abstracts (p.14). United Planters' Association of South India, Tea Research Institute, Valparai.

Crane J C 1964. Growth substances in fruit setting and development. Ann. Rev. Plant Physiol. 15 : 303-326.

Enhancement of genetic variability in chilli (*Capsicum annuum* L.) following hybridization, mutation and hybridization with mutation

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Abstract

Two varieties of chilli viz., Ceylon and Byadagi and their F_0 seeds were irradiated with different doeses of gamma rays to generate one control F_2, seven F_2M_2 and two M_2 populations with the objective of isolating high yielding mutants with medium long wrinkled fruits, and comparing the relative efficiencies of 'hybridization', 'mutation' and 'hybridization with mutation' in shifting of mean, range and variance in the desirable direction. Large populations of these segregating generations were grown and observations on quantitave characters were recorded. The comparison of mean in different populations indicated shifts in both the directions of control F_2 mean due to mutagenesis of hybrid and parental lines depending on the trait. The direction of shifts varied with genotypes, mutagen and character. The changes in mean in the mutagen treated population were followed by changes in variance for all the characters. However, the combined effect of hybridization and mutation was not cumulative. In general, F_2M_2 was found preferable to M_2 thereby leading to the inference that 'Hybridization + Mutation' outperformed 'Hybridization' and 'Mutation', in this study.

Key words: chilli, F_2M_2, gamma rays, hybridization, mutation.

Introduction

The yield levels (at the most 600 kg/ha of dry chilli) of the chilli varieties (Byadagi, Mysore, Gauribidanur, NP 46 - A, G - 3 and Pusa Jwala) presently under recommendation for drylands in Southern Karnataka are not satisfactory. A breeding programme was initiated at the AICRP on dryland agriculture, UAS, Bangalore in 1994, which resulted in the identification of a few elite genotypes superior to the present recommended ones for yield. But, they were not having the desirable fruit type. Hybridization and/or mutation programmes were to be initiated to introduce these characters into the elite selections. To hasten the achievement of this objective and to generate some basic information, it was decided to compare "only Irradiation" with "only Hybridization" and "Hybridization coupled with Irradiation".

Materials and methods

Two varieties, Ceylon and Byadagi and their F_0 were irradiated with different doses of gamma rays from 5 to 40 kR. The irradiation was done at the BARC, Mumbai. The control populations of Ceylon, Byadagi and their F_2, their M_2 populations (25 KR Byadagi and 25 KR Ceylon) and the F_2M_2 populations (5, 10, 15, 20 and 25 KR) were comapared for changes in mean, variance and co-efficient of variation (CV). The experimental material was raised in a RCBD with three replications. The plot size was 25 sq m and spacing adopted was 60 x 45 cm and other standard cultural practices recommeded for chilli was followed.

Results and discussion

The mean, range and varience obseved in different populations for number of fruits per plant, fruit length, fruit width and dry fruit yield per plant are presented in Tables 1- 4.

The increase in mean, variance, CV. and alteration in the skewness and kurtosis of distribution curves as compared to control F_2 was observed in all or majority of the F_2M_2 treatments for all the four characters. These increases/alterations were not dose dependent for number of fruits and fruit length. But in case of fruit width, the increase in range was positively correlated with the does of gamma rays, while increase in mean was negatively correlated with the dose. Similarly, the

Table 1. Range, mean, skewness and variance for number of fruits per plant in F_2, M_2 & F_2M_2

Treatment	Minimum	Maximum	Mean ±		Comparison with Ceylon (C)		Comparison with Byadagi (C)		Comparison with F_2(C)		Variance	CV%	Skewness	Kutosis
					Shift in mean	Per cent of control	Shift in mean	Per cent of control	Shift in mean	Per cent of control				
Ceylon	40	115	79.65	1.88	-	100.00	-13.15	119.77	11.51	116.89	32.66	76.18	0.626	0.259
Byadagi	38	98	66.5	1.66	-13.15	83.49	-	100.00	-1.64	97.69	43.64	9.93	0.727	0.166
F_2 Control (C)	5	108	68.14	1.19	-11.51	85.54	1.64	102.46	-	100.00	150.77	18.02	0.273	0.180
F_2M_2 5 kR	12	147	81.05	2.26	1.40	101.75	14.55	121.87	12.91	118.94	478.09	26.98	1.633	6.727
F_2M_2 10 kR	4	105	79.10	1.45	-0.55	99.30	12.60	118.94	10.96	116.08	265.65	20.60	0.200	-0.484
F_2M_2 15 kR	13	127	82.00	1.36	2.35	102.95	15.50	123.30	13.86	120.34	119.50	16.83	0.578	0.187
F_2M_2 20 kR	7	132	75.60	1.53	-4.05	94.91	9.10	113.68	7.46	110.94	280.47	22.15	0.772	0.684
F_2M_2 25 kR	10	114	73.00	1.97	-6.65	91.65	6.50	109.97	4.86	107.13	407.48	27.60	0.459	-0.066
M_2 25 kR Bydagi	8	62	78.26	1.37	-1.39	98.25	11.76	117.68	-18.12	114.85	228.34	19.30	0.053	-0.944
M_2 25 kR Ceylon	8	92	63.52	1.24	-16.13	79.74	2.98	95.51	-4.62	93.21	164.77	20.20	0.104	-0.658

Table 2. Range, mean, skewness and variance for fruit length (cm) in F_2, M_2 & F_2M_2

Treatment	Minimum	Maximum	Mean ±		Comparison with Ceylon (C)		Comparison with Byadagi (C)		Comparison with F_2(C)		Variance	CV%	Skewness	Kutosis
					Shift in mean	Per cent of control	Shift in mean	Per cent of control	Shift in mean	Per cent of control				
Ceylon	3.5	10.60	5.72	0.10	-	100.00	-0.96	85.62	-0.50	91.96	1.13	18.58	0.162	0.301
Byadagi	4.0	11.05	6.68	0.14	0.96	116.78	-	100.00	0.46	107.39	1.25	16.74	0.127	0.166
F_2 Control (C)	3.8	10.60	6.2	0.79	+0.50	108.74	-0.46	93.11	-	100.00	4.12	32.63	-1.052	2.167
F_2M_2 5 kR	3.0	11.76	6.41	0.09	+0.69	112.06	-0.27	95.9	0.19	103.05	12.00	54.04	-1.017	1.311
F_2M_2 10 kR	2.9	12.40	6.33	0.88	+0.61	110.66	-0.35	94.76	0.11	101.76	8.00	44.68	-0.681	0.354
F_2M_2 15 kR	2.2	13.20	7.08	0.89	+1.36	123.77	0.40	105.98	0.86	113.82	12.08	49.09	0.441	0.552
F_2M_2 20 kR	3.3	11.13	6.68	0.77	0.96	116.78	0.00	100.00	0.46	107.39	5.43	34.88	-0.169	0.131
F_2M_2 25 kR	3.1	10.75	5.59	0.62	-0.13	97.72	1.09	83.68	-0.63	89.87	3.00	30.98	0.298	1.252
M_2 25 kR Bydagi	2.9	10.20	6.09	0.25	0.37	106.46	-0.59	91.16	-0.13	97.90	4.31	34.08	-1.031	0.485
M_2 25 kR Ceylon	3.4	10.00	6.05	0.93	0.33	105.76	-0.63	90.56	-0.17	97.326	3.66	31.62	0.814	0.518

Table 3. Range, mean, skewness and variance for fruit width (mm) in F_2, M_2 & F_2M_2

Treatment	Minimum	Maximum	Mean	±	Comparison with Ceylon (C)		Comparison with Byadagi (C)		Comparison with F_2(C)		Variance	CV%	Skewness	Kutosis
					Shift in mean	Per cent of control	Shift in mean	Per cent of control	Shift in mean	Per cent of control				
Ceylon	7.2	12.10	9.80	0.25	-	100.00`	0.37	103.92	-0.01	99.89	2.77	16.77	1.211	1.701
Byadagi	7.5	13.00	9.43	0.24	-00.37	96.22	-	100.00	-0.38	96.12	2.09	15.33	1.363	1.946
F_2 Control (C)	7.0	12.5	9.81	0.18	0.01	100.10	0.38	104.20	-	100.00	3.39	18.76	-2.663	9.022
F_2M_2 5 kR	4.5	13.50	9.83	0.23	0.03	100.30	0.40	104.24	-0.28	97.14	5.08	23.65	-1.640	3.191
F_2M_2 10 kR	6.5	15.00	9.53	0.21	0.27	97.24	0.10	101.06	-0.28	97.14	6.82	27.40	-1.476	2.784
F_2M_2 15 kR	4.3	12.50	9.49	0.20	0.31	96.83	0,.05	100.63	-0.32	96.73	4.11	21.36	-1.885	5.178
F_2M_2 20 kR	4.7	15.50	10.07	0.18	0.27	102.75	0.64	106.78	0.26	106.25	4.81	21.77	-1.431	4.544
F_2M_2 25 kR	2.5	12.50	9.37	0.19	-0.43	95.61	-0.06	99.36	-0.44	95.51	3.59	20.22	1.687	3.319
M_2 25 kR Bydagi	7.3	12.00	9.86	0.44	0.06	100.61	0.43	104.55	0.05	100.50	3.96	16.58	0.186	33.095
M_2 25 kR Ceylon	4.8	14.00	9.57	0.23	-0.23	97.65	0.14	101.48	-0.24	97.55`	5.90	25.38	-1.375	1.909

Table 4. Range, mean, skewness and variance for fruit yield (g) in F_2, M_2 & F_2M_2

Treatment	Minimum	Maximum	Mean ±		Comparison with Ceylon (C)		Comparison with Byadagi (C)		Comparison with F_2(C)		Variance	CV%	Skewness	Kutosis
					Shift in mean	Per cent of control	Shift in mean	Per cent of control	Shift in mean	Per cent of control				
Ceylon	18	68.00	40.25	0.77	-	100.00	2.79	107.44	-6.91	120.72	34.35	1456	0.199	0.837
Byadagi	15	55.00	37.46	0.99	-2.779	93.06	-	100.00	-4.12	112.35	25.40	13.45	0.194	0.354
F_2 Control (C)	2.00	77.30	33.34	0.92	-6.91	82.83	-4.12	89.00	-	100.00	104.00	30.59	2.084	6.267
F_2M_2 5 kR	5.00	84.70	43.93	0.88	3.68	109.14	6.47	117.27	-10.59	131.76	73.27	19.48	0.393	-0.700
F_2M_2 10 kR	4.00	70.00	38.33	0.83	-1.92	95.22	0.87	1032.32	-4.99	1014.96	85.66	24.43	2.060	10.081
F_2M_2 15 kR	5.2	85.80	40.45	0.63	0.20	100.49	2.99	107.98	-7.11	121.32	41.34	15.90	0.432	-0.631
F_2M_2 20 kR	3.71	74.50	39.46	0.59	-0.79	98.03	2.00	105.33	-6.12	118.15	41.66	16.36	0.684	0.828
F_2M_2 25 kR	4.00	79.10	37.020	0.98	-3.05	92.42	-0.26	99.30	-3.86	111.57	101.55	27.09	2.792	16.486
M_2 25 kR Bydagi	2.41	47.00	32.65	0.46	-7.6	81.11	-4.81	87.15	-0.69	97.93	52.47	22.18	0.806	0.948
M_2 25 kR Ceylon	3.40	50.69	34.15	0.60	-6.1	84.84	-3.31	91.16	-0.81	102.42	38.43	18.15	0.722	0.280

desirable mean values and the genotypes with desirable values for all the four characters were also noticed in one of the F_2M_2treatments but not in F_2(C) or M_2(*Byadagi 25 kR* or *Ceylon 25 kR*) treatment. Thus hybridization + irradiation turned out to be more advantageous than only irradiation or only hybridization in improving these four characters in chilli.

Greater efficiency of 'hybridization and irradiation' as compared to only 'hybridization' or 'irradiation' in shifting the range, mean and CV was reported by a number of earlier workers starting from Gregory (1955) onwards (Rangaswamy 1980, Govindarasu *et al.* 1997) while other workers reported contradicting results (Sarafi 1978), which revealed the differences in sesitivity of genotypes to irradiation. Though the F_2M_2 treatments recorded greater shift in range, mean and CV, effect of 'Hybridization and irradiation' were not cumulative. Similar observation was reported by Khadar & Frey (1965). The present results lead to the inference that as far as chilli is concerned, 'Hybridization +irradiation' is more efficient than 'Hybridization' or 'Irradiation' alone in realising desirable mutaion.

References

Govindarasu R, Subramanian M, Natarajan M, Sivasubramanian P & Ramamoorthy N 1997. Mutagenic effects of gamma irradiation of varieties and hybrids of sesame. J. Nuclear Agric. Biol. 26 : 37-63.

Gregory W C 1995. X-ray Breeding peanuts (*Arachis hypogaea* L.). Agron. J. 47 : 326-329.

Khadar F H & Frey K J 1965. Effectiveness of recurrent irradiaton on oat breeding (*Avena sativa* L.). Crop sci. 5 : 349-354.

Rangaswamy S R 1980. Induction of variability through mutagenesis of the intraspecific hybrid in sesame (*Sesamum indicum* L.). Ph.D. Thesis TNAU, Coimbatore.

Sarafi A 1978. The effects of selection on some agronomic characters in F_6 hybrids and M_6 mutant lines of three sesame varieties. Abstracts. Univ. Tehran. Cell. Agril. Karad 61 : 72-78.

Association between morphological and quality traits of chilli fruit germplasm

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Abstract

Quality is of much importance in chillies that are used in food preparations. Good pungency, bright red colour, high oleoresin concentration and few seeds in the fruit are the main characters on which quality is based and priced. In the present paper fifty chilli genotype, that were collected from different sources and then grown at NBPGR Regional Station, Bhowali, Nanital (U.P.) were studied for their pungency in terms of capsaicin concentrations, colour value, oleoresin concentrations, seed percentage of the fruits along with other plant characters for selecting the promising lines for use in crop improvement programs. Simple linear correlation coefficients were also computed between different traits for the establishment relationship in plant characters and industrially important qualities of the fruit.

Key words: capsaicin, chillies, colour value, oleoresin, quality.

Introduction

Chillies and capsicum are an important condiment, used widely in routine food preparations in India. The quality of chillies is of utmost importance and chillies are priced, based on various characters like pungency level, bright red colour, a good flavour and less seed in the fruit. Chillies and capsicum with a bright red colour command a higher price than those, which are dull red or even orange or yellow in colour (Purseglove *et al.* 1983).

The pungent principle in chillies is the compound capsaicin. Chemically capsaicin is N-3-methoxy-4-hydroxyl benzyl-8-methyl non- trans-6-enamide (Verama *et al.* 1988). In case of pungent chillies appearance is of much less importat but high capsaicin content is essential.

The principal criterion for evaluating paprika (a ground product of chilli of non pungent fruits, used principally as a colouring agent in food preparations) is its colouring value and for chillies it is the degree of pungency (measured as capsaicin content)

In the present investigation, an attempt has been made to study the association of quantitative morphological characters of chillies with industrially important quality traits of the fruit such as capsaicin concentration, colour value, oleoresin concentration, and seed percentage of the fruit, for selecting the superior genotypes for use in crop improvement programme.

Materials and methods

Fifty genotypes of chillies obtained from different sources were grown in augmented design at NBPGR Regional Station, Bhowali, Nanital (U.P). The observations of five plants in each genotype were taken. The mature fruits were used in chemical analysis.

Capsaicin and oleoresin percentage was determined by method of Mandal *et al.* (1998). Colour value of the oleoresin was determined by the absorbance of 0.01% solution of oleoresin at 458 nm. The absorbance value was multiplied by 61,000 to obtain the nesslerimeter colour value. Correlation between traits was studied using Pearson coefficient product method.

Resullts and discussion

Chilly germplasm exhibited a wide range of variability in percentage of seed per fruit (1.85%-42.67%), oleoresin content (4.1%-15.8%), capsaicin content (0.135%-1.004%), colour value (1,464-46,970 ASTA units), leaf length (2.0-11.8 cm), leaf width (1.0-5.0 cm), days to 50% flowering (148-191 days), days to 50% fruiting (163-208 days), plant height (16-120 cm), fruit (10)

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green weight (4.8-86.15 g), number of fruits per plant (1-90), fruit length (3.0-14.5 cm) and fruit width (0.28-7.35 cm). The promising accessions identified based on the above traits are shown in Table 1.

The capsaicin content and the red colour of ripe fruit are the two industrially significant characters for chilli fruits. In the present study, these two parameters are found to have negative association. More work is required to break this unfavourable association for improving the quality of the crop.

Less coloured and more pungent fruits are found to give more oleoresin. Seed does not contribute significantly to pungent principle (capsaicin content) in chillies; however, the fixed oil present in the seed contributes to increase in oleoresin concentration. Here no significant correlation has been observed between oleoresin and seed percentage of the fruits. Thus, it may be concluded that pulp is the more important part for contributing oleoresin concentration of the fruit.

Significant positive correlation was observed between seed percentage and fruit length($r = 0.393^*$) and seed percentage and fruit width($r = 0.309^*$). Thus, with the increase in seed volume the seed percentage also increases. Therefore right kind of genetic material are

Table 1. Promising accessions identified in chilli germplasm.

Character	Promising accessions
Seed percentage in the fruit	EC 378696(1.85%), EC 382081(2.25%) EC 391086(5.18%), EC 378686(5.81%)
Oleoresin percentage	EC 378632(15.8%), EC 345656(14.8%) EC382081(14.3%)
Capsaicin percentage	EC 345641(1.004%), EC 246024(0.825%) EC378624(0.767%)
Colour value	EC 382185(46,970),EC391083(28,726), EC 382015(26,962)
Leaf length	EC 382187(11.8cm), EC 382079(10.4cm), EC382035(10.6cm), EC 382053(10.2cm)
Leaf width	EC320525(5.2cm),EC382081(4.3cm) EC378628(4.16cm), EC 382035(3.7cm).
Days to 50% flowering	EC 382175(191days), EC 382081(191 days), EC 345656(191 days), EC 378638(167days).
Days to 50% fruiting	EC 345656(208days), EC 378626(179days), EC 378632(181days), EC 378633(181days).
Plant height	EC 382079(105cm), EC 382063(102cm), EC 378632(102cm), EC 382035(115cm).
Fruit (10) green weight	EC 391082(86.15), EC 378635(53.15), EC382017(46.2), EC 378626(40.2).
Number of fruits per plant	EC 382053(90), EC 246024(89), EC 378628(87), EC 378626(75).
Fruit length	EC 378628(14.5cm), EC 378624(12.2cm), EC 382026(10.5cm), EC 382017(13cm)
Fruit width	EC 391682(7.35cm), EC 388994 (2.08cm), EC 382053(1.97cm), EC 388995 (1.81cm).

needed to have industrially important genotypes containing less seed in the fruit. At the same time the seed percentage show negative correlation with capsaicin content. Therefore small fruit is expected in exhibiting high pungency. Moreover, capsaicin concentration shows significant positive correlation with number of fruits per plant ($r = 0.417^{**}$). Thus more is the number of fruits per plants smaller will be their size and more pungent they will be. From the present study, it has also been observed that plants having longer leaf produces higher colour value fruits ($r = 0.332^{*}$). These studies will be helpful in future selection programmes for crop improvement.

References

Purseglove J W, Brown E G, Green C L & Robbins S R J. Spices. Volume I.

Verma S K, Pant K C & Muneem K C 1998. Evaluation of chillies germplasm. Indian J. Pl. Genet. Resources 11(2) : 237-239.

Mandal S, Poonam Suneja & D K Hore 1998. A colorimetric method for estimation of capsaicin in chilli fruit. Indian J. Pl. Genet. Resources 11(2) : 213-218.

Breeding of Indian paprika for high-value additions "organic colour" and "oleoresin" by Sarpan Dharwad.

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Introduction

Genus *Capsicum* is a well known in the family Solanaceae for its varied value additions in the commercial hivalue farming of agricultural crops. Value additions developed are in their wide spectrum of applications, right from natural colour (organic colour) pigment used for food colouring, fabric dyeing, meat colouring, as a stimulant and catalytic agent in poultry and animal feed industry, pharmaceutical industry for capsule colouring, cosmetic industry for safe facial products and such other applications, where natural colour is prominently and safely used. Capsaicin, a principal chemical component extracted from the dry fruits of hot chilli, is used in manufacture of painkillers, sprays, lotions etc. The concentrated oil – "oleoresin" extracted from pericarp of dry fruits with various levels of colour units and heat units, aromatic and volatile oils, to the various protective levels are used in various food preparations. The bulk material in tonnage (dry fruits) is reduced to kilos (oleoresin oil), which has highest value additions. With the globalization in the field of agro industries and change in export policies, new horizons, concepts and products are being identified for various international markets. The increase in demand for natural colour has further reflected on demand for paprika in international market.

Paprika (*Capsicum annuum*.L) is a chilli exclusively known for its colour and sweetness, which is classified morphologically between the categories of hot chilli *(Capsicum annuum*.L *acuminatum)* and bell pepper *(Capsicum annuum*.L *grossum)*. Globally paprika is known for its natural colour and sweetness. Spain and Portugal are the leading countries in paprika cultivation, processing value additions and oleoresin extraction.

Most known paprikas are adapted to alpine and

Table 1. Yield attributes of paprika lines supplied by Spices Board.

Characters/Entries	KTPL 8	KTPL 18	KTPL 19	Spanish Paprika	SPH-1	SB-106
No. of fruits/plant	15	18	20	15	24	78
Wet yield/plant (g)	225	450	600	300	600	1170
Dry yield/plant (g)	42	58	64	36	91	218
Wet to dry % recovery	18.5	13	10.6	12	15.2	18.6
Fruit length (cm)	10.2	11.8	11.8	2.3	12	12
Width (cm)	2.7	3.2	2.5	4	3	2.6
Fruit weight wet (g)	17.5	26.5	32.4	22.3	27.4	16.5
Fruit weight dry (g)	3	3.4	3.4	2.6	4	3
Pericarp/fruit (g)	1.6	2	2.4	1.2	2.8	1.8
Seed weight/fruit (g)	1.2	1.2	0.8	1.2	1	1
Stock weight/fruit (g)	0.2	0.2	0.2	0.2	0.2	0.2
% of pericarp	53	59	70	46	70	60
% of seed	40	35	24	46	25	33
% of stalk	7	6	6	8	5	7

temperate climatic conditions and are determinate in their growth behavior. India with its wide spectrum of agroclimatic situation is blessed with significant level of genetic variability, which could be harnessed efficiently to meet out the needs of consumers, process industries and market.

Efforts were made during 1992-93 by Spices Board, Govt. of India, to introduce already existing Spanish and Moroccon paprika for cultivation in Indian conditions, which was not satisfactory and was a failure. At Sarpan Agri-Horticultural Research Centre also, we had a trial of the crop sent by Spices Board (Table 1). We did not find any interesting features compared to the locally available milder form of paprika "Byadagi Dabbi,"which performed superior to these introduced paprika in all respect, yield, colour units, yield and oleoresin levels and aromatic flavors, volatile oils.

Looking at the unique features of the crop, we at 'SARPAN" have initiated chilli breeding progamme in 1987-88 at Dharwad, Karnataka-India. The first mild paprika SB-106, a hybrid was released during 1992 for commercial cultivation with high colour value 181.8 ASTA units and oleoresin content of 15.19% EDC extractable having heat units of 11,000 SHU (0.08% HPLC capsaicin).

Spain, Hungary, Portugal and Morocco etc., are the major paprika producing countries. India can also emerge as a lead country producing high quality paprika in years to come. Dharwad being 160 kms away from Goa, does carry lot of genetic features of paprika in its local popular breed – Byadagi , which was introduced through Portuguese, Spanish colonies into these regions of Karnantaka during 16th and 17th century. However, today with several genetic recombinations and higher percentage of cross pollination in *Capsicum annuum* var, *acuminatum*, we have the best genetic diversity available for the future programme. However, with introduction of several commercial breeds at national and regional level by government agencies, universities and private companies during 70's and 80's the local breed Byadagi has losts its unique genetic features and is now as common as a regular hot chilli breed and has lost its original existance. Now the breed is highly genetically corrupted because of out crossing nature in hot chillies.

Looking into all these events of 80's and the present status of Byadagi chilli and several technical deliberations discussions in various forums, Sarpan initiated its research work in 1986-87 and collected large genetic variants, populations and stocks available in chilli growing areas and serious efforts are made on improvement of paprika features in the breed by various conventional breeding techniques. Multilinial hybrid and single cross hybrid technology, back cross method for lines and population improvements and CGMS techniques for single cross F1 hybrids were adopted in this programmes for developing potential breeds for cultivation for various agroclimatic regions. The Centre released its first mild paprika breed – SB-106 in 1992 for commercial cultivation. Later, interactions with process industries, exporters and Spices Board, we released another sweet paprika – SPH-1 with highest colour units and with high productivity. Commercially on field scale, a yield of 4.2-4.5 metric tonnes/ha was realised.

Materials and methods

Genetic diversity available and maintained at Sarpan Agri-Horticultural Research Centre, (SAHRC) on "Byadagi Dabbi," a paprika version is utilised in the project. The wide genetic diversity, populations, local selections and other variability available in Dharwad district, Karnataka, India is collected and maintained at the Centre. These are further grouped under GDC-5000 and GDC-6000 series for the research purpose. Further classifications of these material is made in to SB-100, SB-200, FTL, ST, SP, GDC series, based on characteristic morphological features.

Transgressive segregents identified and isolated from populations, are further involved in generating potential segregating populations, which would throw potential transgressive segregants of great genetic combinations and recombinations of high quality features. Accordingly back cross progenies, single cross and multiple cross progenies of selected genotypes and Spanish Paprika were generated and their segregating populations were handled for various characteristic features, combinations representing paprika.

Since 1987-88, the selection, classifications and hybridization of selected stocks begin and potential progenies were handled by pure line selection, early generation selection method, which resulted in generating the most potential lines with promising characteristic features (Table 2).

Table 2. Salient quality features of few promising hybrids of Sarpan-Dharwad

Sl. No.	Breed particulars	ASTA colour units	S H U (capsain level)	Fruit wt. (g)	Seed wt.% of fruit wt. (g)	Pericarp wt. % of fruit wt.
1	99-FB-7	160-165	12000	2.4	33	58
2	99-6023	110-120	25000	2.2	27	63
3	99-38	160-170	6000	2.6	23	69
4	99-ST-18	130-140	12000	2	30	60
5	99-FT-49	150-160	20000	2.2	36	54
6	99-B-15-F-23	120-130	18000	2.6	38	54
7	99-SB-106	190-200	8000	3	27	66
8	99-114	190-200	Negligible	3.4	24	71
9	99-37	120-130	6000	2.8	29	64
10	99-6028	160-170	12000	2.4	33	58
11	99-5073	120-130	25000	3.4	29	65
12	99-GDC-836	120-130	Sweet (0)	4.4	27	68
13	99-113	150-160	15000	2.8	28	640
14	99-FT-71 & 72	140-150	20000	2.2	27	64
15	99-55-20/21	110-120	22000	2.2	36	54
16	99-GDC-3193	130-140	Sweet (0)	2.2	36	54
17	99-SPH-1	210-220	Sweet (0)	4	30	65
18	99-5086	180-190	Sweet (0)	2.4	36	64
19	99-25	110-120	20000	2	30	60
20	99-6019	160-170	8000	3	33	60
21	99-FT-80	150-160	12000	2.6	38	54
22	99-24	80-90	18000	2.2	27	64
23	99-FTL-03	140-150	15000	2.4	33	54
24	99-34	150-160	10000	3.2	44	50
25	99-39 Sweet	90-100	Sweet (0)	1.6	21	75
26	99-FTL-21	90-100	18000	2.6	31	62
27	99-FTL-6	130-140	18000	2.4	33	58
28	99-FT-13	170-180	10000	2	30	60
29	99-FT-41	120-130	15000	2.4	33	58
30	SB-150	200-220	6000	3.4	28	64
31	FTL-99-2-1-P	175-000	0 (Sweet)	3.4	30	62
32	GC-99-735	135-140	0 (Sweet)	4.2	28	64
33	GDC-99-3526	175-180	0 (Sweet)	3.6	30	64
34	GDC-99-3629	190-200	0 (Sweet)	3.8	28	66
35	GDC-99-3711	125-130	0 (Sweet)	2.6	26	68
36	GDC-99-3372	185-190	0 (Sweet)	3.2	28	64
37	SARPAN MADHU	130-140	0 (Sweet)	2	30	62

SB-106, SB-150, SPH-1 and Sarpan Madhu are commercially released from the Centre.

A highly productive "sweet chilli" and "paprika" with sweet / mild / hot, high colour having other quality parameters of paprika, tall with high level branching, good root system, suitable for tropical environment having resistance to mites, fruit rot and fruit borer, with low seed and high pericarp content was the plant type identified for successful cultivation of paprika in tropical environment. Accordingly selection was made on segregating population and the hybridisation techniques used did generate potential transgressive segregants in the programme.

Results and discussion

After a dedicated efforts of more than 11 years into paprika / chilli breeding, today center is ready with many promising pure lines F1 hybrids, multilinial hybrids, populations excelling in high productivity, easy picking, resistance to mites, thrips and diseases, climatic resistance and other unique salient features of paprika in them for tropical climates are developed. A sweet chilli "Sarpan Madhu" with a yield potential of 4.2 to 4.5 tonnes per hectare (irrigated) and ASTA of more than 180 are now ready at the centre for release.

Promising material with salient features is mentioned in table 2 and many others with unique features are in pipeline. Most promising breeds SB-106, SB-150, SB 3193, SBG-14, ST- 21, ST- 22, SPH-1 and SPH-2 are released for cultivation by the centre under back ward intigration programme. Various coloured paprikas with various pungency levels, mild, hot and sweet are in pipeline.

Variability, heritability and correlation studies in coriander (*Coriandrum sativum* L.)

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Abstract

Forty strains/ genotypes of coriander (*coriandrum sativum* L.) including checks were evaluated to work out phenotypic and genotypic coefficient of variations (PCV, GCV), heritability, genetic advance (GA) and correlation coefficients for 10 matric trails.High estimates of PCV, GCV, heritability and G.A. indicated substantial genetic variability and scope for selection for days to maturity, secondary branches^{-1}, days to flowering, 1000 seed weight in the experimental material. There was little variability and scope for improvement through selection for number of unbellete per umbel, primary branches per plant and plant height. Correlation studies indicated that plant height, number of secondry branches, days to flowering, days to maturity and number of umbel^{-1} were the major yield components where as number of primary branches number of umbellet per umbel and number of seeds per umbel, being negatively correlated with yield were less important.

Key words: genetic variability, heritability, yield components

Introduction

Spices are considered to be essential in the culinary art all over the world as they play an important role in enhancing the taste and flavour of foods. Many of the spicesd are digestive, stimulant and carminative. Some of the spices act as antetoxidants and preservations some of them have medicinal value and used in the pharmaceutical industry with an annual out put of about two million tonnes, India enjoys a dominating position in the world.Although nearly 60 out of the recorded 107 species are cultivated in India, only 16 are important. Among them only six are classified as seed spices and cariander has gat very important place in the group.

Coriander (*Cariandrum sativum* L.) is used as powder in curry, soup etc. The leaves arevery rich in vitamin C (250 mg per 100 g) and carotene (250 mg per 100g). The aormatic taste and odour of coriander fruit is due to valatile oil (0.1%). The distt. oil contains 65-70% (+) coriandrol and pinenc. The chief consumption of cariander fruit is as flavouring agent in cooking. The dried fruit is generally used as infusion in sore threat,flatulence indigestion, vomiting and other intestinal disorder. The plant is alleged to have antiseptic, antitubercular properties and is an antidote for snake bite.

In order to make this crop more productive and resistant to diseases and insect pests breeders have to launch an intensive breeding programme for releasing array of variability.

plant-Breeding according to Dudley and Moll (1969) can be divided into three stages; assembly or creation of pool of variable germplasm, selection of superior individual from the pool and the utilization of selected genotypes in the process to evolve a superior variety. The success of breeding programme is essentially a manifestation of efficiency of selection genetic variation in quantitative traits in plant population is of prime concern to breeder much information is warrented from a careful study of several imprtant individual characters. The range of variability for the characters throw much light on the scope of selection.

Heritability has been used as an index of transmissibility of a character from the parent to its off springs (Luch 1940) and thus and aid to for see the improvement that can be made in a crop by selection for various characters. Genetic advance is an added advantage in selection and to make it more meaningful.

Yield, being a complex character, is influenced by several genetic factors interacting with environment. Correlation studies are meant to detal the inter relationship between various plant characters. While making selection of plants, correlation between yield and various characters and between plant characters could be taken as a reliable guide. Selection is the most effective technique. In artificial selection, the breeder is mainly concerned with selection of best combination of characters, which contribute towards maximum yield.

Materials and methods

The materials for the investigation comprised of 40 elite genotypes of coriander including checks. The genotypes are maintained in genetic stock at vegetable Research station Kalyanpur. To carry out present investigation, an experiment was conducted in Randomized Block Design with three replications at vegetable Research Station, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during rabi 1996-97. Observations were recorded on 10 morphological/meteric traits viz. plant height, primary branches, secondry branches^{-1}, days to flowering, days to maturity, number of umbel^{-1}, number of umbellets per umbel, number of seeds per umbel, 1000 seed weight and seed yield^{-1}. The mean values of ten plants were used for statistical anlysis.The phenotypic and genotypic coefficient of variability (PCV, GCV), (Burton 1952), heritability (broad sense) and genetic advance (GA) (Johnson *et al.* 1955) were computed. The formula devised by Rabinson *et al.* (1949) was adopted for the calculation of correlations.

Results and discussion

The mean of square showed that treatments differed significantly for the all characters except primary bmaches^{-1}, umbel and 1000 seed weight which indicated that material under study was consisted of different genetic constitution.

The range of mean performance, general mean and their standard errors (Table 1) related that the days to maturity had maximum range of mean performance (113.33 to 150.33) with mean value of 131.12 followed by plant height (110.80-140.50) with a mean value of 126.98 and days to flower 58.33 to 87.00 with an average of 73.39. The minimum range of mean performance (5.03 to 6.77) with a men of 5.81, however was observed for umbellet per umbel.

A better idea can be ganied by comparing the relative amount of coefficient of phenotypic and genotypic variance for the actual strength of variability. The phenotypic coefficient of variance was slightly higher than the genotypic coefficient of variance. The maximum PCV (19.40) was observed for secondry brances per plant fallowed by primary branches (11.63) and number of seeds per umbel (11.05). The maximum GCV was observed for secondary branches (18.08) followed by days to flowering (10.45) and number of seeds per umbel (8.46). It indicated that simple selection for number of secondry branches may be advantageous as compared to other components under study.

With the help of PCV and GCV alone it is not possible to determine the amount of variation which is heritable. The heritabilily estimates along with genetic advance is more meaningful.

The estimates of heritability in broad sense (Table 1) showed that the estimates range from 33.2 to 94.9%. The maximum heritability value (94.9%) was observed for days to flowering fallowed by 1000 seed weight (90.1%), number of secondry branches^{-1} (86.8%). The minimum estimate was observed for number of primary branches^{-1} (33.2%).

The genetic advance in per cent of mean was found maximum for secondry branches per plant (34.7%) followed by days to flowering (20.97%), 1000 seed weight (14.49%) number of seed per umbel (13.34%). The low genetic advance in per cent of mean was observed for number of primary branches^{-1} (7.98%), plant height (7.44%) and number of umbellete per umbel (7.228 %). These results are in confermative with studies of Jindal *et. al.* (1985) and Sharma *et al.* (1989).

Success of any breeding programme depends upon the efficiency of the selection. Selection can not be applied on the basis of single character because most of characters are palygenic in nature and are influenced by each other. The association study among characters (Table 2) revealed that seed yield was positively correlated with plant height, number of secondry branches, days to flowering, days maturity and number of umbel per plant but the significant and positive association was observed with days to flowering, days to maturity and number of umbel^{-1}.

The results have found favour of Sevda (1980) & Chaudhary (1987). Seed yield was negatively correlated with number of primary branches, number of umbellet per umbel, number of seed per umbel and 1000 seed weight.

Positive and significant correlation were also found

Table 1. Estimates of general mean, mean sum of square, heritability genetic advance, genetic advance as per cent of mean alongwith their coefficient of variances of 10 characters in coriander

Character	Range	General mean ± SE.	Mean sum of square	Heritability broad sense (%)	Genetic Advance	Genetic Advance as % of mean	P.C.V.	G.C.V.
Plant height	110.80-140.50	126.98 ± 2.35	90.61**	76.8	9.45	7.442	4.71	4.13
Primary branches per plant	4.90-7.43	6.395-0.49	0.92	33.2	0.51	7.981	11.63	6.70
Secondary branches per plant	14.53-30.73	23.86-1.37	58.63**	86.8	8.28	34.702	19.40	18.08
Days to flowering	58.33-87.00	73.39-1.44	179.50**	94.9	15.39	20.970	10.72	10.45
Days to maturity	113.33-150.33	131.12-3.38	210.6**	79.0	14.70	11.21	6.89	6.12
No.of Umbel per plant	25.20-34.13	29.23-1.69	14.83**	44.8	2.58	8.826	9.57	6.41
No. of Unbellet per plant	5.03-6.77	5.81-0.34	0.49	38.2	0.42	7.228	9.12	5.64
No.of Seed per umber	37.43-24.77	31.40-1.82	26.17**	58.6	4.19	13.343	11.05	8.46
1000 seed weight	6.32-8.45	7.52-0.15	0.96	90.1	1.09	14.494	7.79	7.40
Seed yield	23.87-30.17	27.65-0.58	8.87**	84.6	3.16	11.428	6.56	6.04

P.C.V. = Phenotypic Coefficient of Variance G.C.V.= Genotypic Coefficient of variance

Table 2. Estimates of phenotypic and genotypic correlation oefficient in coriander

Characters	1	2	3	4	5	6	7	8	9	10
Plant height	rg	-0.09	0.043	0.055	-0.066	-0/018	-0.225*	-0.251	-	0.074
	rg	-	0.036	0.056	0.076	-0.023	-0.059	-0.090	0.0198*	0.072
		0.070							-0.0198*	
Primary branch-1		rg	-0.048	-0.311**	-0.058	-0.175*	0.420**	0.146	0.146	-0.314**
		rp								
Secondary branch-1			rg	0.302**	0.139	-0.019	-0.244**	0.024	0.108	0.142
				0.284*	0.128	-0.034	-0.172	0.013	0.124	0.114
Days to flower				rg	0.358**	0.064	0.086	-0.213*	-0.216*	0.480**
				rp	0.300**	0.032	0.088	-0.169	-0.194*	0.419**
Days to maturity					rg	-0.131	-0.229*	0.060	-0.103	0.507**
					rp	-0.015	-0.216*	-0.015	-0.075	0.409**
No.of umbel-1					rg	rg	-0.076	0.250**	0.209*	0.168
					rp	rp	-0.092	0.066	0.114	0.124
No.of umbellet/ umbelt							rg	-0.224*	-0.056	-0.153
							rp	-0.101	-0.026	,-0.077
No.of seed/Umbel								rg	-0.044	-0.130
								rp	-0.016	-0.032
1000 grain seed weight									rg	-0.197*
									rp	-0.188*

rp = Phenotypic correlation coefficient; rg = genotypic correlation coefficient
*Denote significant at 5% level; ** Denote significant at 1% level.

between primary branches with number of umbellet per umbel, days to flower with days to maturity, number of umbel^{-1} with number of umbellet per umbel, and 1000 seed weight. Therefore while making a programme for improvement of crop through selection these characters may be taken into account.

References

Burton G W 1952. Quantitative inheritance in grasses. Proc. 6th intern, Grassland Cong. 1 : 277-283.

Dubey J W & Moll R N 1969. Interpretation and use of estiamate of heritability and Genetic variance in plant breeding. Crop Sci. 9 : 259-262.

Johnson H W, Robinson H F & Comstock R E 1955. Genetics and environmental variability in saybeans. Agron. J. 47 : 314-318.

Jindal L N, Singh T N, Rangallah & Bansal M L 1985. Genetics variability and path coefficient analysis in coriander crop imp. 12 : 133-136.

Lush J L 1940. Intra-sire correlation and regression of offspring on dams as a method of estimating heritability of characters. Proc. Amer. Soc. Animal Prof. 33 : 293-301

Robinson H F, Comstock R E & Harvey P N 1949. Estimates of heritability and degree of dominance in corn. Agron. J. 41 : 353-359.

Sevda P L 1980. Study on variability and correlation in local collection of coriander. M.Sc.Ag. Thesis, University of Udaipur Campus. Jobner (Rajsthan).

Sharma K C & Sharma R K 1989. Variation and character association of grain yield and its component characters in coriander . Indian J. Genet. 49 : 135-139.

Naturally occurring spices and aromatic plants of North-West Indian Himalayas and their domestication potential

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Abstract

The North-West Himalayas ranging from Kashmir to Kamoun holds rich diversity of spices and aromatic plants. There are several plants that occur naturally and used extensively not only by the people in their daily life but also extracted commercially and sold in the market. Plants that are commonly used for spices and aromatic purposes are *Achillea millefolium, A. latifolia, Acorus calmus, Artemisia* sp. *Carum carvi, Bunium perscium, Angelica glauca, Crocus sativus, Hedychium acuminatum, Hippophae rhamnoides, Jurenia dolomiaea, Arnebia euchroma, Rhododendron* sp., *Allium* sp., *Chenopodium ambrisoides, Mentha* sp., *Prinsepia utilis, Skimmia laureola, Valeriana jatamansi, Cinnamom tamala, Murraya koenigii* and *Ocimum basilium etc.* Many of these naturally occurring species are a good source of earning to the hill people and all these come form the state of their wild growth. Plants are extracted by both legal and illegal means and it is mentioned that much higher quantity is extracted using illegal means and supplied to pharmaceuticals and business houses in the cities. Surveys conducted in Kinnaur, Shimla, Lahaul & Spiti, Chamba, UP hills and Leh & Ladakh areas showed that a large quantity of *Bunium persicum* and *Angelica glauca* collected by the local people and sold at Rs 500-600/kg and 200-300/kg, respectively. Many of these naturally occurring plants have a potential for domestication, cultivation and they can be easily promoted as a new commercial crops. However, intensive agricultural studies leading to genetic improvement and domestication are needed.

Key words: aromatic plants, domestication, spices, North-Western Himalayas

North-Western Indian Himalayan region comprising Himachal Pradesh, Jammu & Kashmir and parts of UP hills has rich repository of spices and aromatic plants generally occurs in the wild state. Despite that most the plants have not exploited to their full potential and still being extracted from wild habitats. Many of them without even tried for domestication have reached at the verge of extinction with the passage of time due to human ignorance or greed for collecting more quantity to earn instant money. The best example of this is *Bunium persicum* being extracted from Kinnaur and Pangi areas of Himachal Pradesh and has not being put under cultivation even by single farmers of the areas. The National Bureau of Plant Genetic Resources, Shimla has undertaken survey exploration trips to the entire north-western part of the country and it was of great surprise that non of the plant which is being used as spice or aromatic plant and also in big demand by the pharmaceuticals houses has been found under cultivation. In this paper an attempt has been made to identify the plant that have value as spices and aromatic plants, their status, occurrence and scope of domestication.

Achillea millefloium L.

It is herbaceous perennial plant with aromatic leaves, attain a height of 1 m. The plant is common in temperate and alpine parts of Himachal Pradesh, UP hills and J&K at an elevation of 2000-3800 m in the semi-forest areas. Flower in July-August. Grows best in ordinary rich soil and open sunny conditions. The propagation is done by divisions of tubers and also by seeds but the germination of seeds is very less. Suckers can be planted at a spacing of 30 cm x 30 cm during spring. The leaves and flowering tops when fresh possess an agreeable and aromatic odour. The bitter principal present in the plant is achilleine - an acid known achilleic acid and tannin and for its volatile oil known as milfoil oil. Entire plant in full bloom is harvested for medicine purpose. It is mild aromatic tonic and astringent. Poultice made from the plant is applied to cure skin rash.

Allium spp.

Except *Allium cepa* and A. *sativum*, this region has many wild species of *Allium*, which are consumed by the hill people. These are annual or perennial, bulbous plants with single, or many scales/ cloves. The leaves are both flat or round hollow depending upon the species. Flower colour varies from white, pink to purplish. The commonly occurring wild *Allium* species are *A. carolinianum, A. humile, A. lilacinum, A. prattii, A. przewalskianum, A. rubellum, A. semenovii, A. sikkimense, A. stracheyi, A. thomsonii, A. tuberosum and A. wallichii*. All these species occur in one or the other part of the North-Western Himalayan region. They are generally used as spice but some times used as medicinal plant also. The NBPGR, regional station, Bhowali, in UP hills maintaining about 25 species of *Allium* collected from different parts of the world and some of them have been successfully domesticated at the station. Dry leaves of some wild species are also sold in the Bhotia markets (tribal of Trans Himalayan region) at Rs. 200-300/= per kg.

Angelica glauca Edgew.

Occur in the temperate hills in deep moist soils, humus rich soils and shady habitats. It is a glabrous herb, stem erect hollow, finely grooved, leaves usually large, 1-3 pinnate, ovate or lanceolate, sharply toothed, umbels compound, long stalked, flowers white or purple. are ideal. Generally, propagated by seeds. Taproots are short and thick and used as spice almost in every household in the hills. It is also sold at the rate of Rs. 100 – 150/= per kg in the local markets of the hills as 'choora' and consider as very important spice for non-vegetarian preparations. The plant population is decreasing at an alarming rate in the natural habitats because root being an economic part is uprooted, thereby, making further propagation very difficult. Keeping in view the demand some local people in upper Shimla and Kinnaur area have tried its cultivation but to the extent of kitchen gardens. It is also considered as stimulant and is beneficial for flatulence and dyspepsia. The dry roots yield 1.3% essential oil, resin and valerianic acid. Root and seeds have aromatic odour and a warm, pungent, bittersweet taste.

Cinnamomum tamala (Buch. Ham.) Nees ex. Fberm.

In the forests, a moderate sized evergreen tree, leaves simple, opposite, fruits ovoid, fleshy, supported by enlarged perianth tube. They require a compost mixture of loamy soil, decayed cow dung, leaf mould, little sand and grows best in moist atmosphere. The leaves are extensively used as flavouring agent for tea and other cookies. The dry leaves collected from the dense forests .are sold at Rs. 20-25 per kg. Scattered population as one or two trees occur in the backyards of people of foothills. Plant requires sufficient shade in the early stages of growth and the shade tress are cleared after 8-9 years. The fields are not usually manured or otherwise cared for. Leaves are also useful cardiac disorders, helminthiasis, colic, hypertyalism, diarrhoea, rectal pains, and splenopathy.

Mentha sp.

A small genus of perennial aromatic herb distributed mainly in the temperate regions. About 6 species have been recorded in India. Grows well in the moist places, an erect aromatic herb with suckers, leaves simple, opposite, flowers lilac in auxiliary distant whorls, fruits nutlets, smooth. The crop requires well-drained, deep, organic rich soil having capacity to retain water. Sandy loam soil, humid growing conditions and sunny situations under temperate and sub-temperate climate are good for the cultivation. At the time of sowing 25 tonnes of FYM and NPK in the ratio of 120:60:60 is recommended. The crop is harvested when it comes to flowering in a bright sunny day at 10 cm above ground level. Rooted suckers taken from old vigorous plants used in propagation. Rooted suckers planted in March and liberally irrigated during summer, flower in July. The same crop gives a second flush in October. Good crops are obtained in second and third year also. The yield of oil diminishes after the third year and it is economical to uproot the crop and replant after suitable rotation. The plants are harvested at full bloom in the morning on a bright sunny day after the dew is cleared. Cut plants are dried in the shade to about 1-3 their fresh weight. The herb yields, on steam distillation, a volatile oil known in the trade as Peppermint oil. Leaves and flowering tops gives the highest yield. Every household uses leaves and tender shoots in chutney particularly in summer as it is considered cool and appetizer. Juice of mint leaves infused with onion juice is given to patients suffering from diarrhoea and vomiting and considered very effective. The yield of fresh herb on an average is around 15 tonnes, which yield about 50 kg oil/ha. Fruits when mature are eaten by children and considered cool in nature. The leaves are useful in arthralgia, halitosis, indolent ulcers, flatulence, peptic ulcer, vomiting, diarrhoea, cough, jaundice and fever.

Murraya koenigii Sprang

Occur as wild as underneath growth in the forests and along road sides, a small aromatic tree with dark green foliage, leaves imparipinnate, leaflets alternate, gland dotted and strongly aromatic, flowers white, fruits subglobose berries and purplish black when ripe. The plant is propagated from seeds and can be sown directly in the pit or seedlings transplanted. Plants are spaced at a distance of 5 m apart. Every year 5 kg FYM and 1 kg cake is applied to each plant. Leaves in small quantity picked after 5-6 months. It is mainly used for seasoning curry and other food preparations especially in the plains. The plant has a great domestication potential and can be easily brought under cultivation. People in the foothills collect the leaves from forests and sell in the adjoining cities of the plains and high hills. The people also eat fruits and fat oil is produced from the seeds. The roots, bark and leaves are useful in hyperdipsia, pruritus, leucoderma, anorexia, flatulence, diarrhoea, dysentery, inflammations and foul ulcers.

Ocimum basilicum L.

Wild in fields and waste lands of the mid and foothills, a pubescent herb, leaves elliptic-lanceolate, entire or faintly toothed, flowers white, pink or purplish, nutlets pitted, mucilaginous when wetted. It grows in a wider variety of soils and climatic conditions. Well-drained soil, humid weather, long days and high temperature are favourable for good growth of these plants and yield of essential oil. Plants are propagated from seeds. Plants are spaced at a distance of 50 cm x 50 cm. 25 tonnes FYM with fertilizer dose of NP (80:40) is optimum for an hectare. It is not cultivated at large scale in the hills but almost every house hold in rural areas grow this plants in backyards. For higher yield of essential oil, leaves and tender shoots are to be harvested at full bloom stage. The leaves are extensively used as spice in the month of June – September. An excellent salt infused with the leaves of *Allium, Ocimum basilicum, Mentha* and green chillies is prepared and consumed by many people in the hills. This salt is generally used in preparing fruit and vegetable salad and some time even bread is eaten with this salt by the patients suffering from fever and stomachache. The dried leaves and flower stalks are also used for preparing tea in winter months which is given to cure influenza and headache. In its medicinal use leaves are said to be thermogenic, appetising, digestive, carminative and expectorant and are useful in anorexia, flatulence, dysentery, parasitic affections, migraine, malaria and fever. It is also distilled in fresh form.

Chenopodium ambrisoides L.

Occur in the waste places, a tall erect much branches aromatic herb, with camphoraceous odour in the high hills of Kinnaur, Lahual & Spiti, Shimla and other hill districts of UP & J&K. Leaves oblong-lanceolate, obtuse, sinuate-dentate, flowers minute clustered. A volatile oil of medicinal value is found in the glandular hairs, especially of the pericarp of the fruit. The plant is anthelmeintic and the volatile oil obtained from it is generally employed in medicine. It has domestication poteneitl but its market has not been established in India. The plant is used in pectoral complaints, nervous affections, compression cough, and also recommended for the expulsion of dead foetus, inflorescence used as anthelmintic. Another species *C. botrys* grows above 2500 m is also highly aromatic.

Hedychium spicatum Ham. Ex Smith

In the open grasslands of hills at an altitiude between 1000-2800 m, rhizomatous herb, leaves reaching 30 cm, oblong, glabrous, spike up to 30 cm, flowers white, capsules glabrous, globose. The plant is commonly grown in gardens and succeeds best in well-pulverized solid rich in humus, high humidity and warm moist weather. Plants are spaced at distance of 40 cm x 40 cm. 50 tonnes of FYM with NPK (120:80:40) is optimum for better growth. It is sold at Rs. 30-60 per kg. Kapurkachari is employed in the preparation of Abir, a fragrant coloured powder used in religious ceremonies. The plant is not cultivated on large scale but some pharmaceuticals are getting this plant cultivated by giving contracts to farmers in some parts of the region. The plant occurs in plenty in the region and tremendous variability exists, however, this variability need to be screened for better genotypes. The rhizomes also have insect repellent properties and are used for preserving cloths. Mats for domestic use are woven from its leaves. The dried fruits are added to soften meat and pulses during cooking. The rootstock is astringent, useful in inflammations, asthma, foul breath, laxative, and tonic, to the brain, stomacache and stimulant.

Punica granatum L.

A large deciduous under-shrub, often spinescent branches, leaves opposite, shining above, bright green beneath, flowers scarlet red, mostly solitary, seeds angular with red, pink or whitish fleshy testa. It occurs as wild growing plant in many parts of the foot-hills of Jammu, Sirmour, Mandi, Bilaspur, Solan, Shimla and parts of mid hills of UP. The plant has been exploited very much for its seed collection thereby, making its further propagation difficult. The ried seeds without extracting juice are sold in the local market as anardana @ Rs. 150-200/kg. The dried seeds are used as spice for souring many racepies and it makes excellent chutney infused with *Mentha* and *Allium* leaves and prepared by almost every household of the Himachal. This chutney is also given to patients suffering from fever or stomach troubles especially when there is loss of appetite. The roots are good for tapeworm, and for strengthening gums. The flowers are styptic to the gums and its extract very specific for nose bleeding. The fruits are useful in anaemia, hyperdipsia; fruits rind is good for dysentery, and gastralgia. The seeds are stomachache, diuretic and cardio tonic.

Rhododendron anthopogon D. Don.

The plant is a small shrub or a scrub with an aromatic odour. Branchlets are scabrous and scaly. Leaves 2.5 to 4.0 cm long, elliptical broad oblong, shining above and brown tomentose beneath having short petiole. Flowers are yellow and in dense, terminal corymbs. Flower in June-July and leaves which is an economic part sold at Rs. 20-30/- per kg. Leaves possess stimulant properties and are aromatic. There is need to screen this plant chemically. Harvesting of leaves, top shorts is done during September-October.

Viola odorata L.

Perennial stock short, branches, knotted with the remains of old leaf stalks, leaves in radical, broadly cordate, flowers nodding, bluish purple, scented. It grows wild in the mid to high hills. It is not a cultivated plant in this region but local people collect the plant at its flowering stage in a very large scale in the month of March-April. The dried flowers and tender leaf tops are sold in the market as vanaphsha and also mixed in several home remedies used for cough and cold. People prepare tea from its flowers and consume in the winter that protect them from cough and cold. During season school going children used to sell small packets of it flowers along the high ways. In Ayurveda its leaves are considered as laxative, emollient, diaphoretic and antispasmodic. Flowers used to cure skin affections. Whole herb is also used to cure cough and cold.

Bistorta vivipara S. F. Gray

A common alpine of moist meadows, erect, glabrous, perennial herb, swollen, woody rootstock, leaves variable, crenulate, acute, narrowly lanceolate, flowers white or pinkish and some times red. The roots are reddish in colour and give very good aroma. People in the high hills especially the nomadic and shepherd chew its roots, as they are sweet in taste. Young leaves and rootstocks are edible, tonic, stringent, decoction of herb used as gargle for soar throat and spongy gums.

Nardostachys jatamasi DC.

n the alpine Himalayas at an altitude between 3000-5000 m, an aromatic erect perennial herb, woody long root-stock, covered with reddish brown fibbers of the petioles of radical leaves, flowers rosy pale pink or blue, in dense cymes. Rhizomes sold at Rs. 90-160 per kg. Flower in June-July and fruiting in September-October. The hairy roots contain essential oil having jatamansone and many other chemical constituents. The plant is propagated by cuttings, divisions of roots and some times by seeds. The plant is not cultivated any where in the region and extracted from the natural sources. The plant being of great importance as a drug and having been enlisted as endangered species needs special attention for domestication. The rhizome is highly aromatic, bitter, antiseptic, anodyne, liver stimulant, diuretic, nervine tonic, intellect promoting and is useful in pectoralgia, dermatopathy, epilepsy, convulsions, neurosis, grey hair, falling of hair, hypertension and general debility.

Origanum vulgare L.

The herb is found in temperate Himalayas between 1500-3600 m elevation. It is an aromatic, branched, perennial herb, and 30-90 cm high. Leaves are broadly ovate and flowers are in terminal corymbose cymes. Flowers have pale white colour. Flowering fruiting occurs from June to December. Leaves, top shoot and even entire plant is considered as economic part. The herb is propagated by seeds, cuttings, layers and root divisions. It is sown in March – April in the hills. The leaves and tops, cut prior to blooming are used to flavour foods. The plant is also used as pot-herb in Lahaul & Spiti district of Himachal Pradesh. The herb contains a volatile oil containing 50% thymol. The leaves and tops cut prior to blooming are used to flavour foods The oil possesses carminative, stomachache, diuretic, diaphoretic and emmenagogue properties. The oil is also extensively used cosmetic and soap industry.

Skimmia laureola Sieb. & Zucc.

In the hills, an erect glabrous shrub, bark fairly smooth, blaze yellow, strongly aromatic, leaves crowded towards the end, oblong lanceolate, flower pale greenish yellow, stamens yellow, drupe ovoid red. It is not cultivated and leaves are collected from the forest by the villagers and used to fragrant the local atmosphere. The dried leaves when brunt with desi ghee on red-hot coal, emit out highly scented fumes, which purify the atmosphere. The orange or purple berries are sweet in taste are administered to the fever stricken patients to ally the thirst. The smoke of the leaves purify the air, incense is also prepared from them. Essential oil is also obtained by steam distillation.

Valeriana wallichii DC.

In the Himalayas at an altitude of 1800-3000 m, a tufted hairy herbaceous perennial, basal radical leaves long stalked, deeply cordate, flowers white tinged with pink in terminal corymbs, fruits oblong. It easily responds to cultivation. It prefers deep rich soil and flourishes in shady and moist localities. The plant may easily be propagated by portions of the old root-stocks either in the autumn months or in spring. The divisions of roots are spaced 30 x 60-90 cm. The summer cultivation requires the weeding of beds and cuttings of all the floral stalks to avoid exhaustion and promote the formation of larger root-stocks. The plant can also be propagated by seeds or with seedlings of the wild plants. A liberal application of FYM, which should be worked thoroughly into the soil before the seedlings are transplanted, favours the growth of the plant as well of the roots. A low ridge of the soil is generally raised along the bases of the plants to promote the formation of larger rootstocks. The plant flowers during April – June and the rhizomes and roots are dug out in the autumn. They are cleaned with water and dried in the sun on mats. The dried rhizomes and roots have been recognized as Indian valerin. It is available in the markets as dull yellowish brown pieces of rhizomes, 4-8 cm long x 5-12 mm thick, sub-cylindrical, somewhat flattened, usually slightly curved and unbranched. The dried root and rhizome sold at Rs. 45-50/- per kg. The dried rhizomes are used as perfumes and hair preparations, and as incense, and to a lesser extent in medicine. On stem distillation rhizomes yield a sweet smelling essential oil to the extent of 0.5-2.12%. The oil is pale brown or amber yellow coloured liquid with root like odour with a distinct note of valeric acid. The drug is also in much use in making perfumed powder. The roots are alexteric, emollient, hypnotic, carminative, hepto and cardio tonic, useful in arthalgia, convulsions, cardiac debility, dry cough, falling of hair, and splenopathy.

Arnebia benthamii. (Wall. Ex G. Don.) Johnston

Common on open alpine slopes between 3500-4000 m elevations, erect, tall, robust, grey hair, perennial herb, stem simple leafy. Leaves lanceolate, 5 nerved, densely hispid with long hairs, flowers purplish hrown or red to blackish, long shaggy bracts. Flower in July-August and roots are sold at Rs. 75-150 per kg depending upon the market location and buying capacity of the people. It grows very well in ordinary rich soils and sunny situations. The plant is useful in disease of tongue and throat and also for cardiac disorders. People also prepared syrup, jam from the flowering shoots and considered good for tongue and throat. Used as colouring matter in cookeries and various foodstuffs. The plant is not cultivated in any part of the Himalayan region and roots are collected from its wild habitats. It can be easily propagated through seeds and divisions of roots. Roots are also considered as hair tonic and red coloured oil commonly marketed as lal tael is prepared by infusing its roots in the mustard oil by the local communities. Other species used for the same purpose is *Arnebia euchroma* and both of them are generally adulterated by A. *hispida, A. guttata, Geranium nepalenses, G. wallichianum and Onosoma* spp.

Artemisia brevifolia L.

A strongly aromatic perennial herb, stems 30-60 cm high, grooved and ribbed, leaves long, sessile, linear, sharply toothed, flowers heads almost round yellow to yellowish-red arranged in clusters of axillary spikes. Well-drained organic rich light loamy soil is suitable for its cultivation. They prefer cold winter and moderate summer. Propagation is done by seeds. Seeds are sown in nursery beds in March-April and seedlings are transplanted in April-May in a well-prepared fertile land. The crop is harvested at flower initiation stage and plants are cut above 40-50 cm above ground level. Second harvest can be obtained in September-October. These are dried in shade and after drying leaves and flower buds are separated from the stalk. One hectare of land may yield 5-6 tonnes of dried plant matter. The aromatic leaves are credited with aperient, stomachic, stimulant, and febrifuge properties.

Bunium persicum (Boiss.) Fedt.

It is often found as weed in cultivated land, or as wild growth on grassy slopes of mountains. It is tuberous herb, tuber covered with black scales outside, white inside, leaves 2-3 pinnate, finely dissected, fruits yellowish brown, ridges thin. The plants come out in the month of march-April after the snows melt. It flowers in May-June and seeds mature at the end of July or first week of August. The rhizome remains dormant from August to February and the cycle goes on upto 12-15 years depending upon the conditions. It can be propagated by both seeds and rhizome but the crops raised through seeds takes 3-4 years to produce seeds but the crop raised through 3-4 years old rhizomes,then it gives seeds in the same year. It grows well in sand loam soils rich in humus and proper drainage system because rotting of rhizomes may occur under water stagnation. The seeds must be sown before mid of November i.e. before snowfall. The seeds can be sown 2-3 cm apart in 50-60 cm spaced rows, whereas rhizomes can be planted 20 cm apart in 50-60 cm spaced rows. Under optimum management conditions it require 200-300 q well rotten FYM, 200 kg super phosphate, 50 kg murate of potash and 350 kg Calcium ammonium nitrate per ha. Half of the nitrogen can be applied in top dressing in two doses i.e. one just after the snowmelt and rhizomes sprouts and the second at the time of flowering. The seeds are sold at Rs. 300-400 per kg. Seeds contain 2.5% essential oil having 45-65% carvone. Tubers eaten raw or as vegetable and seeds as spice. Seeds commonly known as kalazeera are considered as prized spice in cooking and generally and added to special dishes. Considered as useful carminative, allay gripping in the abdomen and appetizer.

Carum carvi L.

It is commonly known as kalazeera or caraway but inferior grade to *B. persicum*. It is a biennial forming tap root, stem erect, leaves pinnate with several pairs sessile segments, upper leaves smaller and less divided. The species is cultivated in cool climates in well-tilted soils rich in humus. The fruits may be sown either in broad cast or sown in rows 12 inch apart. The seeds are collected before ripening and sold at Rs. 200-250 per kg. Well-ripened fruits may also be reaped in the early mornings when the plants are bathed in dew. The plants are dried and fruits threshed out, cleaned and stored in bags. Under recommended package of practices seed yield up to 2000 kg/ha can be obtained. It is widely used as a spice for culinary purposes and for flavoring fast foods. The oil known as kummel is a strong carminative, stimulant and aromatic. Seeds used for flavoring foods, stimulation of appetite, relieving gastric discomfort, roots sometimes used as vegetable.

Crocus sativus L.

A small bulbous perennial, 6-10 inch high, cultivated for its large scented blue or lavander flowers in the alpine region, rootstock a sheathed corm, leaves radical, narrowly linear, perianth funnel shapes, tube very slender, flowers violet, anthers yellow. It thrives well in cold regions with warm climate. It requires a rich well-drained, sandy or loamy soil. The plant is propagated vegetatively by bulbs. It is planted in August-September, in raised plots (about 5ft square) surrounded by drains 9 inch wide x 6 inch deep laid out in well pulverized soils. The plots are hoed and weeded. No manure is applied or irrigation given, once the plant are established. Bulbs once established continue to live for 10 to 15 years, new bulbs being produced annually and old ones rotting away. The plants flower in October-December. For collecting the saffron, the flowers are collected daily early in the morning after the dew disappear. Heavy rains during flowering are harmful to the crop. Styles and stigmas plucked from freshly collected flowers and dried in the sun. The quality of the final product varies with the method of extraction of floral parts and subsequent treatment. The tripartite stigmas plucked from freshly collected flowers and dried in the sun constitute saffron of the best quality. Depending upon the quality and place it is generally sold at Rs. 35,000 to 55,000 per kg. It is principally used for its colouring and flavouring properties. It is also credited with various medicinal properties as it is fragrant, pungent, anthelmintic, tonic, useful in bronchitis, throat troubles, triodosha, leaves useful in fractures and pain the joints, also stimulant and stomachache.

Hippophoae rhamnoideas L.

Occurs in the riverbeds of drier ranges of the north – western Himalayas at an altitude between 2200-4000 m, a stiff densely branching shrub, bark ashy or silvery grey, twigs and young shoots densely clothed with silvery brown scales, leaves densely clothed on both surface, with silvery brown scales, fruits globose. Flowering and fruiting occur from June to September. Fruits are sold at Rs. 10-15 per kg. Very easy to propagate and can be propagated through seeds, suckers and vegetative cuttings. It is not cultivated and fruits are collected from its wild populations. The fruit is acidic and is made into jelly with sugar. The fruit contains a dark red fatty oil, pleasant odour. The fruits are also a rich source of vitamin C and used as a main agent in sour preparations. The juice powder keeps its vitamin potency for 2-2.5 years. Decoction of plant is also used for cutaneous eruptions, and also in lung complaints. Another species that is equally important is *H. salicifolia* and used almost in similar manner except that its bark is also used in curing certain types of cancers.

Juniperus communis L.

It is dwarf evergreen plant, low and spreading in habit. It occurs in the forests between 3000-4500 m altitude as dense shrub, leaves in whorls, of 3, sharply pointed, bluish white on the upper surface, flowers deciduous axillary, fruits subglobose, blue black. Open well-drained sunny situations with good ordinary soil are ideal. Seeds or cuttings of young branches propagate plants. Fruits are sold at Rs. 20-25 per kg and wood at Rs. 50-60 per kg. Seeds if maintained under proper storage conditions remain viable for several years and take about one year to germinate. The fruit contain volatile oil, sugars, resins, juniperin fixed oil, protein, wax, gum, pectin, organic acids and salts. Indian Junipers yield as low as 0.25% of essential oil. Junieprs fruits are also used spice to food. Leaves are used as incense. The plant has a bad odour, mild astringent to bowels, antipyretic and tonic, useful in stomatitis, bronchitis, and disease of the liver and spleen. Other species that are equally important are *J. macropoda*, and *J. recurva*.

Jurenia dolomiaea Boiss

Common on open slopes at an altitude of 10,000 to 14,000 ft., often gregarious, rosette forming, ashy grey, stemless perennial herb, woody root, leaves prostrate oblong-lanceolate, pinnate, cobwebby above, white tomentose beneath, heads purple, achenes ashy grey, pappus hairy brown. It flower in July and seed mature in September. The plant is not cultivated by the people but extracted heavily from the natural habitats. In some of the accessible habitats it has reached at the verge of extinction because the economic part is roots, which need uprooting of entire plant making further propagation difficult. In the market it is sold at Rs. 50-70 per kg. The aromatic roots are used as incense in house, temples and religious ceremonies. They are the chief ingredients of dhup available in the North Indian markets. The roots are considered to be stimulant and given in fever after child birth. The bruised root is applied to eruptions, and a decoction is given in colic. It is also considered and given in puerperal fever.

Thymus serphyllum Benth

An aromatic prostrate herb, common on dry, rocky slopes, much branched, often tufted, very aromatic, stem hairy, creeping, leaves sessile to very shortly stalked, ovate, feebly toothed, with few long white hairs near base, flowers purplish. Grows well on poor gravelly soil, well-drained and sunny rockeries are ideal. Propagated by seeds or by cuttings. The other two important species of *Thymus* are *Thymus vulgaris* L. and *T. zygis* L. The seeds are either sown in raised beds first and then transplanted at a spacing of 45 cm x 60 cm. or they may be directly sown in final site. If grown from seeds nearly 7 kg seeds are required per ha. The plants yields an essential oil with pleasant flavour and possesses stimulating and diuretic properties. 40 kg of thyme oil can be obtained from one ha of land. In Himachal Pradesh, about 5000 kg herb is collected per year from Kullu and Kangra valley. Generally, it is collected during July-August. The shoots are employed fro flavouring and a non-alcoholic beverage is reported to be prepared from the leaves. Flowering tops are harvested and distilled and yield volatile oil known as 'oil of wild thyme'. The oil is pale yellow liquid, with an agreeable odour, reminiscent of thyme, lemon and geranium. The herb is sold at Rs. 15-20/- per kg. Leaves and flowering tops employed for suppression of urine and menstruation and for convulsive and whooping cough. Oil useful in toothache and hair lotions.

Why do we need domestication and cultivation of naturally occurring spices and aromatic plants?

- There has been tremendous extraction of these naturally occurring spices and aromatic plants from their natural habitats. It is thus a high time that concerted efforts be undertaken to protect, propagate and cultivate these valuable species on large scale. Rich, natural habitats of these herbs have to be identified and declared as 'Biosphere Reserves' with full protection. This reserve can be for a single species or for multiple species depending upon their occurrence in respective areas. In our western Himalayan region, model reserves for *Ephedra geradiana, Artemisia brevifolia, Arnebia euchroma* can be selected in Pooh and Spiti sub-division of Himachal Pradesh, Pomegranate in

Narang, Basantpur, Ranbag areas of Jammu, ***Bunium persicum*** in Pangi and like wise for many other high value plants. Priority should be given to those plants, which are either getting extinct or likely to be.

• Domestication and cultivation make available fresh, genuine and quality raw material for manufacturing of standardised and efficacious drugs. To overcome the maladies being experienced in the present marketing scenario such as spurious material and adulteration, the domestication and cultivation of these plants in indispensable. Cultivation involves several checks at every point, i.e. use of the genuine propagating material, optimum use of fertilizers, proper spacing, adequate protection from disease and pests. The chemical constitutes have to be evaluated at different stages of growth to find out the right part of the plant to be used and the right time of collection of different parts of a plant to provide efficacious and standard material

• To evolve better strains and high-yielding crops of medicinal plants through improvement programmes and tissue culture techniques. Many plants occurring in the natural state have tremendous variability and better genotypes with both high yield and chemical constituents can be screened. Thus, under cultivation not only the bulk of the produce will increase but the production of active constituents is also increased.

• To check the use of spurious substitutes and adulterants which have resulted in the deterioration of the standard products. When we look at the original constituents of the product and the plant mention for its preparation are many times of rare nature. People and many time agents who supply the material mix the plant with the plants of same nature. Domestication of the plants will overcome these adulterations.

• To standardised the collection, storage and post harvest technology for these plants. When we will bring the plants under domestication certainly all agronomy, breeding and many other pre and post harvest parameters will be taken care of.

• To provide regular and alternative source of income to the farmers to ameliorate their economic condition. While collecting the plants from their natural habitats we come across with two losses firstly we loose the plants permanently and secondly it does not provide assured income and also we had to move around hills for the collection and will be waste of time and resources. Cultivation of such plants will be a good source of income and simultaneously pressure on the natural habitats will be lessened.

• For introduction and domestication of useful exotic plants to minimise import and maximise export. Plants having better qualities can be imported and put under cultivation in the respective regions. Extraction of plants from natural habitats does not full-fill the demand of the pharmaceuticals and therefore much of the raw material needs to be introduced from other countries. Domestication and cultivation of our wild natural resources will also meet the domestic requirement and also increase the export potential.

• To conserve the biological and genetic diversity in medicinal plants for the posterity. This is the most important aspect. After extracting plants from natural habitats many of the plants have been extinct and many more are in queue. By bringing them into cultivation this precious biodiversity can be saved not only to meet the requirements of present but also posterity.

• Domestication and cultivation of naturally occurring plants species will diversify the genetic as well as crop base. Increased yield and quality levels and farmers' field and simultaneously preserving them in natural habitats will play an important role in the promotion of national spices production and GDP of the country.

References

Anonymous 1945-1976. Wealth of India, Raw Materials, Vol. I-XI, Publication and Information Directorate, CSIR, New Delhi.

Atkinson E T 1980. Flora of the Himalayas (with special reference to Garhwal, Kumaon and parts of Tibet); Cosmo Publication, New Delhi.

Chandel K P S, Shukla G & Sharma N 1996. Biodiversity in Medicinal and Aromatic Plants in India: Conservation and Utilization. NBPGR (ICAR), New Delhi. Pp. 239.

Collett H 1971. Flora Simlensis a Handbook of the flowering Plants of Shimla and the Neighbourhood. M/s. Bishen Singh Mahendra Pal Singh, New Cannaught Place, Dehra Dun.

Chopra R N, Nayar S L & Chopra 1956. Glossory of Indian Medicinal Plants. CSIR, New Delhi. Pp. 330.

Kirtikar K R & Basu B D 1935. Indian Medicinal Plants. Vol. I-IV. Pub. M/S. Bishen Singh Mahendra Pal Singh, New Cannaught Place, Dehra Dun.

The relative stability of a variant clone of an Indian cultivar of rose-scented geranium for its essential oil composition

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Abstract

The relative stability of a variant clone, No. 64, of an Indian cultivar of rose-scented geranium (*Pelargonium* sp.), 'Bourbon', for its essential oil composition was studied to determine whether its essential oil composition was distinctly different from that of its parental cultivar as well as commercial geranium oils. The clone No. 64 was developed from a variant obtained from plants raised through adventitious bud formation on leaf cuttings of cultivar 'Bourbon'. The essential oil composition of the Indian geranium cultivar, 'Bourbon' is similar to the 'African' geranium oil. Essential oil samples of clone No. 64 and its parental cultivar were obtained from their respective plants grown in the field, at monthly intervals for 12 months starting from August 1997. The contents of 10 important constituents viz., linalool, *cis*-rose oxide, *trans*-rose oxide, menthone, isomenthone, citronellol, geraniol, citronellyl formate, geranyl formate and 10-epi-γ-eudesmol in the essential oils of the two clones were determined by gas chromatography. The contents of citronellol (34%), citronellyl formate (10.1%), *cis*-rose oxide (1.5%), total "rhodinol" (72%) and citronellol/geraniol ratio (2.9) were significantly higher in the essential oil of clone No. 64 than those (24.5, 6.8, 0.9, 69.2% and 1.2, respectively) in the oil of the parental cultivar. The contents of geraniol (16.7%) and 10-epi-γ-eudesmol (0.2%) the oil of clone No. 64 were significantly lower than those (24.6 and 5.4%, respectively) in the parental cultivar. The differences in these constituents of essential oils of the two clones were consistent over 12 months of evaluation. The contents of 6,9 guaiadiene in clone No. 64 was found to be low (0.11%) and similar to that in the parental cultivar. Thus, the contents of 6,9 guaiadiene and 10-epi-γ-eudesmol and the citronellol/geraniol ratio (which are critically used in differentiating commercial geranium oils) in the oil of clone No. 64, suggested that its essential oil composition was different from its parental cultivar as well as commercial geranium oils (Reunion, African, Chinese and Australian).

Key words: essential oil composition, geranium, *Pelargonium*, variant clone

Introduction

Geranium oil obtained from distillation of herb of different species *Pelargonium* is used in high-grade perfumes, cosmetics and toiletries. It is also used as a substitute for the expensive attar of roses. Three main types of geranium (*Pelargonium* sp.) oils are known in essential oil trade viz. "Bourbon", "Chinese" and "African. 'Bourbon' geranium oil is produced in the island of Reunion and is known as 'Reunion" geranium oil. It is considered to be of the highest quality. Chemically the 'Chinese' geranium oil is distinguishable from 'Bourbon' and 'African' geranium oils by its higher citronellol : geraniol ratio (3-4:1) while the 'Bourbon' and the 'African geranium oils are distinguishable from each other by their relative contents of 6,9 guaiadiene 10-epi-γ-eudesmol (Teisseire 1987). Recently, Southwell *et al.* (1995) reported the essential oil composition of an Australian geranium genotype. The oil of this genotype was similar to the 'Bourbon' geranium oil but had intermediate citronellol : geraniol ratio of 3 : 1 as compared with 'Bourbon' and 'Chinese' geranium oils.

In India, commercial geranium oil is mainly produced from two types of cultivars: (1) 'Reunion' or 'Bourbon' and (2) 'Algerian' or 'Tunisian'. The essential oil of the Indian cultivar 'Algerian' resembles the 'Chinese' geranium oil for its citronellol : geraniol ratio while the Indian cultivar 'Bourbon' resembles the 'African' geranium oil. During the course of genetic improvement work on geranium, 21 variants were identified in the progeny obtained from adventitious bud formation on leaf cuttings of the Indian cultivar 'Bourbon'

(Kulkarni *et al.* 1997). The essential composition of one of the clones, No. 64, appeared to be intermediate between the Australian' and 'Bourbon' geranium oils for the ratio of citronellol : geraniol. The relative stability of this clone, No. 64, for its essential oil composition was studied, in comparison with its parental cultivar, over a period of 12 months to determine whether its essential oil composition was similar to any of the known geranium oil or constituted a different type. The results, which showed that the essential oil composition of clone No. 64 is different from those of the reported geranium oils, are reported here.

Material and methods

Plants of the two clones, No. 64 and the Indian cultivar 'Bourbon' were raised by stem cuttings from their respective plants. The rooted cuttings of each clone were planted in six plots of 6.25m^2 size each on 17 February 1997. The clones were allotted to the plots randomly. A random sample of the herb of two clones was distilled in a clavenger's type apparatus every month for 12 months starting from 20 August 1997. Identification and estimation of constituents of essential oils of two clones was carried out by GC, GC/MS analysis, as described earlier (Kulkarni *et al.* 1998).

Results and discussion

The two clones did not differ significantly for oil content (Table 1), as found in an earlier study (Kulkarni *et al.* 1997). However, the contents of citronellol, citronellyl formate, *cis*-rose oxide and total 'rhodinol' as well as the citronellol/geraniol ratio were significantly higher in the oil of clone No. 64 than in the oil of the parental cultivar (Table 1). Further, the oil of clone No. 64 had significantly different from the parental cultivar as it had only traces of (<1.0%) of 10-epi-γ-eudesmol. These differences were further found to be quite consistent over the 12- month period of evaluation (Fig. 1). The oil of the Indian cultivar 'Bourbon' is considered to be similar to the 'African' geranium oil of commerce because of the absence of 6,9 guaiadiene and the presence of significant quantity of 10-epi-γ-eudesmol in it. The oil of the clone No. 64, however, contained only trace quantities of both these

Table 1. Values of mean, standard error (SE) and range of oil content and some of its constituents in the geranium clone No. 64 and its parental cultivar, Bourbon

Constituent	Mean ± SE		Range	
	Parental cultivar	Clone No. 64	Parental cultivar	Clone No. 64
Oil content	0.24 ± 0.008	0.26 ± 0.009	0.20 - 0.30	0.20 - 0.32
Linalool	9.6 ± 0.55	8.7 ± 0.83	6.5 - 12.7	3.1 - 11.8
Cis-Rose oxide*	0.9 ± 0.20	1.5 ± 0.23	0.3 - 2.3	0.6 - 2.9
Trans-Rose oxide	0.4 ± 0.05	0.5 ± 0.07	0.1 - 0.8	0.3 - 1.0
Menthone	0.3 ± 0.05	0.4 ± 0.04	0.1 - 0.7	0.2 - 0.6
Isomenthone	9.6 ± 0.56	10.4 ± 0.42	6.8 - 13.1	8.1 - 13.0
Citronellol*	24.5 ± 1.80	34.0 ± 2.20	18.5 - 35.4	25.3 - 47.0
Geraniol*	24.6 ± 2.06	16.7 ± 2.06	10.2 - 32.4	4.7 - 25.8
Citronellyl formate*	6.8 ± 0.36	10.1 ± 0.48	5.3 - 8.7	7.9 - 12.6
Geranyl formate	2.9 ± 0.42	2.4 ± 0.36	0.4 - 5.9	0.4 - 4.2
10-epi-γ-eudesmol*	5.4 ± 0.32	0.2 ± 0.02	3.7 - 7.2	0.1 - 0.4
Citronellol/geraniol ratio*	1.2 ± 0.26	2.9 ± 0.83	0.6 - 3.5	1.0 - 10.0
Free Rhodinol	58.6 ± 0.87	59.5 ± 0.65	52.1 - 61.8	54.8 - 62.2
Total Rhodinol*	69.2 ± 0.73	72.0 ± 0.68	65.3 - 73.8	67.5 - 75.4

The contents of these constituents in the essential oil of clone No. 64 were significantly different than those of the parental cultivar

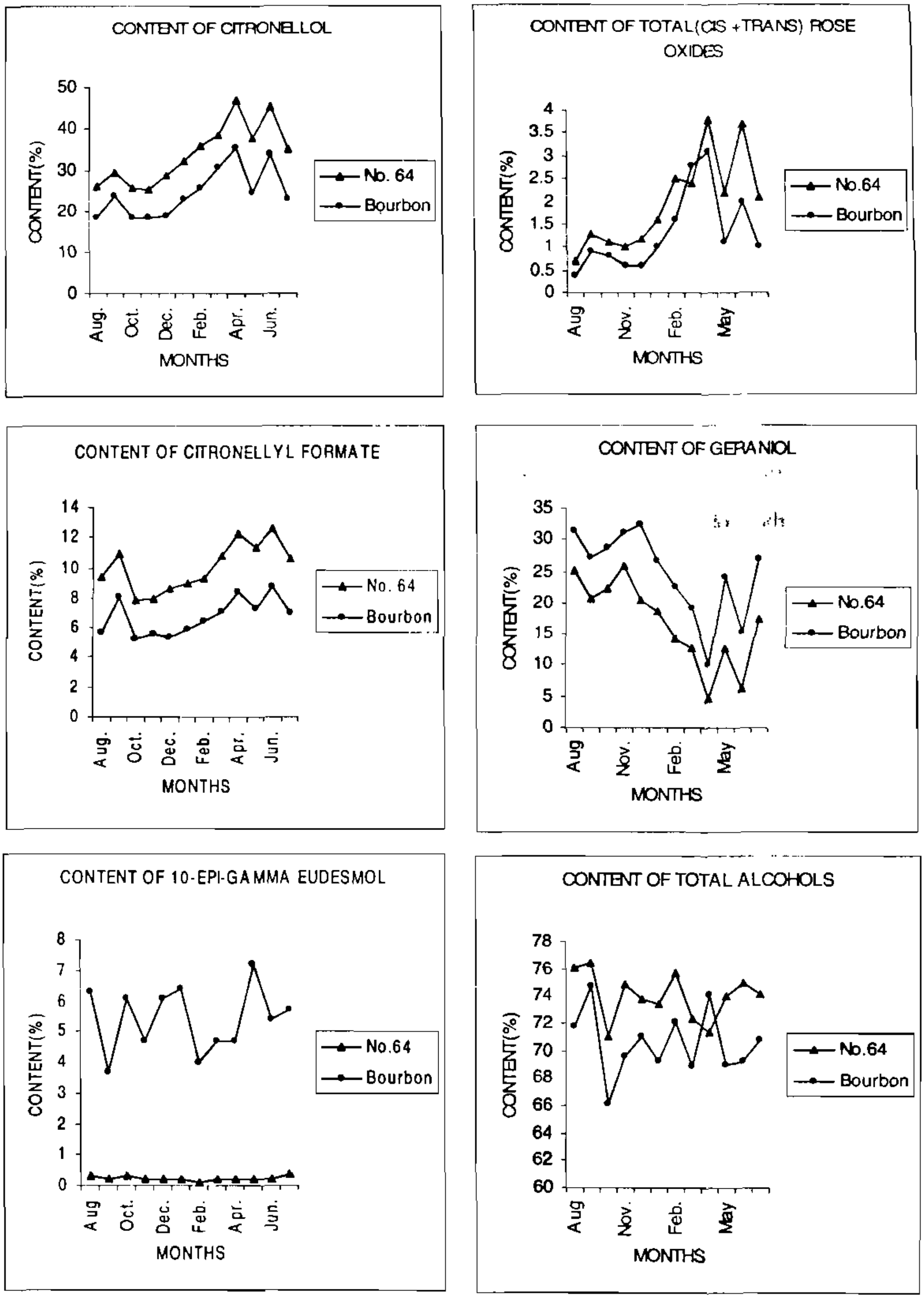

Fig. 1. Contents of essential oil constituents of geranium clone 64 in comparison with the parental cultivar, 'Bourbon'

compounds and, therefore, does not fall in to any of the four (Bourbon, African, Chinese and Australian) reported types of geranium oils. The essential oil composition of the clone No. 64 appeared to be similar to the reported composition of the essential oil of the Australian geranium clone, except for its low content of 6,9 guaiadiene (Southwell *et al*. Essential oil composition 1995). The contents of citronellol, geraniol and their esters and rose oxides in the oil of the clone No. 64 were generally on the higher side as compared with their contents in its parental cultivar and other geranium oils reported by Southwell *et al*. (1995) and Cu (1996) and therefore may contribute to better quality (olfactory) of its oil. The results of this study thus suggest the essential oil of this geranium clone, No. 64, is distinctly different from the reported composition of commercial geranium oils.

The commercial 'Bourbon' or 'Reunion' geranium oil is reported to be derived from *P. graveolens* while the 'African' and the 'Chinese' geranium oils are reported to be derived from *P. odoratissimum* (Anonymous 1990). However, Demarne and Van der Walt (1989) concluded that the geranium cultivar, 'Rose' grown on the island of Reunion is a hybrid between *P. capitatum* and *P. radens*. The Australian geranium genotype is reported to be a hybrid between *P. graveolens* and *P. capitatum* (Southwell *et al*. 1995). The relative contents of citronellol and geraniol and the presence or absence of two compounds, 6,9 guaiadiene and 10-epi-γ-eudesmol, have been critically used in the classification of commercial geranium oils and in determining the parentage of geranium cultivars (Teisseire, 1987, Demarne and Van der Walt 1989). The clone No. 64 obtained the Indian cultivar 'Bourbon' (whose oil is considered as 'African' type), contained negligible quantities of both 6,9 guaiadiene and 10-epi-γ-eudesmol in its essential oil. Thus the essential composition of clone No. 64 and its mutant origin from the Indian cultuvar 'Bourbon', along with a few other variants (Kulkarni *et al*. 1997,1998), once again demonstrate that data only on the essential composition are not sufficient for determining the parentage of cultivars (Kulkarni 1995, 1997). This fact is further supported by the statement of geranium breeders, mentioned in a recent paper (Lis-Balchin and Roth, 1999), that many *Pelargonium* crosses have no resemblance to their parents.

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References

Anonymous 1990. Application of gas-liquid chromatography to the analysis of essential oils. Part XV. Determination of "Rhodinol" in oils of geranium. Analyst 115 : 459-463.

Cu J Q 1996. Geranium from Yunan, China. Perf. Flav. 21(5) : 23-24.

Demarne F E & Van der Walt J J A 1989. Origin of the rose-scented Pelargonium cultivar grown on Reunion Island. South Afr. J. Bot. 55: 184-191.

Kulkarni R N 1995. On the use of essential oil profiles for the determination of parentage of cultivars of unknown or suspected interspecific origin. J.Essent. Oil Res. 7 : 463-472.

Kulkarni R N 1997. On the use of essential oil profiles for the determination of parentage of cultivars of unknown or interspecific origin: A reply to the response. J. Essent. Oil Res. 9 : 253-254.

Kulkarni R N, Baskaran K, Ramesh S & Sushil Kumar 1997. Intra-clonal variation for essential oil content and composition in plants derivedfrom leaf cuttings of rose- scented geranium (*Pelargonium* sp.). Industrial Crops Products 6 : 107-112.

Kulkarni R N, Mallavarapu G R, Baskaran K & Sushil Kumar 1998. Composition of the essential oils of two isomenthone-rich variants of geranium (*Pelargonium* sp.). Flavour Fragr. 13 : 389-382.

Lis-Balchin M & Roth G 1999. Citronellic acid : A major component in two *Pelargonium* species (Geraniaceae). J Essent Oil Res. 11 : 83-85.

Southwell I A, Stiff I A & Curtis A 1995. An Australian geranium oil. Perf. Flav. 20(4) : 11-14.

Teisseire P 1987. Industrial quality control of essential oils by capillary GC. In : Sandra P & Bicchi (Eds.), Capillary Gas Chromatography in Essential Oil Analysis. Huethig, Heidelberg, pp. 215-258.

Micropropagation studies in jasmine (*Jasminum sambac* Ait.)

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Abstract

Jasmine (*Jasminum sambac* Ait.) belonging to the family Oleaceae is one of the important commercial crops valued for its fragrance and appealing nature. Studies were conducted to standardize the type of explant and level of plant growth regulators for callus production, shoot proliferation and elongation of rhizogenesis. Different explants like stem bit, leaf bit and shoot tip were used to induce callus in MS media supplemented with BAP and IAA at different concentrations. Leaf bit recorded highest callusability in MS medium supplemented with 1mgl^{-1} IAA and 10 mgl^{-1} BAP within 23 days. Development of shoots were observed from leaf bit callus cultured on MS medium supplemented with BAP 12 mgl^{-1} when compared to kinetin. Among the auxins tried, NAA 3mgl^{-1} proved to be the best for rhizogenesis.

Key words: callus, indirect organogenesis, *Jasminum sambac*, tissue culture.

Introduction

In India jasmine ranks first in the area occupied (8000 ha) among flowering plants. There are four species of jasmine that are popularly cultivated. Arabian jasmine (*Jasminum sambac* Ait.) is one among the leading commercial flowers of South India. This crop can be profitably cultivated in the coastal tract through the research work carried out at Annamalai Academe for adoption, saline tolerance and response to growth regulators on yield. The commercial cultivation of this crop mostly depends upon the availability of genuine planting material, which is exclusively propagated by vegetative means. The clonal multiplication through conventional methods of asexual propagation is not rapid enough to meet the sharp increase in the demand for the propagating material of this crop. Hence an attempt was made to justify the rapid multiplication of this crop through *in vitro* techniques like standardization of type of explant, level of plant growth regulators to be used, callus production, shoot proliferation and elongation and also for rhizogenesis.

Materials and methods

Jasmine (*Jasminum sambac* Ait.) plants available in the floriculture yard in the Department of Horticulture were used for the regular supply of explants. Various explants like stem bits, leaf bits and shoot tips were collected from the stock plants and were thoroughly washed with 0.2% tween 20 solution followed by washing is distilled water thrice. The explants were further sterilized in 70% ethanol for 30 seconds followed by washing with sterilized distilled water thrice. Before inoculation into the media, the surface sterilized explants were trimmed to a size of 1.0 cm^2. The culture medium consisted of Murashige & Skoog (1962) medium added with 3% sucrose, 0.8% agar and 1.5% deproteinised coconut water. This medium was supplemented with auxins (IAA and NAA) and cytokinins (BAP and kinetin) at various combination for callus induction. pH of the media was adjusted to 5.8. The medium (15 ml) was transferred evenly to clean cultures tubes of 25 x 150 mm size that were sterilized and autoclaved. The inoculations of explants were done after 5 days ensuring that the test tubes were free from contamination. The cultures were incubated at a 16 h photo period that was maintained with 2000-3000 lux intensity at a temperature 25± 2°C and under 75% relative humidity. Given 6 weeks time, induced callus was subcultured for further calli proliferation. After 30 days of subculturing, the proliferated greenish matured callus was transferred to shooting media and then to rooting media at various concentrations of cytokinins (Kinetin and BAP) and auxins (IAA and NAA), respectively. Well rooted plantlets were transferred from test tubes to small perforated containers consisting of sterile vermiculite and sand at 1:1 ratio. After such hardening for specific periods, plantlets were transferred to bigger pots containing red earth, sand and FYM in equal proportion and then maintained in mist chamber.

Results and discussion

Stem, leaf and shoot explants were able to produce callus in MS medium with auxin alone (IAA) or in combination with cytokinin (BAP) at different concentrations. Among the various explants tried, leaf bits recorded the highest interaction average of 64.50% when compared to shoot tips (61.00) and stem bits (59.75). The callus induction increased with increasing concentration of BAP. The *maximum callus induction* was obtained from leaf bits and shoot tips (90%) with IAA 0.1 mgl^{-1} and BAP 10.0 mgl^{-1}. However the callus ability reduced with increasing concentration of IAA. Stem bits required 2.0 mgl^{-1} IAA and 10 mgl^{-1} BAP for maximum callus induction.

In general, callus can be induced from different aerial organs and tissues of *J. sambac* when cultured in MS medium supplemented with auxins. It is a known fact that auxins lead to cell enlargement alone. But for cell division, cytokinins are required in addition. In the present investigation, it was observed that for callus proliferation, IAA 1 mgl^{-1} and BAP 10 mgl^{-1} together were essential to bring out the desirable change in callus proliferation rate. Similarly, successful results have been obtained on callus induction and proliferation using auxins in various crop species like gladiolus (Mederos & Rodriquez 1987), carnation (Choudhary 1991)and antirrhinum (Tejavathi & Sharadamma 1996).

Addition of auxins to the basal media in the form of IAA and NAA at varying concentrations resulted in the induction of roots from leaf bit callus. Compared to different levels of NAA, addition of IAA @ 2.0 mgl^{-1} registered 80% culture response. Though NAA also enhanced root formation, the maximum response realised was 75% at the concentration of 2 mg l^{-1}. In general, increasing concentration of auxin upto 2 mgl^{-1} increased rhizogenesis from leaf bits.

The shoot regeneration from mature callus has been found to be enhanced by the use of BAP and kinetin. The response of cytokinin to shoot regeneration seems to be influenced by its concentration in the culture media. The culture response was only 60% even at bigher concentration of kinetin (12.0 mgl^{-1}) BAP also showed similar response (55%) at 12 mgl^{-1} concentrations. The number of shoots produced at maximum concentration of cytokinin, was two. Immediately after subculturing, the callus starts proliferating instead of regeneration. The shoot primordia developed 36 days after subculturing at 12.0 mgl^{-1} of BAP or kinetin.

The shoot regeneration from leaf bit callus was enhanced by the addition of BAP 12.0 mgl^{-1}. However during subculturing for the shoot regeneration large amount of callus was produced which surrounded the meristem and impeded the shoot differentiation. This result is in agreement with earlier finding of Scaramuzzi & Delta (1984) in *J. primulinum* Hemm.

Table 1. Effect of IAA and BAP on callusability of different explants in jasmine (percentage)

BAP mgl^{-1}	Leaf bit						Stem bit						Shoot tip					
IAA mgl^{-1}	0.0	2.0	4.0	6.0	8.0	10.0	0.0	2.0	4.0	6.0	8.0	10.0	0.0	2.0	4.0	6.0	8.0	10.0
0.0	05	25	35	40	45	55	10	25	40	50	45	55	05	20	35	40	45	50
1.0	30	50	65	70	85	90	35	40	60	55	65	80	35	40	55	65	70	90
2.0	45	60	55	65	80	85	30	55	60	65	75	85	45	50	65	75	80	85
3.0	35	55	65	55	60	70	45	50	55	60	70	65	30	45	40	55	65	75
4.0	30	45	60	55	65	55	35	45	50	60	45	55	25	40	45	65	55	60
Mean			54.50						52.16						51.83			
Overall			29.00						31.00						28.00			
IAA			34.16						37.50						32.50			
BAP			64.50						59.75						61.00			
IAA x BAP																		

Table 2. Effect of growth regulators on rhizogenesis from leaf bit callus in jasmine

Growth regulators (mgl^{-1})	Culture response (per cent)	Time taken for rhizogenesis (days)	Mean number of roots / callus	Mean length of roots / callus (cm)
MS medium alone	-	-	-	-
+ NAA 1.0	45	29 ± 0.89	4 ± 0.31	2.9 ± 0.59
+ NAA 2.0	60	24 ± 0.31	7 ± 0.54	4.3 ± 0.42
+ NAA 3.0	75	26 ± 1.09	5 ± 0.70	3.0 ± 0.29
+ NAA 4.0	50	27 ± 0.63	4 ± 0.44	2.6 ± 0.51
+ IAA 1.0	55	28 ± 0.94	4 ± 0.89	3.0 ± 0.68
+ IAA 2.0	80	24 ± 0.54	6 ± 0.63	4.1 ± 0.74
+ IAA 3.0	70	26 ± 1.14	5 ± 0.77	3.5 ± 0.13
+ IAA 4.0	50	27 ± 0.70	3 ± 0.89	2.9 ± 0.72

Table 3. Effect of growth regulators on shoot formation from leaf bit callus in jasmine

Growth regulators (mgl^{-1})	Culture response (per cent)	Time taken for shoot formation (days)	Mean number of shoot / callus	Mean length of shoot (cm)
MS medium alone	-	-	-	- MS
+ BAP 3.0	05	45	1 ± 0.89	0.8 MS
+ BAP 6.0	20	41	1 ± 0.71	1.0 MS
+ BAP 9.0	45	36	1 ± 0.54	1.1 MS
+ BAP 12.0	60	36	2 ± 0.33	1.2 MS
+ K 3.0	10	46	1 ± 1.2	0.5 MS
+ K 6.0	25	43	1 ± 0.67	1.0 MS
+ K 9.0	40	37	1 ± 0.54	1.1 MS
+ K 12.0	55	35	2 ± 0.33	1.3

References

Choudhary M C 1991. Vegetative propagation of carnation *in vitro* through multiple shoot development. Indian J. Hort. 48(2) : 177-181.

Mederos S & Rodriquez M J 1987. *In vitro* propagation of "Golden Lines" roses. Factors affecting shoot tips and axillary bud growth and morphogenesis. Acta Hort. 212: 619-624.

Murashige T & Skoog F 1962. A revised medium for rapid growth and bioassays with tobacco tissue culture. Physiology Pl. 15:473-497.

Saramuzzi F & Delta C 1984. (Plantlet induction in meristem cultures of *Jasminum primulinum* Hemm.) Induction the plantules dans des cultures de meristems de *Jasminum primulinum* Hemm. Comptes Rendus Scances de Academic des science III science delanie 284 (4) : 107-112.

Tejavathi D H & Sharadamma A M 1996. Micropropagation studies in *Antirrhinum majus* Linn. Paper presented at National Symposium on Horticultural Biotechnology held at Bangalore, October 28-30, 1996. p.24.

Evaluation of ginger varieties for high altitude and tribal area of Andhra Pradesh

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Abstract

An experiment was conducted to evaluate five ginger varieties for high altitude area of Visakhapatnam district at Regional Agricultural Research Station, Chintapalle for three crop seasons. Accession 64 released as IISR Varada was significantly superior in its productivity of fresh rhizome. Further, it was noted that the characters such as plant height, number of tillers/plant, leaf length and leaf breadth varied significantly among the varieties. The variety IISR Varada is highly suitable for the high altitude areas of Visakhapatnam district.

Introduction

Ginger (*Zingiber officinale* Rosc.) is a rhizomatous herbaceous perennial usually grown as annual. Ginger of commerce is the dried rhizome. India is the largest producer of dry ginger in the world accounting for more than half of the world production. In India ginger is cultivated in an area of 58008 ha with an annual production of 1.89 lakh tonnes (Velappan 1994). In Andhra Pradesh, it is cultivated in an area of 2508 ha. In the agency areas of Visakhapatnam district, it is mostly grown by the tribals and they cultivate ginger using local varieties. As a result the productivity of ginger is low in these parts thus making ginger cultivation less remunerative. Systematic efforts on introduction and evaluation of improved varieties of ginger were not undertaken in the high ranges of Visakhapatnam district of Andhra Pradesh. Hence the present study was carried out to evaluate suitable variety for this area.

Materials and Methods

The investigation was carried out at the Regional Agricultural Research Station, Chintapalle in Visakhapatnam district of Andhra Pradesh (Alt. 900 m). The trial was laid out in Randomized Block Design with four replications using five varieties namely V_1S_1-8, V_3S_1-8, V_1E_8-2, SG-554 and IISR Varada with Chintapalle local as check. Rhizome weighing 15 to 20 g each were planted in spacing of 30 x 20 cm at a depth of 5 cm in a plot size of 3 x 1 m. The trial was started during 1996-97 and repeated in 1997-98 and 1999-2000 crop seasons. Standard package of practices recommended by Indian Institute of Spices Research , Calicut was followed and five clumps from each plot were selected at random for studying various growth parameters (plant height, number of tillers/plant, number of leaves/plant, leaf length, leaf breadth, rhizome weight/clump and rhizome yield).

Results and discussion

The results of growth parameters and yield attributing characters are presented in the Tables 1 & 2. It is evident from the tables that the cultivars differed significantly among themselves in all the parameters studied. The variety, IISR Varada was significantly superior with a plant height of 63.32 cm. This was followed by V_1S_1-8 (57.97 cm) and V_3S_1-8 (56.82 cm) and were on par. The number of tillers per plant were maximum in V_1S_1-8 (9.57) and V_3S_1-8 (8.70) which were significantly superior to other varieties followed by IISR Varada (7.85). Significantly higher number of leaves/plant were recorded in V_1E_8-2 (90.5) and V_3S_1-8 (88.6) whereas maximum leaf length was recorded in IISR Varada (18.92 cm). The varieties viz, V_3S_1-8, SG-554 and V_1S_1-8 recorded maximum leaf breadth and were on par with each other. Significant variation in rhizome yield of ginger was also noticed among varieties. IISR Varada recorded significantly higher rhizome weight per clump of 176.8 g followed by V_3S_1-8 (160.5 g). This was followed by V_1E_8-2 (140.2 g) and SG-554 (130 g) which were on par with each other.

IISR Varada was significantly superior its productivity of fresh rhizome 21.54 t/ha (1996-97) 25.0 t/ha (1997-98) and 23.37 t/ha (1999-2000) followed by SG-554 which recorded 20.04 t/ha and 18.5 t/ha during 1996-97 and 1999-2000 respectively (Table 2). The varieties, SG-554 and V_3S_1-8 were on par with IISR Varada in respect of rhizome yield during 1996-97

Table 1. Morphological and yield attributing characters of ginger varieties.

Variety	Plant height (cm)	Tillers/ plant	Number of laeaves/ plant	Leaf length (cm)	Leaf breadth (cm)	Rhizome weight/ clump (g)
SG-554	54.30	5.95	82.50	17.95	2.30	130.0
Acc-64 (IISR Varada)	63.32	7.85	80.50	18.92	2.00	176.8
V_3S_1-8	56.82	8.70	88.60	16.50	2.37	160.5
V_1E_8-2	46.60	7.55	90.50	16.37	2.00	140.2
V_1S_1-8	57.97	9.57	82.00	17.55	2.30	120.8
Chintapalle local	51.62	7.62	75.80	14.42	2.22	109.5
CD at 5%	3.46	0.96	6.80	0.63	0.21	15.0

Table 2. Fresh rhizome yield (t/ha) of ginger varieties

Variety	Source	Fresh rhizome yield (t/ha)		
		1996-97	1997-98	1999-2000
SG-554	Solan, H.P.	20.04	16.67	18.50
Acc-64 (IISR Varada)	IISR, Calicut	21.54	25.00	23.37
V_3S_1-8	HARS, Pottangi	9.15	26.62	15.45
V_1E_8-2	HARS, Pottangi	5.50	20.83	8.25
V_1S_1-8	HARS, Pottangi	13.93	9.17	14.19
Chintapalle local	Chintapalle	16.67	15.40	13.25
CD at 5%		2.49	1.62	2.38

and 1997-98. The higher yields in IISR Varada were also reported by Sasikumar *et al.* (1996). The lowest yield was recorded by V_1E_8-2 during 1996-97 and 1999-2000. The higher yields in IISR Varada could be attributed to higher weight of rhizome per clump. The variety is characterised by plumpy rhizomes with flattened fingers.

In the present study all the characters studied varied significantly among the varieties. In ginger such phenotypic variations in growth and yield attributing parameters has been reported by Nybe and Nair (1979), Rattan *et al.* (1998) and Ravindran *et al.* (1994). These differences in varieties under uniform conditions may be due to genetic factors.

From the present study, the ginger variety, IISR Varada is identified as most suitable for cultivation in the high altitude areas of Visakhapatnam district, Andhra pradesh, because of its optimum growth and higher productivity during all the three years of study.

References

Nybe E V & Nair P C S 1979. Studies on the morphology of ginger types. Indian Cocoa, Areacanut and Spices J. 3 (1) : 7-13.

Rattan R S, Korea B N & Dehroo N P 1988. Performance of ginger varieties in Solan area of Himachal Pradesh. Proc. of National Seminar on Chillies, Ginger and Turmeric, Jan - 1998, Hyderabad. pp. 71-73

Sasikumar B, Johnson K George & Ravindran P N 1996. IISR Varada - a new high yielding ginger variety.

Velappan 1994. Integrated programme for the development of Spices in India during VIII five year plan. Indian Cocoa, Arecanut and Spices J. 18(1) : 1-4

Micropropagation of *Zingiber officinale* Rosc. and *Curcuma amada* Roxb.

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Abstract

Local varieties of ginger (*Zingiber officinale* Rosc.) and mango ginger (*Curcuma armada* Roxb.) were successfully propagated through tissue culture using apical bud as explant, on Murashige and Skooge medium, augmented with different concentrations of benzyladenine and stimulated shoot elongation in MS medium containing 1 mg l^{-1} benzyladenine. Maximum number of multiples obtained within 15 days and they showed 97.5% rooting frequency. These clonally propagated rooted shoots were readily established (98%) in the mixture of garden soil, sand and the compost (40:20:40).

Keywords: *Curcuma amada*, clonal propagation, ginger, mango ginger, *Zingiber officinale*

Abbreviations:

BA = 6-benzyl adenine

NAA = α-naphthalene acetic acid

Introduction

Both *Zingiber officinale* Rosc. (ginger) and *Curcuma amada* Roxb. (mango ginger) are perennial herbaceous spice crops belonging to the family Zingiberaceae. The branched and robust rhizome grows horizontally near the soil surface. The aromatic rhizomatous part, called as 'hands', is used as a spice and medicine. *Curcuma*, used in salads and pickles, is carminative, blood purifier and tonic.

In both *C. amada* and *Z. officinale*, the multiplication rate is very slow in growing season (8-10 months). Only 10-15 lateral buds can be produced by the conventional methods (Bhagyalakshmi & Singh 1988). Since the seed setting is very rare, it is impossible to raise the crop from seeds by hybridization to improve the growth characteristics of the crop, quality, yield of rhizome and adaptibility to different environmental conditions. Therefore, *in vitro* clonal multiplication comes in rescue through rapid multiplication of selected superior types in relatively short periods. The present study deals with the protocol of rapid production with high rate of multiplication.

Materials and methods

Rhizomes of ginger (var. Satara) and mango ginger were bought from the local market and planted in the botanical garden of M.S. University of Baroda. The sprouting buds with few petiolar sheaths were collected as explants and washed thoroughly with tap water. The washed explants were subjected to pretreatment (18-20 hrs) with a solution containing bavistine (0.25%) and chloramphenicol (0.5%) on a rotary shaker (100 rpm). Such pretreated explants were washed with distilled water (4-5 times) prior to surface sterilization with 0.1% $HgCl_2$ (4-5 min). The traces of $HgCl_2$ were removed by repeated washing (4-5 times) with sterilized distilled water. Meristematic dome (0.7-1.0 mm) were dissected out and implanted on the MS (Murashige & Skoog 1962) medium in culture tubes (25 x 150 mm) which were plugged with cotton (wrapped in gueze cloth). Auxin (NAA) and cytokinin (BA) were incorporated into the basal media in different concentrations and combinations. The pH of all media was adjusted to 5.8 using 0.1N NaOH or HCl before autoclaving at 120°C (15 min). The cultures were incubated at 25°C temperature with 16: 8 hrs. light-dark photoperiod. *In vitro* regenerated plantlets were transferred to polyethylene bags containing sand, soil and farm-yard manure (20:40:40) and acclamatized under high humidity conditions in plastic tunnel (diameter 90 cm). The plants were later transplanted to the field.

Results and discussion

Apical meristems excised from *Z .officinale* and *C. amada* plants were initially cultured on hormone free

MS medium. But such cultures did not give any considerable results. Fortification of cytokinin (BA) to the MS basal media not only enhanced shoot growth but also supported root induction. BA (2 mg l^{-1}) was most effective among the other concentrations (Table 1). Plantlets (8-7 cm) with well developed roots and lateral shoots were obtained on MS medium within 4 weeks of incubation. More effective growth of shoots and roots were obtained in liquid medium than agar-based semi solid medium (Table 2&3). MS media

Table 1. Bud sprouting response in *Zingiber officinale* Rosc. and *Curcuma amada* Roxb. on MS medium

Conc. of NAA (μm)	Conc. of BA (μm)	Bud growth %	
		Z. officinale Rosc	*C. amada* Roxb.
-	-	16.66	-
5.37	4.40	16.66	33.33
5.37	8.80	33.35	33.33
-	4.40	83.33	100.00
-	8.80	83.33	100.00

Table 2. Effect of BA on shoot multiplication and growth rate *Zingiber officinale* Rosc. in liquid as well as agar-based semi-solid medium

Conc. of BA (μm)	No. of shoots* Mean ± SE		shoot length in cms * Mean ± SE	
	Liquid medium	Agar-based medium	Liquid medium	Agar-based medium
-	2.24 ± 0.27	1.25 ± 0.15	1.96 ± 0.48	1.53 ± 0.19
4.40	5.80 ± 0.28	5.38 ± 0.35	4.08 ± 0.35	1.75 ± 0.16
8.80	10.0 ± 0.53	7.25 ± 0.44	6.30 ± 0.22	3.16 ± 0.2
13.2	3.83 ± 0.28	2.60 ± 0.17	3.00 ± 0.15	1.55 ± 0.1

* Values indicate average ± SE of 3-4 repetitions

Table 3. Effect of BA on shoot multiplication and growth rate in *Curcuma amada* Roxb. in liquid as well as agar-based semi-solid medium

Conc. of BA (μm)	No. of shoots* Mean ± SE		shoot length in cms * Mean ± SE	
	Liquid medium	Agar-based medium	Liquid medium	Agar-based medium
-	-	-	-	-
4.40	3.30 ± 0.26	1.6 0± 0.27	2.4 ± 0.13	2.00 ± 0.14
8.80	8.00 ± 2.99	2.60 ± 0.27	2.6 ± 0.19	2.16 ± 0.13
13.2	2.00 ± 0.12	1.33 ± 0.27	1.2 ± 1.0	1.36 ± 0.28

* Values indicate average ± SE of 3-4 repetitions

supplemented with NAA were comparatively less effective for shoot elongation and root induction.

For rapid mass multiplication, *in vitro* shoots raised on MS medium supplemented with 1.0-3.0 mg l^{-1} of cytokinin were used as the explants. Among all the media combinations tested, maximum bud elongation and regeneration of multiple shoots occured on MS medium supplemented with BA (2 mg l^{-1}). On an average 20-25 plantlets of 7-8 cm height could be obtained from a single apical meristem segment within 6-8 weeks.

The present study utilized shoot bud culture techniques with a possibility for mass clonal propagation of *Zingiber officinale* Rosc. and *Curcuma amada* Roxb. Cytokinin BA had been reported to be the most generally effective cytokinin for meristem, shoot tips and bud cultures of various species followed by kinetin. Earlier studies recommended a combination of BA and kinetin for bud cultures in ginger (Hosoki & Sagawa 1977, Nadgauda *et al.* 1980). However, in the present study BA alone in the medium supported multiple shoot production and elongation of the *in vitro* shoots (Table 3). In ginger and mango ginger conventional method of multiplication produces 10-15 lateral buds in 8-10 months. In contrast, the present report indicated the production of 20-25 plantlets from a single explant within 3-4 months. The cytokinin requirement for shoot multiplication was much higher (5 mgl^{-1}) for "Wynad local" ginger (Hosoki & Sagawa 1977; Nadgauda *et al.* 1980). On the other hand present study necessiated only 2 mg l^{-1} BA for the multiple shoot production. In addition to the chemical composition of the medium, its physical form can also influence the kind of growth and *in vitro* responses (Mellor & Smith 1977). More effective growth was obtained in liquid culture, compared to the agar based semisolid medium (Table 2). In *Zingiber officinale* Rosc. shoot elongation and root induction obtained during shoot proliferation simultaneously in liquid as well as solid medium, whereas in *Curcuma amada* roots were formed on agar-based MS medium containing 1 mg l^{-1} BA.

Once vigorous root systems were established (3-4 weeks), the plantlets thus formed were transferred to plastic bags containing sand, soil and farm yard manure (20:40:40). Maintenance of high humidity (80-95%) during the early hardening phase in the plastic tunnel was essential for a high rate of survival (95-98%) of plants. The plantlets developed into normal plants in terms of morphology and growth pattern.

This procedure for successful micropropagation of *Zingiber officinale* Rosc and *Curcuma amada* Roxb. through apical bud culture and its proliferation will be useful for rapid cloning of elite strains of such plants as a solution for the poor rate of multiplication by conventional method of vegetative propagation and almost no seed setting.

References

Bhagyalakshmi & Singh N S 1988. Meristem culture and micropropagation of a variety of ginger (*Zingiber officinale* Rosc.) with a high yield of oleoresin. J. Hort. Science 63(2) : 321-327.

Hosoki T & Sagawa Y 1977. Clonal propagation of ginger (*Zingiber officinales* Rosc.) through tissue culture. Hort. Science 12 : 451-452.

Mellor I C & Stace-Smith R 1977. Virus free potatoes by tissue culture. In Reinert J & Bajaj YPS (Eds) Applied and fundamental aspects of plant cell tissue and organ culture (p 618-635) Springer-Verlag, Berlin.

Murashige T & Skoog F 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiol. plant. 15 : 437-497.

Nadgauda R S, Kulkarni D D, Mascarenhas F & Jaganathan V 1980. Clonal propagation of ginger *in vitro*. In : Rao PS, Heble MR & Chadha MS (Eds) Plant tissue culture, genetic manipulation and somatic hybridisation of plants (p 358-68). Proceedings of national symposium held at BARC, Bombay, India.

Seed viability of *Syzygium aromaticum* (L.) Merill & Perry during storage

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Abstract

Syzygium aromaticum of the family Myrtaceae is an important spice crop for its dried unopened flower buds, the clove of commerce. Normal propagation of this species is through seeds which have short viability period. In the present study, correlation that exist between moisture content and storage temperature with respect to viability of *Syzygium aromaticum* seeds were analysed for standardizing suitable germplasm storage conditions. Depulped seeds kept at 28±3^0 C and 70% RH lost their viability due to 10% decrease in initial moisture content in 4 days. Seeds stored in polyethylene bags at freezing temperature (0^{0}C) was found to be fatal while at chilling temperature (10^{0}C) they remained viable for a month. Depulped seeds stored in polyethylene bags kept at 20 and 30^{0}C retained their viability upto 6 and 9 months respectively though sprouted under storage. Seeds stored in closed polyethylene bags at 30^{0}C was found to be a suitable germplasm respository.

Key words: germination, storage, *Syzygium aromaticum*, viability.

Introduction

S. aromaticum of the family Myrtaceae, is an important spice crop for its dried unopened flower buds, the clove of commerce (Purseglove *et al.* 1981). Normal propagation of this species is through seeds which have short viability. According to Sabale *et al.* (1992), in clove considerable loss of germination and seedling vigour occurred when seeds were stord for 7 to 14 days. In the present study, correlations that exist between moisture content and temperature with respect to viability of *S. aromaticum* seeds were analysed for standardizing suitable germplasm storage conditions.

Materials and methods

Ripened fruits of *S. aromaticum* were hand-harvested during the month of June from a tree growing at an altitude of 500 m in a plantation of Nagercoil. From the collection, randomly selected 2,500 fruits were equally divided into five lots and were stored separately in five polyethylene bags as pulpy seed lot. Another 3000 fruits were dupulped by smearing with saw dust and then washed with water. Cleaned seeds were spread evenly over a blotting paper and dried under fan for a short time. These fresh seeds were equally divided into six lots, from which five lots were packed and kept separately in individual polyethylene bags. The sixth lot comprising 500 seeds were used for studying the relationship between seed moisture content and viability.

Preliminary observations showed that the optimum temperatures for seed germination was between 30 to 32 ^{0}C and that light was not an influencing factor initially. Pulpy and depulped seeds were sown separately in the field and laboratory conditions for studying their germination behaviour. In the field, the germinating medium was pure sand taken in earthen seed pots which were watered twice a day and the conditions were 30/20^{0}C and 60% RH. In the laboratory, germination studies were conducted in paper towels kept in a seed germinator set at 30 ^{0}C and 85% RH without light. Each experiment in field and laboratory, consisted of 50 seeds each in 5 replicates. All experments were conducted a minimum of 5 times separately and values are expressed as mean ± S.D. Pulpy seed denotes a fruit while seed means a dupulped fruit. Seeds were sown with and without pulp for studying the effect of pulp on seed germination. For storage studies pulpy and dupulped seeds were stored separately at different conditions to study the effect of pulp on seed viability.

About 500 dupulped seeds were allowed to dry under normal room conditions and at an interval of 12 hrs., seed samples were analysed for moisture content and corresponding germination percentage. Seed moisture content was determined according to high constant temperature oven method (ISTA 1985) by drying at 130°C for one hour in an oven and was expressed as percentage of fresh weight. These experiments were replicated five times, each with randomly selected three seeds and average value taken. Seeds with and without pulp were stored separately in polyethylene bags (200 gauge, size 60 x 30 cm). Preliminary experments showed that when the storage bags were completely filled with pulpy ad depulped seeds, within a few days seeds became brown and dead. Therefore in all the expermental conditions, half portions of the polyethylene bags were kept empty to facilitate enough air supply to stored seeds. The conditions of storage were as follows.

Open room with 60%RH and 25±5°C, Polyethylene bags kept in room with 60% RH and 25±5°C, incubator with 80% RH and 30°C, incubator with 80% RH and 20°C, incubator with 80% RH and 10°C and refrigerator with 45% RH and 0°C. Polyethylene bags were opened for seed retrieval only at definite intervals decided as per preliminary experimental results. The intervals were 24 hrs, 4 days, 1 month, 2 months, 3 months, 6 months and 9 months.

Results and discussion

Pulp is found to retard the germination percentage as well as speed of germination by encouraging insect and microbial infections. The percentage germination of pulpy seeds was ony 40 while depulped seeds registered 100% germination. Irrespective of the difference in storage conditions, pulpy seeds became yellow-green and died in 15 days while the depulped seeds retained thier viability/regenerability for a period of 6 months at 30°C (Table 2)

Fresh seeds with 48.9% moisture content (Table 1) registered 100% germination in five days. When seeds were allowed to dry for 12 hrs at open room conditions, 3% reduction of moisture content and 94% gemination occurred in 10 days. As the seeds were dried for 24 hrs, their moisture content became 42%, black spots appeared over green cotyledons and radicle lost its brightness and became red. On further drying for 36 hrs, the moisture content drastically reduced (10% reduction) and only 72% of seeds germinated, which took 24 days for the completion of germination. When seeds were dried for 48 hrs at open room conditions, their cotyledons became brown, radicle became brown red and when tested, the moisture content was found to be as low as 33% with a corresponding germination of only 20% reported within 15 days.

Pulpy seeds of *S. aromaticum* retained viability maximum for a week at open room conditions beyond which there was severe fungal infections while depulped seeds lost their viability in 4 days. In all other storage conditions pulpy seeds remained viable only for 15 days, though dupulped seeds behaved differentially to different storage temperatures (Table 3). Seeds stored in polyethylene bags at room conditions retained their

Table 1. Desiccation responses of *Syzygium aromaticum* seeds.

Period of drying (hrs)	Moisture content (% ± SD)	Germination (% ± SD)	Time for completion of germination (days ± SD)	Morphological features
0	48.9 ± 0.7	100	5±2.6	Cotyledon-green, radicle-bright red
12	45.5 ± 0.5	94 ± 5.5	10.4 ± 2.9	Cotyledon - green with slightly brown ends, radicle - bright red
24	42.0 ± 0.7	86 ± 5.5	24.0 ± 6.5	Cotyledon - pale green with brown areas and black spots, radicle - red
36	38.2 ± 0.6	72 ± 8.4	23.6 ± 2.7	Cotyledon - pale green with more brown areas and black spots, radicle - yellow red
48	33.5 ± 0.1	20 ± 7.1	15.6 ± 2.9	Cotyledon - brown, radicle - brown red

Table 2. Effect of storage and temparature on germination of *Syzygium aromaticum* seeds.

Temperature °C	Duration days	Moisture content (% ± SD)	Germination (% ± SD)	Morphological features
0	1	48.9 ± 0.7 (48.9 ± 0.7)	0 (0)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
10	1	48.9 ± 0.6 (48.9 ± 0.7)	100 (100)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
	4	48.8 ± 0.4 (48.7 ± 0.9)	92.0 ± 4.5 (90.0 ± 7.1)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
	15	47.6 ± 0.5 (47.1 ± 0.2)	90.0 ± 7.1 (72.0 ± 4.5)	Cotyledons green and radicle bright red (Cotyledons yellow green and radicle red)
	30	48.2 ± 0.7	78.0 ± 8.4	Cotyledons green and radicle bright red
	60	48.3 ± 0.4	32.0 ± 8.4	Cotyledons green and radicle bright red
20	1	48.9 ± 0.4 (48.9 ± 0.6)	100 (100)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
	4	48.6 ± 0.2 (48.9 ± 0.3)	100 (84.0 ± 5.5)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
	15	47.8 ± 0.3 (50.8 ± 0.3)	100 (0)	0.3 ± 0.4 cm of radicle growth (Cotyledons yellow green)
	30	48.1 ± 0.3	100	0.8 ± 0.5 cm of radicle growth
	60	48.3 ± 0.3	98.0 ± 4.5	2.0 ± 0.6 cm of radicle growth
	90	48.7 ± 0.3	88.0 ± 4.5	3.4 ± 0.4 cm of radicle growth
	180	49.4 ± 0.4	62.0 ± 4.5	3.4 ± 0.7 cm of radicle with lateral roots of 1.8 ± 0.2 cm
30	1	48.9 ± 0.7 (48.9 ± 0.7)	100 (100)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
	4	48.5 ± 0.4 (48.8 ± 0.5)	100 (86.0 ± 5.5)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
	15	48.1 ± 0.2 (47.1 ± 0.1)	100 (0)	2.3 ± 0.3 cm of radicle growth (Cotyledons yellow green and radicle red)
	30	48.4 ± 0.2	100	2.7 ± 0.1 cm of radicle growth
	60	48.9 ± 0.2	98.0 ± 4.5	4.5 ± 1.1 cm of radicle growth
	90	50.3 ± 0.6	96.0 ± 5.5	7.0 ± 2.4 cm of radicle growth
	180	54.0 ± 0.2	72.0 ± 4.5	6.1 ± 3.2 cm of radicle growth and 1.4 ± 1.0 cm of lateral root growth
	270	55.1 ± 1.6	65.0 ± 5.5	Cotyledons dark green with sporadic black spots
Room*	1	48.9 ± 0.6 (48.7 ± 0.2)	100 (100)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
	4	48.9 ± 0.5 (48.9 ± 0.4)	100 (76.0 ± 5.5)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
	15	47.0 ± 0.2	98.0 ± 4.5	0.8 ± 0.2 cm of radicle growth

Table 2 (contd.)

Temperature °C	Duration days	Moisture content (% ± SD)	Germination (% ± SD)	Morphological features
		(49.0 ± 0.4)	(0)	(Cotyledons yellow green and radicle red)
	30	44.9 ± 0.7	88.0 ± 4.5	1.0 ± 0.1 cm of radicle growth, cotyledons became dark green & wilted
	60	35.30	0	Coyledons became black and hard
Control	0	48.9 ± 0.7	100	Cotyledons green and radicle bright red
Room**	1	42.0 ± 0.7 (48.9 ± 0.7)	86.0 ± 5.5 (100)	Cotyledons green and radicle bright red (Cotyledons green and radicle bright red)
	4	25.7 ± 0.6	0	Cotyledons became black, hard and plumule became black and brittle
		(50.3 ± 0.6)	(82.0 ± 4.5)	(Fruit wall shrunken and cotyledons green)

Values and data in parentheses are of pulpy seeds * At 25 ± 5°C in polyethylene bags ** At 25 ± 5°C and 70% RH in open trays.

viability up to one month. By this period they began to sprout under storage and consequently became dead as their moisture content was reduced to 35% in 2 months of storage. Both pulpy and depulped seeds lost their viability in a day when stored at 0°C. At 10°C seeds retained their viability up to one month along with the retention of their fresh appearance without any sprouting but two months of storage reduced their viability to 32%. At 20°C seeds retained 100% viability up to 60 days of storage, and the radicle growth measured up to 3 cm. After 180 days of storage the germination percentage was reduced to 62%. At 30°C, from 90 days of storage the moisture content began to increase gradually though the initial germination percentage was maintained with the average root length of 7 cm. The regeneration capacity was 65% when examined with the seeds stored for 270 days.

There are many characteristics specific to recalcitrant seeds, perhaps the most documented of these is that they are desiccation sensitive. The desiccation rate in *S. aromaticum* seeds is very fast under room conditions and the critical moisture content is found to be about 40% (Table 1). Dehydration injury has been reported in recalcitrant plants like *Aporusa lindleyana* (Anil kumar *et al.* 1996).

Both pulpy and depulped seeds of *S. aromaticum* lost viability in 24 hrs without any change in moisture content at 0°C. Since the seed contains about 50% moisture, at 0°C they are subjected to chronic freezing injury resulting in loss of viability. This is characteristic of almost all recalcitrant seeds (Ellis 1991).

However, as the temperature of storage increased to 10°C, viability of pulpy seeds was found to be lost within 15 days without any change in moisture content. The viability of depulped seeds got reduced gradually and was completely lost by two months storage. The viability loss is due to chilling injury of the seeds at 10°C. At 20°C, seeds were viable for six months without any change in moisture content but after 15 days of storage radicle growth started. At 30°C, the viability of seeds was retained up to nine months. In contrast to that of 20°C, the seeds at 30°C registered a gradual as well as a significant increase in moisture content after two months, maximum being at 9th month (Table 2). In this condition the radicle elongation started 15th day onwards and lateral root formation was noticed up to 9th month. The vigorous growth of seeds/seedlings at 30°C resulted in a significant loss of moisture content.

In many recalcitrant seeds, development and germination appear more or less to be in continuum (Ellis 1991). Once the radicle growth is started, the seeds/seedlings can withstand the desiccation atleast for a short period. This character may be the reason for survival of *S. aromaticum* seeds stored in polyehylene bags at room temperature where the initial temperature as well as RH were not much deviated from the original condition of the fresh seeds. So the radicle protrudes and these seeds retained their viability for one month. On the contrary, the seeds kept at room open conditions were subjected to immediate desiccation, so radicle protrusion is not occurring and hence lose viability.

Berjack *et al.* (1984) suggested that the increasing desiccation sensitivity of recalcitrant seed in storage may result from the initiation of germination associated events and may therfore be analogue to the desiccation sensitivity of imbibed/germinating seeds of orthodox species. As mentioned earlier, seeds of *S. aromaticum* stored at 10, 20, 30°C and room (polyethylene) are found to increase their storability for longer times (Table 2). Inspite of sufficient quantity of water to initiate germination, during prolonged storage, the seeds are subjected to desiccation because further water is not supplied. Notwithstanding, the germination, especially radicle elongation, is progressing, seemingly not much affected by desiccation. This character is in agreement with the view of Wu *et al.* (1994) according to whom root growth is often less inhibited than shoot growth at low water potential.

According to Sabal *et al.* (1992), the length of storage period has significant influence on germination percentage and the seedling vigour. It has been proved that transferring the sprouted seeds to soil condition is superior to direct sowing (Sabal *et al.* 1995). *S. aromaticum* seed longevity is maximum up to 9 months at 30°C and 80% RH and though sprouted, they serve as suitable germplasm repository.

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References

Anil kumar C, Thomas J & Pushpangadan P 1996. Storage and germination of seeds of *Aporusa lindleyana* (wight) Baillon, an economically important plant of Western Ghats (India). Seed Sci. Technol. 25 : 1-6.

Berjak P, Dini M & Pammenter N W 1984. Possible mechanisms underlying the differing dehydration responses in recalcitrant and orthodox seeds: desiccation associated sun-cellular changes in propagules of *Avicennia marina*. Seed Sci. and Technol. 12 : 365-384.

Ellis RH 1991. The longevity of seeds. Horticultural Sciences 26 : 1119-1125.

International Seed Testing Association 1985. International rules for seed testing. Rules 1985. Seed Sci. Technol. 13 : 356-513.

Purseglove J W, Brown E J, Green C L & Robbins S R J 1981. Spices. Tropical Agriculture Series, Longman, London 1 : 229-285.

Sabale S S, Nadkarni H R & Nawale R N 1992. Effect of seed storage on germination and seedling establishment in clove. Indian Cocoa, Arecanut and Spices Journal 16 : 26-28.

Sabale S S, Nawale R N, Jamadagni B M & Nadkarni H R 1995. Effect of different media on germination and seedling growth of clove. Indian Cocoa, Arecanut and Spices Journal 19 : 43-45.

Wu Y W, Spollen W G, Sharp R E, Hetherington P R & Fry S C 1994. Root growth maintenance at low water potentials. Pl. Physiol. 106 : 607-615.

In vitro rhizogenesis of tamarind (*Tamarindus indica* L.) microshoots

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Abstract

Microshoots derived from *in vitro* axillary bud culture of the tamarind genotype Urigam were transferred to MS (Murashige and Skoog, 1962) medium of varying strengths namely, ¼, ½, ¾ and full, fortified with sucrose as the carbon and energy source at varying concentrations namely, 1.5, 3.0, 4.5, 6.0 and 7.5 per cent, the auxins Indole Acetic Acid and Indole Butyric Acid at 0.5, 1.0, 1.5 and 2.0 mgl^{-1} in various concentrations and combinations and activated charcoal in varying concentrations (0.5, 1.0, 1.5, 2.0 and 2.5gl^{-1}). Those microshoots transferred to half strength medium fortified with 3.0 per cent sucrose, 0.5mgl each of Indole Acetic Acid and Indole Butyric Acid and 2.0gl^{-1} charcoal recorded the maximum response to *in vitro* rhizogenesis. An increase in the concentration of any one/ all of the four aspects namely, strength of the medium, concentration of sucrose, concentration of auxins and concentration of charcoal was found to have a negative correlation with the response to rhizogenesis. This negative correlation is attributable to the fact that supra-optimal levels of any of these four aspects would induce more of vegetative growth and in turn would suppress the process of rhizogenesis. Subsequent growth of the initiated rootlets was favoured better by half strength hormone free medium rather than by a medium fortified with growth regulators.

Key words: microshoots, rhizogenesis, *Tamarindus indica* L.

Abbreviations:

MS = Murashige and Skoog's medium

IAA = Indole Acetic Acid

IBA = Indole Butyric Acid

Introduction

Rapid and progressive deforestation is causing innumerable ecological hazards. Since conventional propagation methods of tree species are inefficient in meeting with the never- ending demands for quality planting materials, standardization of micropropagation techniques of economically important woody species would be of immense help to overcome such ecological hazards. Of the innumerable hurdles encountered during the micropropagation of woody species, the most serious ones are those associated with excessive phenolic exudation and the recalcitrant nature of the shoot or root formation related to the ontogenic stage of maturity inherent in a perennial woody species. In the present investigation, the ability of *in vitro* derived microshoots of tamarind to undergo *in vitro* rhizogenesis was analysed and an optimal chemical environment for *in vitro* rhizogenesis was standardized.

Materials and methods

The investigation was conducted at the Tissue Cultur Lab of the Horticultural College and Research Insti tute, Tamil Nadu Agricultural University, Coimbatore Standardization of the optimum chemical environmen for *in vitro* rhizogenesis of the axillary bud-derive microshoots involved four strengths of MS medium (ful ¾, ½ and ¼), five concentrations of sucrose (1.5, 3.0 4.5, 6.0 and 7.5 %), five concentrations of charcoa (0.5, 1.0, 1.5, 2.0 and 2.5gl^{-1}) and various concentra tions and combinations of the auxins IAA and IBA as given in table 3).

Result and discussion

Strength of culture medium and in vitro rhizogenesis

The maximum response (53.3 per cent) to rooting i the shortest duration (21.6 days) was recorded by th microshoots transferred to half strength MS medium. These microshoots produced the maximum number of roots per culture (7.7) and the longest roots (3.3 cm) (Table 1). Microshoots transferred to ¼ strength MS medium did not respond to rhizogenesis at all, while an increase in the strength of the medium from ¼ to ¾ strength and full strength was found to have a negative correlation with response to rooting, number of roots produced per culture and length of the roots.

This phenomenon of better response to rhizogenesis on ¼ strength medium agrees with the earlier finding of Woodward & Thomson (1996) who have reported better rooting of *in vitro* cultured plantlets of *Garrya elliptica* Dougl. on ¼ strength MS medium. The promotory effect of reducing the salt concentration of the culture medium on *in vitro* rooting has also been reported earlier (Purohit & Ashish 1996) in in vitro culture of the woody species *Sterculia urens* Roxb.

Concentration of sucrose and response to in vitro rhizogenesis:

The microshoots transferred to the medium with three per cent sucrose recorded the maximum response (46.7 per cent) to rooting in the shortest duration of 20.7 days. Further, these cultures also produced the maximum number of roots per culture (7.10) and the longest roots (3.0cm) (Table 2). Microshoots transferred to medium with six per cent and seven per cent sucrose did not respond to rhizogenesis. These microshoots developed callus at the base followed by withering of leaves and wilting.

Table 1. Influence of strength of culture medium on response of microshoots to rhizogenesis.

Strength of medium	% Response to rooting	No. of days taken for rooting	No. of roots per culture	Length of root (cm)
¼ MS	-	-	-	-
½ MS	53.33	21.60	7.70	3.31
¾ MS	44.44	32.83	4.50	1.83
Full MS	33.33	45.50	3.00	1.25
Sed	-	0.95	0.98	0.40
CD (P=0.05)	-	2.02	2.08	0.86

Table 2. Influence of concentration of sucrose on response of microshoots to rhizogenesis.

Conc. of sucrose (%)	% Response to rooting	No. of days taken for	No. of roots per culture rooting	Length of Root (cm)
1.5	44.44	25.50	3.18	1.45
3.0	46.67	20.70	7.10	3.01
4.5	33.33	28.33	2.13	0.90
6.0	-	-	-	-
7.5	-	-	-	-
Sed	-	5.92	0.63	0.27
CD(P=0.05)	-	12.34	1.32	0.56

Concentration of auxins and response to in vitro rhizogenesis:

The maximum response to rooting (50.0 per cent) in the shortest duration of 21.7 days and the maximum number and length of roots (6.7 and 4.0 cm respectively) were recorded by the microshoots transferred to medium supplemented with 0.5 mgl^{-1} each of IAA and IBA (Table 3).

The synergistic effect of IAA and IBA in promoting *in vitro* rhizogenesis observed in the present investigation is in corraboration with the earlier findings (Douglas *et al.* 1989 and Rahman *et al.* 1992) in *Rosa* spp. wherein, the highest percentages of *in vitro* rooting in axillary bud cultures were recorded with IAA and NAA. Further, the role of IBA in inducing more number of roots under *in vitro* conditions noted in this investigation has supporting evidence from Campos & Pais (1990) who have reported that fortification of rooting medium with IBA resulted in induction of more number of roots in *Rosa* spp.

Concentration of charcoal and response to in vitro rhizogenesis:

Charcoal when added to the medium at a concentration of 2.5 g l^{-1} induced the maximum response (13.3 per cent) to *in vitro* rhizogenesis. The number of roots produced per culture was the maximum (6.3) in this treatment, and the roots produced were the longest (2.6 cm) (Table 4). The other concentrations of charcoal did not induce any positive response.

As encountered in the present investigation, charcoal has already been reported to improve the *in vitro* growth and rooting of several plant species (Franclet & Boulay 1982, Volkaert *et al.* 1996), but the reasons for this effect are uncertain.

Table 3. Influence of concentration of auxins on response of microshoots to rhizogenesis.

Conc of auxins (mgl-1) IAA+IBA	% response to rooting	No. of days Taken for Rooting	No. of roots per culture	Length of root (cm)
0.5+0.5	50.00	21.67	6.67	4.03
1.0+1.0	33.33	26.00	3.00	2.60
1.5+1.5	-	-	-	-
2.0+2.0	-	-	-	-
Sed	-	5.99	1.30	0.85
CD(P=0.05)	-	13.04	2.84	1.85

Table 4. Influence of concentration of charcoal on response of microshoots to rhizogenesis

Conc. of charcoal (gl^{-1})	% response to rooting	No. of roots per culture	Length of root (cm)
0.5	-	-	-
1.0	-	-	-
1.5	-	-	-
2.0	13.33	6.33	2.65
2.5	-	-	-
Control	-	-	-

References

Campos P & Pais S 1990. Mass propagation of the dwarf rose cv. Rosamini. Scientia Horticulturae 43 : 321-330.

Douglas G C, Ruttledge C B, Casey, A D & Richaedson D H S 1989. Micropropagation of Floribunda, ground cover and miniature roses. Plant Cell, Tissue and Organ Culture 19(1) : 55-64.

Franclet A & Boulay M 1982. Micropropagation of frost-resistant eucalyptus clones. Australian Forest Research 13 : 83-89.

Purohit S D & Ashish D 1996. Micropropagation of Sterculia urens Roxb. – an endangered tree species. Plant Cell Reports 15 : 704-706.

Rahman S M, Hossain M, Raiful Islam A K M & Joarder O J 1992. Effects of media composition and culture conditions on *in vitro* rooting of rose. Scientia Horticulturae 52 : 163-169.

Volkaert H, Schoofs J, Pieters A & De Langhe E 1990. Influence of explant source on *in vitro* axillary shoot formation in oak seedlings. Tree Physiology 6 : 87-93.

Woodward S & Thomsoon R J 1996. Micro propagation of the silk tassel bush, *Garrya elliptica* Dougl. Plant Cell, Tissue and Organ Culture 44 : 31-35.

Per se performance of individual progenies of F_3 generations of the cross Ramanathapuram Local X Jalapeno hot pepper (*Capsicum annuum* L.)

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Abstract

The extent of variability in yield and its components is an essential prerequisite for the improvement of crops. The variability can be brought out in the segregating populations through hybridization. The segregating population provides a good source to exert selection of superior plants effectively. In the present study, F_3 populations of Ramanathapuram Local and Jalapeno Hotpepper were studied to assess their potential based on mean, range, coefficient of variation, Skewness and Kurtosis. The plant numbers 35 and 8 exhibited highest estimated for yield per plant, number of fruits and capsaicin content. It can be forwarded for further generation.

Key words: chilli, segregating population

Introduction

The genetic progress attainable through selection in a population depends largely upon selection intensity, population size and the relative magnitude and composition of genetic variance. A study on the genetic variability is important since the individual plant selection is solely dependent upon it. Knott (1972) reported that selection in a spaced F_2 population has profound effect on the yield on F_3 progenies. It is necessary to gather information on those crosses, which are most likely to give the highest proportion of superior segregation from those crosses and an early evaluation of the potentialities of the segregants from those crosses is also necessary. Study on the selection of superior genotypes from segregating generation will be rewarding because of the presence of more transgressive segregants. Further, segregating generation may provide a base population for the simultaneous improvement of the favourable traits. The aim of the present study was to estimate the variability in F_3 population of chilli.

Materials and methods

The investigation was carried out at the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The experimental materials included were the progenies of F_3 generation. F_1 hybrids were obtained by crossing 6 parents in diallel fashion. The parents are CA 59 (Coimbatore), CA 84 (Ramanathapuram Local), CA 94 (Keelapavoor), CA 86 (Sadayampatti), CA 140 (Rahuri) and CA 133 (Jalapeno Hotpepper). The best cross combination, Ramanathapuram Local (P_2) X Jalapeno Hotpepper (P_6) was selected in F_1 generation and it was forwarded to next generation. In F_3 generation, totally 38 plants were maintained and each and every plant is considered as single genotype. Hence observations were recorded on yield and quality characters of individual plant. Mean, range and coefficient of variation were worked out. Skewness and Kurtosis was worked out following the method suggested by Panse and Sukhatme (1967).

Results and discussion

In F_3 generation, the plant height ranged from 30.2 to 110 cm with a mean of 72.39 cm (Table 1). The highest plant height recorded by the plant number 13 and the lowest by the plant number 30. The coefficient of variation was found to be 22.32 per cent. Among the 38 plants, 19 plants exceeded the mean value. Number of branches per plant varied from 4.0 to 17.0. Twenty-five plants exceeded the mean value. Coefficient of variation was of 25.79 per cent. The highest number of branches per plant recorded by the plant number 8 and the lowest by 15.

Number of fruits per plant is a reliable index for selection besides yield per plant.

The most outstanding two plants for number of fruits in F_3 generation was the plant number 35 and 8. These plants recorded the highest number of fruits (182 and 178, respectively). Coefficient of variation was found to be 70.29 per cent with a mean of 52 fruits.

Fruit weight has got strong association with yield besides number of fruits per plant. The same plant has recorded highest fruit weight of 620 g with a mean of 231 g. The coefficient of variation was found to be 71. 81 per cent.

The maximum fruit length was observed in the plant umber 17 and minimum by 38. Fruit length ranged from 6.87 cm to 5.18 cm with a mean of 5.90 cm. Coefficient of variation was found to be 8.64 per cent. For *fruit length the coefficient of variation is less, it indicates* this character id mer consistent or less variable.

The maximum fruit girth was noticed in the plant number 35 and minimum by 16. Fruit girth varied from 3.1 to 3.9 cm with a mean of 3.45 cm. Coefficient of variation was 6.72 per cent. Here the coefficient of variation is less, it indicates the stability of the character.

The maximum colour value as recorded in the plant number 34 and minimum by 5. Colour value varied from 20.1 to 25.6 with a mean of 23.06. Twenty plants exceeded the mean value. The coefficient of variation was 6.53. Capsaicin varied from 0.31 to 0.563. Seventeen plants exceeded the mean value of 0.42. Coefficient of variation was found to be 20.06 per cent. The maximum capsaicin content was noticed in the plant number 25 and minimum by 7. The highest oleoresin was observed in the plant number 31 and lowest by 21. The oleoresin ranges from 9.1 to 11.5 with a mean of 10.6. Coefficient of variation was found to be 6.44 per cent. Since F_3 generations exhibit maximum segregants, the selection procedures could be made effective by using the mean performance and coefficient of variation. The plant exhibits high mean is relatively effective in identifying the superior segregants. In the cross Ramanathapuram Local X Jalapenio Hotpepper which is the best yielder in F_2 generation. However the cross-exhibited a wide range for yield in F_2 generation. Selected segregants in that cross from F_2 were evaluated in F_3 generation. Mean performance, which *should have facilitated the selection of superior segregants.* It is noteworthy to point out that the selected segregants showed stability in F_3 generation for yield. Among the segregants, plant numbers 35 and 8 which were found to be superior for number of fruits per plants, weight of fruits per plant and colour value (Table 2). It could be well exploited for the further improvement of respective characters.

Immer (1942) observed that the correlation between the yield of single plant in segregating generation and the mean. If plant progeny row is very low, as the yields of single plant appears to be determined largely by environment. In such a situation to understand the distribution of segregants near to far away from the mean, the skewness and kurtosis were computed.

The frequency distribution of the F_3 generation showed

Table 1. Mean, range, variance and CV of the progeny of the cross Ramanathapuram Local X Jalapeno hot pepper

Characters	Mean	Range	Variance	Coefficient of variation (%)
Plant height (cm)	72.39	30.2-110	261.18	22.32
Number of branches	11.42	4-17	8.68	25.79
Number of fruits per plant	52.00	1-182	1605.56	70.29
Fruit weight (g)	231.00	10-620	27520.3	71.81
Fruit length (cm)	5.90	5.18-6.87	0.26	8.64
Fruit girth (cm)	3.45	3.1-3.9	0.05	6.72
Oleoresin (%)	10.60	9.1-11.5	0.466	6.44
Colour value	23.10	20.1-25.6	2.26	6.53
Capsaicin (%)	0.42	0.31-0.56	0.00	20.04

Table 2. Description of the two plants identified in the F_3 generation

Character	Plant number 8	Plant number 35
Vegetative characters		
Habit		
Plant type	Medium spreading	Medium spreading
Vigour	Moderate	Moderate
Height in cm.	70	75
Branching		
Number of branches (Main)	6	5
Number of laterals	15	17
Stem		
Round/cylindrical	Round	Round
Pubescent / Non pubescent	Non pubescent	Non pubescent
Colour	Green	Green
Floral characters		
Single / clusters	Single	Single
Nature of pedicel	Pendulous	*Pendulous*
Colour	Light green	Green
Length of pedicel (cm)	1.5	1.8
Bud size	Medium	Medium
Fruit characters		
Position	Pendent	Pendent
Shape	Globular	Globular
Colour	Red	Red
Attachment of calyx	Moderately firm	Moderately firm
Apex of the fruit	Blunt	Blunt
Fruit length (cm)	6.82	6.23
Fruit girth (cm)	3.6	3.9
Economic characters		
Days taken for flowering	72.3	75.6
Days taken for fruit set	80.2	81.6
Drying percentage	11.5	11.9
Number of green chillies	178	182
Weight of green chillies (g)	1549.2	1529.3
Yield of dry chillies	610	620
Oleoresin	10.6	9.9
Capsaicin content	0.541	0.523

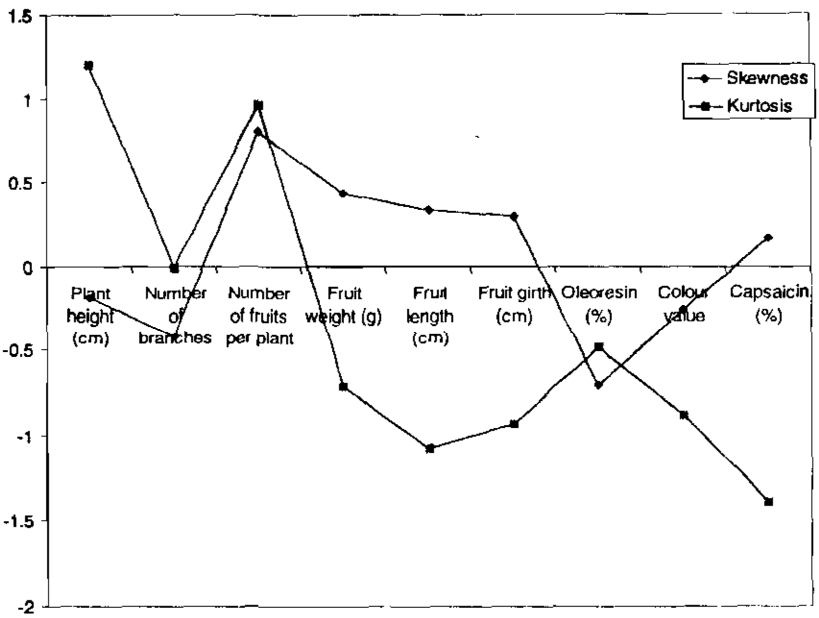

Fig. 1. Skewness and Kurtosis of the progeny from the cross Ramanathapuram Local x Jalapeno hot pepper

a conspicuous departure of the population from normality leading to an asymmetrical distribution (Fig. 1). This departure might be due to the occurrence of transgressive segregants. The skewness was positive for number of fruits per plant, fruit weight, fruit girth and capsaicin content and negative for plant height, number of branches, oleoresin and colour value. This positive skewness indicates the well distribution of population for economic characters.

The plant numbers 35 and 8 exhibited highest estimates for yield per plant, number of fruits and capsaicin content. It can be forwarded for further generation.

References

Immer F R 1942. Relation between yielding ability and homozygous in barley crosses. J. Amer. Soc. Agron. 33 : 200-205

Jayasankar S 1985. Studies on yield and other characters in the segregating generations of chilli (*Capsicum annuum* L.). M. Sc. Thesis, Tamil Nadu Agricultural University, Coimbatore.

Knott D R 1972. Effects of selection for F_2 plant yield in subsequent generations in wheat. Can. J. Plant Sci. 52 : 721 – 726.

Panse V G & Sukhatme P V 1967. Statistical methods for Agricultural Workers. ICAR, New Delhi.

Ponnuswami V 1990. Studies of F_1 & F_2 generations in egg plant (*Solanum melongena* L.). Ph. D Thesis, Tamil Nadu Agricultural University.

Genetic divergence in coriander (*Coriandrum sativum* L.)

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Abstract

The population consisting of 40 genotypes of coriander (*Coriandrum sativum* L.) was subjected to multivariate analysis using D^2 statistics. The characters studied were plant height, primary branches^{-1} secondary branches^{-1}, days to flowering, days to maturity, number of umbel^{-1} number of umbellets per umble, number of seeds per umbel, 1000 seed weight and seed yield^{-1}. The assessment revealed considerable variability among the stock for all characters except primary branches^{-1}, umbellet per umbel and 1000 seed weight. The 40 genotypes were grouped into four clusters depending on similarities of their D^2 values. Cluster number I had 12 genotypes, III retained 11. Cluster number II and IV captured 10 and 7 genotypes. The inter-cluster D^2 values were ranged from 0.62 to 30.7, suggesting considerable diversity among the groups of the genotypes. Based on cluster means, characters such as days to flowering, days to maturity and number of secondary branches^{-1} were major factors of differentiation among genotypes, which may be taken into account while selecting parents for hybridization programme. The clustering pattern of strains did not follow the geographical distribution exactly.

Key words : genetic diversity, multivariate.

Introduction

Coriander (*Coriandrum sativum* L.) is a native of the mediterranean region. It is an annual herb and belongs to family apiacea. It is a cross pollinated crop. The coriander is mainly cultivated in Rajasthan and Gujrat with a sizeable acreage in Madhya Pradesh, Haryana, Punjab, Uttar Pradesh, Andhra and Bihar. Rajasthan alone shares with 40-45 percent of area and production of coriander. The area of coriander in the country is about 3.49 lakh/ha. While productive is about 1.58 lakh tonnes. The area under this crop has gone up during last decade (0.49 lakh ha. in 1984-85 to 3.49 lakh/ha in 1994-95) but the productivity of the crop is not good. In order to make it more productive and resistant to diseases and pests, breeders have to launch an intensive breeding programme for releasing wide range of variability in the population to ensure the assembly of a pool of variable germplasm.

The use of D^2 statistic of multivariate analysis gives an understanding of genetic diversity in the crop. Mahalanobis (1936) generalized distance, D^2 measures the degree of diversification and determines the relative proportion of each component traits to the total divergence. This concept is well understood that the crosses made from inbred lines selected from a cross, perform on average, consistently lower than the single crosses made from inbred of diverse genetic origin. The present analysis will eventually help in choosing desirable parents for hybridization and thus help considerably in the evolution of superior varieties.

Materials and methods

Forty genotypes of coriander maintained in the genetic stock at vegetable research station, Kalyanpur, Kanpur, belong to various parts of the country, constitute the material for the present investigation. An experiment was conducted to evaluate the material, in Randomized Block Design with three replications at vegetable research station, Kalyanpur of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during *rabi* 1996-97. Ten randomly chosen plants were taken from each treatment to record the obeservations on 10 characters under study. The data were subjected to multivariate analysis by using Mahalanobis generalised distance D^2 and the genotypes were clustered on the basis of minimum generalized distance using Tocher's method as given by Rao (1952).

Results and discussion

The analysis of variance revealed highly significant differences among the treatments for all the characters except primary braches^{-1}, umbellet per umbel and 1000 seed weight.

Intra and inter cluster D^2 values are presented in Table 2. Providing interesting information on the nature of genetic divergence at inter and intra cluster - cluster level. Cluster IV which had seven lines had the lowest intra cluster D^2 value 24.89 while cluster III had the highest intra-cluster D^2 (49.90) and comprised 11 genotypes clusters I and II had moderate D^2 values (40.65 and 48.07 respectively) indicating the cultivars were diversed genetically.

The genetic divergence (D^2) between cluster I and III, III and IV and I and II were largest with 30.78, 30.16 and 23.48 values, respectively. Distance between II and III was moderate 7.30 while minimum distance was recorded for I and IV (0.62) indicating less diversity available among the genotypes belonging to these clusters.

The character means of cultivars in four clusters are given in Table 2. Cluster I had maximum mean value for seed yield^{-1} (28.63), number of umbel^{-1}(30.04), days to maturity (135.64), days to flowering (79.69) and number of secondary branches^{-1} (27.69) indicating the importance of these characters in the total divergence. The minimum mean volume (6.24) was recorded for the character, number of primary branches $^{-1}$ followed by umbellet per umbel (5.65).

Cluster II had maximum mean value for number of primary branches^{-1} (6.58), number of seed per umbel (33.10) and 1000 seed wight (8.00) and minimum values for days to flowering (66.43), number of seeds per umbel (33.10) and seed yield (25.69), days to maturity (125.77) and plant height (123.17) which is indicated that genotypes of this clusters are of short duration, poor plant type, of short types and poor yielders.

Cluster III comprising 11 strains had maximum mean value for plant height (130.68) and minimum for 1000 seed weight (7.10) and number of secondary branches^{-1} (21.01).

Cluster IV comprised of 7 genotypes had maximum mean value for number of umbellet per umbel (6.30) and minimum for number of seed per umbel (28.57) and number of umbel^{-1} (26.62).

Table 1. Analysis of variance for 10 characters in coriander (mean sum of square of treatment)

Source	D.F	Height	Primary Branches^{-1}	Secondary flower	Days to maturity	Number of umbel^{-1}	Umbellet per umbel	No. of Seed per umbel	1000 seed weight	Seed yield^{-1}	
Treatment	39	90.61**	0.92	58.63**	179.50**	210.6**	14.83**	0.49	26.17**	0.96	8.87**

* and ** denotes the level of significance at 5% and 1 % respectively.

Table 2. Grouping of 40 genotypes of coriander into different clusters.

Cluster	Genotypes	No. of genotypes into different clusters
I	Raj - 1, 8922, 8924,9103,9104,9105,9107, PC -1, 9102, 9301,9302,9303.	12
II	8901,8903,8905, Azad Dhania - 1, 8909 8919,8919, Raj - 2, 8920,9106.	10
III	8902,8904,8907,8911,8912,8914,8915,8916, 8917,8921,8923	11
IV	Local 8908,8010,8913, New selection -1 9101,9102.	7

The distances between the clusters and contribution of various characters towards divergence may be the true guide lines for the selection of the parents for hybridization. In the present investigation the crosses between the genotypes from cluster I and II are more productive and useful in comparison to I and III while the distance between these two are maximum.

The clustering pattern of the varieties indicated that geographic diversity had no significant impact on genetic diversity As genotype Raj-1 and Raj-2 from Rajasthan could get place in different clusters i.e. I and II like wise Azad Dharia, and local type from Kanpur also placed in cluster II and IV seperately.

References

Mahalanobis P C 1936. Proc. Nat, Inst. Sci. 12.49.

Rao C R 1952. Advanced statistical methods in Biometeric Research. John Wiley & Sons, New York.

Table 3. Average intra (diagonal) and inter clustra distances in coriander.

Cluster	Cluster			
	I	II	III	IV
I	40.650 (6.375)	23.4855 (4.846)	30.7867 (5.540)	0.6213 (0.788)
II		48.07 (6.933)	7.3012 (2.702)	22.4642 (4.781)
III			49.90 (7.06)	30.1654 (5.492)
IV				24.89 (4.98)

Values in parenthesis indicate $\sqrt{D^2}$ values
Values underlined are intra cluster distances.

Table 4. Cluster mean for 10 characters in coriander

Trait	Cluster			
	I	II	III	IV
Plant height	127.38	123.17*	130.68**	125.94
Number of primary branches^{-1}	6.24*	6.58**	6.31	6.52
Number of secondary branches^{-1}	27.69**	22.41	21.01*	23.84
Days of flowering	79.69**	66.43*	71.18	76.00
Days of maturity	135.64**	125.77*	132.42	129.00
Number of umbel^{-1}	30.04**	29.77	29.55	26.62
Number of umbellet per Umbel	5.65*	5.83	5.68	6.30**
Number of seeds per umbel	30.55	30.10**	32.62	28.57
1000 seed weight	7.67	8.00**	7.10*	7.27
Seed yield^{-1}	28.63**	25.69*	28.62	27.29

* Indicates minimum mean value **Indicates maximum mean value.

Path analysis in coriander (*Coriandrum sativum* L.)

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Abstract

The path coefficient analysis was done in 40 genotypes of coriander to determine the direct and indirect effects on seed yield *via.* plant-height, number of primary branches, number of secondary branches, days to flowering, days to maturity, number of umbels, number of umbelets umbel^{-1}, number of seed^{-1} plant^{-1} and 1000 seed weight. About 70 per cent of characters had positive direct effect on seed yield. Days to flowering had highest direct effect on seed yield followed by days to maturity and number of umbels per plant. Plant height, number of primary branches and number of seeds per umbel had weak direct effect on seed yield.

Key works: path coefficient

Introduction

Breeder before chalking out any breeding programme, would like to know the association/ relationship among the plant characters, for a particular crop. The degree of association termed as correlation coefficient varies from -1 to +1. Correlation provides a measure of genetic association between characters and is generally used in selecting for one character as a mean of improving another. Dewey and Lu (1959) and Frakes *et al.* (1961) reported the utility of path coefficient in plant selection. This type of analysis furnishes a mean of measuring the direct and indirect effects of one character over the another.

Materials and methods

Forty genotypes of coriander were used as a material for the present investigation which are maintained in the genetic stock available at Vegetable Research station, Kalyanpur, of C.S.A. University of Agriculture and Technology, Kanpur. The experiment was conducted in randomized block design with three replications during *rabi* 1996-97. Ten randomly chosen plants were taken from each treatment to record the observations on 10 characters. The data were used to work out correlation coefficients and further seperation of correlation coefficients into components of direct and indirect effects. The causal system gives mutual association as measured by correlation coefficient and the direct influence as measured by path coefficient as was suggested by Deway and Lu (1959).

Results and discussion

The genotypic correlation coefficient of grain yield with its contributing characters were partitioned into direct and indirect effects through path coefficient analysis. The estimates of direct and indirect effects have been presented in Table 1. Graphic representation of the causal system has been presented in Fig.1.

The association between plant height and seed yield was positive and non significant. The plant height had weak direct positive effect on yield where as it had positive indirect effect via primary branches, secondary branches, days to flowering, umbelets umbel^{-1} and 1000 seed weight. Days to maturity and umbels plant^{-1} had negative indirect effect.

Number of primary branches had negative genotypic association with seed yield and its direct effect was also noted to be negative. The negative indirect effect on seed yield was noted for secondary branches^{-1}, days to flowering, days to maturity, number of umbels, number of seeds per umbel and 1000 seed weight.

Low positive direct effect of number of secondary branches over seed yield was noted whereas positive indirect effects were noted days to flowering, days to maturity and number of umbelets umbel^{-1}. The indirect negative effect of secondary branches on seed yield was found *via* number of umbels, number of seed per umbel and 1000 seed weight.

The association between days to flowering and seed yield was highly significant at genotypic level. It may be due to high positive direct effect of this trait. The positive indirect effect of days to flowering on yield were noted *via* number of primary branches, number of secondary branches, days to maturity, number of umbels and 1000 seed weight.

The association between days to maturity and seed yield was found to be positive and highly significant at genotypic level. It may be due to high positive direct effect of this trait, other positive indirect effect of maturity on yield was observed *via* plant height, number of primary branches number of umbelet, umbel^{-1} whereas indirect negative effects was noted *via* number of umbels and number of seeds per umbel.

The genotypic correlation between number of umbels and seed yield was positive and significant. Though the direct contribution of this trait towards yield was significant and positive but its indirect effect through number of secondary branches, days to maturity number of seed per umbel and test weight were negative. The positive indirect effect of number of umbels over seed yield was found *via* number of primary branches days to flowering and number of umbelets.

The association between umbelet and seed yield

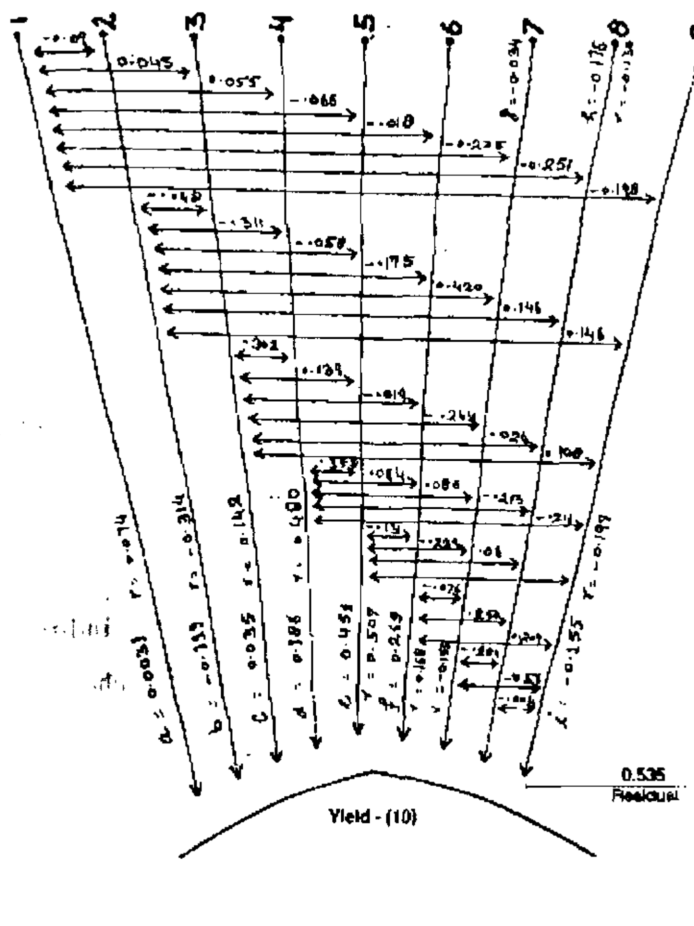

Fig. 1. Path diagram

Table 1. Direct and indirect effect (phenotypic) of different quantitive traits on seed yield in coriander.

Character	1	2	3	4	5	6	7	8	9	Phenotypic Correlation with yield.
Plant height	(0.061)	-0.002	0.000	0.017	-0.023	-0.003	0.002	-0.001	0.002	0.072
No of primary branches/plant	-0.004	(0.003)	0.000	-0.005	-0.004	-0.001	-0.005	0.002	-0.010	-0.045
No. of secondary branches/plant	0.002	-0.002	(-0.002)	0.008	0.039	-0.004	0.006	0.000	-0.014	0.114
Days to flower	0.003	-0.006	0.000	(0.310)	0.091	0.004	-0.003	-0.002	0.021	0.491
Days to maturity	-0.005	0.000	0.000	0.093	(0.305)	0.002	0.007	0.000	0.008	0.409
No. of Umbel per plant	-0.002	0.000	0.000	0.010	0.005	(0.120)	0.003	0.001	-0.013	0.124
No. of Umbellet per Umbel	-0.004	0.005	0.000	0.027	-0.063	-0.011	(-0.034)	-0.001	0.003	-0.077
No. of seed per umberl	-0.005	0.005	0.000	-0.053	-0.005	0.008	0.003	(0.013)	0.002	-0.032
1000 grain weight	-0.012	0.003	0.000	-0.060	-0.023	0.014	0.001	0.000	(-0.110)	-0.188

Revised effect = 0.535

was negative and significant at genotypic level. The direct contribution of this trait was also negative. The indirect effect of this trait was noted *via* plant height, number of primary branches, number of secondary branches, days to maturity and number of umbels plant^{-1}.

The number of seeds plant $^{-1}$ was found negatively correlated with seed yield at genotypic level. The direct effect of this trait on seed yield was also noted negative, whereas negative indirect effect was observed *via* plant height, number of primary branches, days to flowering, the positive indirect effect on seed yield was observed *via* number of secondary branches days to maturity, number of umbels, umbelets umbel^{-1} and 1000 seed weight.

1000 seed weight had negative effect on seed yield whereas negative indirect effect was found in plant height, number of primary branches, days to flowering and days maturity. The indirect positive effects of 1000 seed weight were observed *via* number of secondary branches, number of umbels as umbelet umbel^{-1} and number of seeds per umbel.

Path coefficient would provide a better index for selection rather than the correlation coefficient. Most of the characters had positive direct effect on seed yield particularly days to flowering, days to maturity and number of umbel^{-1} were noted as important traits. The similar findings were reported by Joshi *et al* (1972), Sharma (1984) and Agarwal *et al.* (1994).

References

Agarwal S, Chaudhary G R & Sharma R K 1994. Different aspect for improving the yield of essential oil in coriander. Indian cocoa, Arecanut & Spices J. 18 (2) : 45-48

Dewey O R & Lu K H 1959. "A Correlation and path coefficient analysis of components of crested wheat grass seed production. Agron. J. 57 : 515-518.

Joshi B S, Ramanujam S & Joshi A B 1972. Association of yield and other characters in coriander" Indian J. Genet : 32 (3), 411-417.

Sharma K C 1984. Correlation and path coefficient analysis in coriander (*Coriandrum sativum* L.) M.Sc. Ag. Thesis, Sukhadia University Campus Jobner.

Association studies for seed yield and its attributes in M_4 generation of fenugreek

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Abstract

M_4 families (116 nos.) derived from fenugreek variety RMt-1 after treating the seeds with 20, 30, 40 and 50 Kr doses of gamma radiation were evaluated in randomized block design with 3 replications. Character associations were estimated among days to 50% flowering, plant height, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, test weight, days to maturity, seed yield per plant and biological yield per plant. Significant positive association of seed yield with days to maturity (r=0.329), number of branches per plant (r=0.307), number of pods per plant (r=0.539) and biological yield per plant (r=0.795) in the M_4 families, while non significant association for all these characters except biological yield per plant (r= 0.799) in the parent RMt-1 indicated enhanced correlation after mutagenesis. On the other hand, the correlation between days to 50% flowering and days to maturity, plant height and pod length which were non-significant in RMt-1 but were found to be significant and positive in M_4 families. This may be due to linkage effect, gene mutation or change in the polygenic system.

Key words: correlations, fenugreek, M_4 families.

Introduction

Fenugreek (*Trigonella foenum- graecum*) is mainly cultivated for its seed, leaves (used as vegetable) as well as for fodder. The seed is primarily used in condiments, besides its use as a constituent in several ayurvedic medicines. Fenugreek is an autogamous crop in which available genetic variability is not sufficient to make further genetic improvement (Sharma 1990). The cleistogamous nature of its flowers make controlled hybridization very difficult thereby leading to poor fruit setting. Thus, recovery of transgressive recombination is very low if conventional breeding methods are used. Therefore mutagenesis has been tried in this study. The objective of the present investigation was to investigate the effect of mutagenesis on seed yield and its attributes in M_4 generation

Material and methods

The experimental material consisted of 116 M_4 families randomly selected from M_3 seeds of fenugreek variety RMt-1 (raised during the previous season which were obtained by treating seeds of RMt-1 with 20, 30, 40 and 50 Kr doses of gamma rays). These M_4 families along with parent RMt-1 were raised at agriculture farm, S K N College of Agriculture, Jobner in randomized block design with 3 replications. Each family was sown in a meter space maintaining a spacing of 30 x 10 cm. All the recommended package of practices were followed to raise a good crop. Ten competitive plants from each family/replication were randomly chosen to record observation on days to 50% flowering, days to maturity, plant height, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, biological yield per plant, protein content and powdery mildew incidence. Simple correlations were worked out between different traits in the parent as well as the M_4 families separately.

Results and discussion

Seed yield is a complex character and is the end result of a number of component characters. In general these component characters are expected to have positive association with seed yield.

The associations in M_4 families were stronger in comparison to parent RMt-1 (Table 1). The magnitude and direction of correlations showed little deviation between

Table 1. Simple correlation coefficients between different characters in fenugreek M_4 families and parent RMt-1.

Character	Generation	Days to maturity	Plant height	No. of branches	No. of pods per plant	Pod length	No. of seeds per pod	Test weight	Seed yield per plant	Protein content per plant	Biological yield	Powdery mildew incidence
Days to 50% per cent flowering	M_4	0.146**	0.009	0.04	-0.074	0.007	-0.054	0.026	-0.045	0.007	-0.018	0.031
	Parent	-0.009	0.0161	0.225	0.228	-0.080	0.433	0.280	0.168	0.194	-0.064	-0.180
Days to maturity	M_4		0.315**	0.259**	0.193**	-0.038	-0.049	0.020	0.329**	0.043	0.307**	0.031
	Parent		0.572	0.352	0.522	0.167	0.323	0.455	0.494	0.644*	0.521	0.193
Plant height	M_4			0.087	0.408**	0.112*	0.024	-0.062	0.313	-0.005	0.408**	0.767**
	Parent			0.367	0.631*	-0.015	0.266	0.191	0.580**	0.649*	0.709**	0.172
No. of branches	M_4				0.435**	-0.029	-0.007	0.014	0.307**	-0.085	0.301**	0.464**
	Parent				0.703*	0.496	0.608	0.408	0.307	0.283	0.619**	-0.254
No. of pods per plant	M_4					0.005	0.022	-0.009	0.539**	-0.034	0.631**	0.243**
	Parent					0.085	0.443	0.272	0.543	0.581*	0.750**	0.660**
Pod length	M_4						0.240**	-0.013	-0.034	0.005	-0.022	0.342**
	Parent						0.574	0.515	0.238	-0.028	0.313	0.217
No. of seeds per pod	M_4							0.018	0.043	0.070	0.014	-0.254**
	Parent							0.547	0.551	0.413	0.627*	0.084
Test weight	M_4								0.038	-0.016	-0.011	-0.095
	Parent								0.355	0.162	0.298	-0.712**
Seed yield per plant	M_4									0.329**	0.795**	0.276**
	Parent									0.479	0.799**	-0.221
Protein content	M_4										-0.012	-0.243**
	Parent										0.628*	-0.302
Biologicalr yield per plant	M_4											-0.204*
	Parent											-0.144

* Significant at p=0.05 **Significant at p=0.01

parent RMt-1 and M_4 families.

In the present investigation, in M_4 families, seed yield per plant showed positive and significant association with days to maturity, number of branches per plant, number of pods per plant, protein content and biological yield per plant and had significant and negative correlation with powdery mildew incidence. However, it associated non significantly with all these characters except biological yield per plant in the parent RMt-1 indicating the enhanced correlations in the families after mutagenesis. Positive association of seed yield with other morphological characters was commonly reported by Chandra (1992) in fenugreek.

Among the interrelationships, powdery mildew incidence exhibited negative correlations with all the characters and the associations were mostly significant. Among the other characters days to maturity exhibited positive and significant associations with days to 50 per cent flowering, plant height, number of branches per plant, number of pods per plant and biological yield. The other associations were not significant. Biological yield also exhibited positive associations with most of the other traits. Pod length exhibited positive and significant association with seeds per pod and plant height and number of pods per plant had significant association with plant height and number of branches per plant.

The correlation analysis showed that the correlations of days to maturity with plant height, number of branches per plant, pods per plant, seed yield and biological yield were strengthened in the families. Similarly negative correlations of powdery mildew incidence with plant height, number of branches per plant, number of pods per plant, pod length, seed yield, protein content and biological yield and positive correlation of seed yield with number of branches, pods per plant and protein content also increased in the M_4 families over the parent. Sharma & Sharma (1981) in lentil and Birajdar (1982) in cowpea also observed such results. The correlation between days to flowering and days to maturity, plant height and pod length, changed from non-significant negative to significant positive in M_4 families. This may be due to linkage effect, gene mutation or change in the polygenic system. Choulwar & Borikar (1986) reported similar results in cowpea and Pulivarithi & Mary (1987) in green gram.

The increase in the correlation between traits may be utilized to increase the rate of selection response on primary traits. The present study suggested that seed yield could be improved if selection is done for days to maturity, number of branches per plant, number of pods per plant, protein content and biological yield per plant.

References

Birajdar D V 1982. Mutagenesis in cowpea (*Vigna unguiculata* L). M.Sc.(Ag.) thesis, MAU, Parbhani (unpublished).

Chandra K 1992. Genetic variation and association among yield and yield related characters in fenugreek. M.Sc.(Ag.) thesis, Rajasthan Agricultural University, Bikaner (Unpublished).

Choulwar S B & Borikar S T 1986. Effect of mutagens on character associations in cowpea. Ind. J. Agric. Sci. 56 : 204-206

Pulivarithi H R & Mary T N 1987. Induced high yielding mutant in green gram (*Vigna radiata* L.). Mut. Bree. News Lett. No.30.

Sharma A K 1990. Gamma rays induced variability in fenugreek. M.Sc.(Ag.) thesis, Rajasthan Agricultural University, Bikaner (Unpublished).

Sharma G P & Sharma R K 1978. Genetic variability, correlation and path analysis in fenugreek. Ind. J. Agric. Sci. 51 : 619-22.

Combining ability analysis in varietal diallel cross of fennel (*Foeniculum vulgare* Mill.) for yield and yield related traits

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Abstract

Nine genetically diverse varieties of fennel were crossed in varietal diallel cross combination excluding reciprocals. Variety heterosis (h_j) effects were significant for test weight. Specific heterosis ($S_{jj'}$) effects were found significant for days to flowering, umbels per plant, umbellets per umbel, seeds per umbel, test weight, biological yield per plant and harvest index including seed yield per plant. Based on V_j and h_j values, parents RF - 125 and JF - 29 were found superior. These two parents appeared in majority of crosses which showed superiority on the basis of $S_{jj'}$ effects. The other parents worth considering are UF 134 and UF(M)-1. These varieties represented a good choice to initiate inter-population improvement. There was good agreement between $S_{jj'}$ effects and heterobeltiosis. Cross UF(M)-1 x UF-134 showed significant and positive $S_{jj'}$ effect for seed yield per plant, umbellets per umbel, seeds per umbel and harvest index.

Introduction

Fennel is an important spice crop grown for its seeds which are used for mastication, chewing and for volatile oil which is responsible for pleasant flavour. The crop has a good potential as a cash crop generating an annual foreign exchange of worth Rs. 7.46 crores. The crop has remained neglected as far as genetic improvement is concerned (Anonymous 1997). As a result, local types having low productivity and susceptibility to diseases are being cultivated in marginal areas resulting in poor production. The yield potential of this crop can be increased by producing hybrid varieties. Being an allogamous crop it is easy to produce the hybrid seed provided male sterile lines are available. As an immediate step superior composites may be produced to improve yielding ability.

Materials and methods

The present study was carried out on a diallel set of nine genetically diverse varieties viz. RF-125, UF(M)-1, UF-90, RF-101, UF-134, JF-29, HF-71, HF-102 and Local type. The resulting 36F_1s along with their nine parents were grown during rabi, 1997-98 in a Randomized Complete Block Design with three replications. The entries were grown in a plot of size 2 x 0.9 m size accommodating 2 meters long two rows spaced 45 cm apart with an intra row spacing of 20 cm maintained by dibbling. All the recommended package of practices were followed to raise a good crop (Sharma *et al.* 1996). Observations were recorded on ten randomly selected plants from each plot for height upto main umbel (cm), total plant height (cm), branches per plant, umbels per plant, umbellets per umbel, seeds per umbel, biological yield per plant (g), harvest index (%) and seed yield per plant (g) while for days to 50 per cent flowering and test weight the data were recorded on whole plot basis. Data on growth and yield attributes were subjected to the analysis of variance of variety cross diallel analysis and estimation of genetic constants was done as per the method II as enumerated by Gardner and Eberhart (1996). This model assumes that parents used are a set of fixed set of random mating varieties with no epistasis and diverse gene frequencies and additive and dominance effects for individual loci. When parents and their diallel crosses are grown together, the additive effect (A) and dominance effect (D) are confounded and must therefore be estimated jointly. Singh (1978) and Ordas (1980) have provided details of the necessary calculations. Under such conditions, depending upon the presence or absence of heterosis and its components, 4 models are suggested.

They are:-

$Y_{jj'} = \mu_v + \frac{1}{2}(v_j + v_{j'})$

$Y_{jj'} = \mu_v + \frac{1}{2}(v_j + v_{j'}) + \delta\bar{h}$

$Y_{jj'} = \mu_v + \frac{1}{2}(v_j + v_{j'}) + \delta\bar{h} + \delta(h_j + h_j')$

$Y_{jj'} = \mu_v + \frac{1}{2}(v_j + v_{j'}) + \delta\bar{h} + \delta(h_j + h_j') + s_{jj'}$

Where,

$Y_{jj'}$ = mean of a cross between j and j'

μ_v = mean of all parental varieties included

v = the variety effect when parent varieties are included in the analysis, as done in the present case.

$\bar{h}$ = average heterosis, h_j and $h_{j'}$, refers to varietal heterosis and $s_{jj'}$ refers to the combining ability of the cross between j and j'.

$\delta = 0$ when j = j' and 1 when $j \neq j'$

and $S_{jj'}$ = specific heterosis of the cross j and j'.

Result and discussion

The aim of the plant breeder is to estimate the general combining ability (GCA) effects of each parent and specific combining ability (SCA) effect of each cross to compare these effects and on that basis, the best parents or corss combinations could be selected. In a random mating population however, such effects cannot be obtained as the assumption of homozygosity is not fulfilled. Gardener and Eerhart (1966) however opined that the concept of heterosis is more important in cross pollinated crops and proposed method for their estimation which is the one used in the present investigation.

The analysis of variance indicated significant variation in parents and F_1s. The parents vs F_1s sum of squares was significant for all the characters indicating the presence of heterosis. Partitioning of entries sum of squares into varieties and heterosis (h_{jj}') further indicated the importance of heterosis in the inheritance of the traits. This component accounted for about 80% and above to the total variation (Table 1). Partitioning of heterosis sum of squares into average heterosis ($\bar{h}$), varietal heterosis (h_j) and specific heterosis ($s_{jj'}$) further indicated that among the components of heterosis,

Table 1. Percentage of entry sum of squares accounted for by the heterosis sum of squares; per cent heterosis sum of squares accounted for by average heterosis, parent heterosis and specific combining ability sum of squares.

Character	Heterosis SS ($h_{jj'}$) as % of entry sum of squares	% Heterosis as accounted for by		
		Average ($\bar{h}$)	Variety (h_j)	SCA ($S_{jj'}$)
Days to 50% flowering	85.05	33.96	9.24 #	56.79
Height upto main umbel	92.78	13.28	21.86 #	64.86 #
Total plant height	78.31	13.83	26.86	59.31 #
Branches per plant	98.02 #	22.86	13.45 #	63.69 #
Umbels per plant	91.90	0.05 #	22.49	77.45
Umbellets per umbel	94.14	21.65	24.43	53.91
Seeds per umbel	88.97	4.06	22.59	73.36
Test weight	89.63	4.23	35.37	60.39
Biolgical yield per plant	96.77	14.79	21.83	63.38
Harvest index	79.08	6.93	20.81	72.26
Seed yield per plant	96.49	6.53	11.41	82.06

Mean sum of squares were not significant at p = 0.05

average heterosis ($\bar{h}$) mean sum of squares were significant for all the traits except branches per plant indicating the importance of non-additive gene effects. The parental heterosis (h_j) mean sum of squares and mean squares due to specific heterosis ($s_{jj'}$) were also significant for most of the traits except days to 50% flowering and test weight, for varietal heterosis mean sum of squares and branches per plant and test weight, for specific heterosis mean sum of squares indicating that in general all the three components contributed significantly to the inheritance of the characters.

Although overall heterosis sum of squares were significant for almost all the characters, the heterosis sum of squares accounted for 70% and above of the entries sum of squares (Table 1). This even for the character branches per plant, where the contribution

Table 2. Varieties and crosses showing the best effects in fennel.

Character	Varietal effect (V_j)	Heterotic effect (h_j)	Specific heterosis ⊕ ($S_{jj'}$)
Days to 50% flowering	-	-	JF-29 x Local (-4.29*)
Height upto main umbel	-	-	-
Total plant height	-	-	-
Branches per plant	-	-	-
Umbels per plant	-	-	RF-101 x JF-29 (10.76**)
			RF-125 x HF-102 (10.22**)
Umbellets per umbel	-	-	UF(M)-1 x UF-134 (8.50**)
Seeds per umbel	-	-	UF(M)-1 x UF-134 (176.34**)
			UF-90 x G/f-71 (147.21**)
Test weight	-	0.95* (RF-125)	UF(M)-1 x HF-102 (1.41*)
Biological yield/plant	-	-	UF(M)-1 x UF-134 (33.82*)
			RF-125 x JF-29 (29.75**)
			UF-90 x HF-71 (28.16**)
			RF-125 x Local (27.53**)
Harvest index	-	-	UF(M)-1 x UF-134 (8.42**)
Seed yield per plant	-	-	UF(M)-1 x UF-134 (15.68**)
			RF-125 x JF-29 (9.16**)
			UF-90 x HF-71 (5.77*)
			RF-101 x Local (5.30*)
			RF-125 x HF-102 (4.85*)
			RF-125 x RF-101 (4.63*)
			RF-125 x Local (4.62*)
			UF-134 x HF-102 (4.43*)

⊕ Only significant and desirable crosses listed.

* Significant at p=0.05 and ** Significant at p=0.01

was more than 85% to the entries sum of squares. This indicates that all the characters were controlled by additive, dominance and epistatic components (Baile *et al.* 1980).

The partitioning of heterosis sum of squares indicated that the contribution of average heterosis ($\bar{h}$) which otherwise reflects dominance, was very low for most of the traits except days to 50% flowering branches per plant and umbellets per umbel, whereas the variety heterosis (h_j) ranged between 9.24 to 35.37 per cent for various traits. The portion of specific heterosis ranged between 53.91 to 82.06 per cent. Partitioning of overall heterosis sum of squares indicate that contribution of specific combining ability was the highest (above 50% in general) among the three components (Table 1). This suggests that data should fit to the model 4. The data did fit to the model supporting the observation of complex inheritance. Because of the confounding effect, each of the genetic components in the model II (Gardner & Eberhart 1996) cannot be estimated separately.

The estimates of genetic constants for 11 characters have been presented in Table 2. None of the constants were found to be significant for height upto main umbel, total plant height and branches per plant. Varietal heterosis (h_j) effect was observed to be significant for test weight only while specific heterosis effect (S_{ij}) was found significant for most of the traits. This further supports the conclusion reached regarding the presence of complex type of inheritance. For seed yield per plant, specific heterosis effects of UF (m)-1 x UF-134 (15.68**), RF-125 x JF-29 (9.16**), UF-90 x HF-71 (5.77**) RF-101 x local (5.30*), RF-125 x HF-102 (4.85*), RF-125 x RF-101 (4.63*), RF-125 x local (4.62*) and UF-134 x HF 102 (4.43*) showed positive effect. Again the cross UF(m)-1 x UF-134 showed highest s_{ij} effect for umbellets per umbel, seeds per umbel, biological yield per plant and harvest index. Hence improvement in yield can be expected even when selections are based on these component traits. This cross UF(m)-1 x UF-134 had the highest heterosis (data not presented) and therefore, the must heterotic combination.

Parents RF-125 and UF-134 consistently appeared in majority of crosses which showed superiority on the basis of S_{ij}. The other parents worth considering are UF(M)-1 and JF-29.

Based upon this study, it was concluded that as high amount of heterosis exists for various traits including seed yield, development of hybrid varieties hold promise. RF-125 and UF-134 should invariably be included as one parent in the development of hybrids. Crosses in fennel is difficult due to small flower size hence use of recurrent selection and development of composites is suggested to improve yielding ability in fennel.

References

Anonymous 1997. Seed spices in Rajasthan, Rajasthan State Agricultural Marketing Board, Pant Krishi Bhawan, Jaipur. pp 93.

Bailey T B, Qualset Jr Co & Cox D F 1980. Predicting heterosis in wheat. Crop Sci. 20 : 339-342.

Gardner C O & Eberhart S A 1996. Analysis and interpretation of the variety cross diallel and related populations. Biometrics 22 : 439-452.

Ordas A 1980. Algebric formulas to compute sum of squares in the Analysis of II of Gardner and Eberhart Genet. Inbev. 32 : 133-137

Sharma R K, Dashora S L, Choudhary G R, Agarwal S, Jain M P & Singh D 1996. Seed spices Research in Rajasthan Directorate of Research. Rajasthan Agricultural University, Bikaner (Rajasthan).

Singh D 1978. On the variety cross diallel analysis of Gardner and Eberhart. Indian J. Genetic. 38 : 115-118.

A new method of emasculation in fennel (*Foeniculum vulgare*)

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Abstract

Fennel is an important spice crop of Rajasthan. It is an allogamous crop. The flowers are very small and it is difficult to do emasculation, a first step in hybridization. In this paper we present a new method of emasculation which is very quick and least damages the stigma. Comparison of emasculation done using the traditional forceps tweezing and the new method revealed that the seed set with the new method is higher in comparison to traditional forceps tweezing.

Key words: emasculation, fennel

Introduction

Fennel (*Foeniculum vulgare* Mill) plant is a stout aromatic, generally annual herb (biennial with potency of regeneration). It bears decompound leaves, the lower leaves are smaller and less incisioned. Inflorescence is a compound umbel with bright yellow flowers. The volatile oil which is present in the seeds is used in the manufacture of cordials and used in the preparation of fennel water, which is commonly given to infants as medicine. It is an important foreign exchange earner. Yet, the crop is neglected from the point of crop improvement. One of the problems associated with this crop is the small flower size, which makes it difficult to cross.

Materials and methods

Emasculation if fennel can be done by tweezing the anthers with forceps. The tweezing is done in flowers during morning hours (7-8 hrs). Ideally the flowers which will open in two days hence are selected for emasculation. At this stage the flowers are still closed. Gently the flower is opened and the anthers squeezed out. This method is very slow and very cumbersome. In order to emasculate an umbel, about half an hour is required. Damage to the stigma is common. Our experience indicate that the seed setting upon pollination with such an emasculation method is around 20%.

The new method developed by us does not involve the forceps and damage to the stigma is least. The method essentially involves the following steps.

1. Selection of flowers: the flowers are selected as detailed above.

2. Anchoring the flowers between the fingers. The flowers are held between thumb and index fingers. Whole of the umbellet is held between the fingers in such a way that maximum pressure upon pressing is put at the base of the petals. The anthers are located inside and below the petals.

3. Gently pressing, the umbellet is twirled between the fingers. The petals and enclosed anthers are detached from the flower and as a result, exposing the bare stigmas. An emasculated umbel is very distinct and is visible from a distance. Most of the flowers of an umbellet are emasculated in one go. Yet, care be taken that no flower remains un-emasculated. If such a flowers are seen, it is suggested that such flowers be nipped.

This method hardly takes 5 minutes to complete the process for a given umbel with minimum damage to stigma.

For pollination, selected umbels (to be used as male) are bagged before anthesis to avoid contamination. The pollination is done in the morning hours. Pollen availability starts around 10 AM. The male umbel is cut and is brushed on the emasculated umbel. The male umbel after brushing is put on the female umbel and is bagged again.

An experiment to compare the crossing efficiency of both the methods was done. 50 umbels were randomly selected in a field of RF 125, such that no two umbels were on the same plant. In each umbel, 18 umbellets were maintained and in each umbellet, an average of 15 flowers were maintained. Of the 50 umbels, 25 were emasculated by forceps squeezing and 25 by twirl method. The emasculated umbels were pollinated with RF-101. The harvested seed were counted and efficiency calculated.

Results and discussion

Table 1 reveals that twirl method is more efficient. This method is now routinely used by us for emasculation.

Table 1. Comparison of efficiency of emasculation methods in fennel.

Method	Number of umbels	Number of umbellets/umbel	Flowers per umbellet	Seed harvest after pollination (RF-125)	Efficiency (%)
Forceps squeezing	25	18	15	1283	19.00
Twirl method	25	18	15	3475	51.48

Breeding of seed spices - nigella (*Nigella sativa* L.)

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Abstract

The varietal improvement of nigella has been successfully conducted at Vegetable Research Station, C.S.Azad University of Agriculture & Technology Kalyanpur, Kanpur. As a first step, the germplasm collections have been screened for earliness, yield and other desirable traits and a line 9301 was observed highly promising on the basis of yield evaluation tests vis a vis other lines and local check. On the basis of overall mean, it has given an yield of 10.93 q/ha which was 51.8 per cent higher besides being 10-15 days earlier in maturity over check. This line has also performed better in yield and other ancillary traits in Eastern, Central & Western cultivating regions of state. It has been released by the State Variety Release Committee as 'Azad Kalaunji' (Mangral) for general cultivation.

Introduction

Nigella (*Nigella sativa* L.) in vernacular is known as Mangrail or Kalaunji. It is grown during winter season. The seeds are used in pickles, candies etc. and possess medicinal properties. The seeds contain 1.5 to 4 per cent essential oil which is used in food, flavour and pharmaceutical industries. It has very low productivity which may be mainly due to poor quality of seeds. Being such an important seed spice, not much research work was done on its improvement. With a view to develop early, high yielding & disease resistant varieties the research work on improvement of this crop was undertaken.

Materials and methods

Germplasm collections of nigella maintained at Vegetable Research Station, Kalyanpur are being regularly selfed to maintain purity for a number of years. On the basis of observations recorded on yield and other ancillary traits, five lines viz. 9301, 9201, 9003, 9002, 9001 were found promising. During 1990-91 these lines along with one local check were sown in unreplicated 5 rows each and bulked. The bulk seed of selected plants was sown during 1991-92 and again promising plant selections were made. The cycle was repeated during 1992-93 & 1993-94. Finally the bulked seeds of these promising lines were procured for conducting yield evaluation trial. Thus a trial consisting of 5 lines and a local check was sown in randomized block design with four replications which was conducted for 3 years from 1994-97 at Vegetable Research Station, Kalyanpur. The multilocation trial was also conducted during 1995-96 at Basti and Babugarh besides Kalyanpur to test the adaptabily of these lines in central, eastern and western cultivating regions of the state.

Results and discussion

The performance of five selected lines from the collection of nigella revealed that line 9301 has given the maximum average seed yield of 10.93 q/ha which was significantly higher than local check yielding only 7.2 q/ha registering an increase of 51.8 per cent over a period of 4 years. It has also given highest seed yield of 9.20 q, 11.92 q, 11.00 q and 11.60 q per ha during 1994-95, 1995-96, 1996-97 and 1997-98 respectively. At Babugarh it has yielded 7.60 q seed per ha which was higher other variety which at Basti it has recorded a seed yield of 1.58 q/ha against check 1.37 q/ha however the level of yield was poor due to adverse weather conditions at these locations during crop season. Besides, it was 10 days earlier in seed maturity and produces bold seed which contribute to enhance the market value of the variety. The variety has profuse branching with high number of fruits per plant (40-50) and more seeds per fruit (60-90). The high seed return was achieved under 60 kg each of nitrogen and phosphorus per ha at a row spacing of 30 cm and seed rate of 8 kg per ha. On the basis of these results, the line 9301 was released as Azad Kalaunji (Mangral) in 1998 by State Variety Release Committee for general cultivation.

Table 1. Salient features of proposed variety 9301 and check variety

Character	9301	Local check
Days to flower	60-70	70-80
Plant height (cm)	60-75	70-85
Days to maturity	140-150	150-160
No.of Primary branches	6-8	4-6
No.of branches per plant	40-55	30-45
No.of fruit per plant	40-50	30-40
No.of seed per fruit	60-90	45-75
Average yield(q/ha)	8-10	7-8

Table 2. The performance proposed variety 9301 at Kalyanpur during 1994-95 to 1997-98 (yield q/ha)

Variety	1994-95	1995-96	1996-97	1997-98	Average
9301	9.20	11.92	11.00	11.60	10.93
9201	11.60	8.40	11.07	11.04	10.52
9003	10.56	9.52	9.20	9.80	9.77
9002	9.60	7.72	8.72	8.40	8.61
9001	7.68	6.40	6.01	6.52	6.65
Local check	7.60	5.70	7.39	8.12	7.20
C.D.at 5%	1.08	1.01	1.95	1.91	
CV %	7.91	7.23	12.94	13.73	

In vitro propagation of tuberose (*Polianthes tuberosa* L.)

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Abstract

A protocol for direct plant regeneration was developed in tuberose using bulb segments as explant. The explants were surface sterilized with mercuric chloride 0.1% for six minutes and cultured on MS medium supplemented with different concentrations of Kinetin and BAP. Best regeneration response was obtained on MS medium containing kinetin 3 mgl^{-1}. The regenerated shoots on transfer to MS medium supplemented with IBA 2 mgl^{-1} induced rooting in 90% of the shoots. The isolated plantlets, hardened in vermiculite were transferred to pots containing garden soil and sand.

Key words: direct organogenesis, tuberose, *Polianthes tuberosa* L., tissue culture.

Introduction

Tuberose (*Polianthes tuberosa* L.) occupies a prime position among the commercially grown flowers because of its position in the cut flower trade and its importance in the essential oil industry. It is also grown for garden decoration in pots, beds and borders. Besides, the individual flowers are used in making artistic garlands, floral bouquets and button holes. The commercial cultivation of this crop mostly depends upon the availability of genuine planting material since it is exclusively propagated by vegetative means. Therefore, an attempt was made to study the feasibility of mass multiplication of the elite plant material through tissue culture. In this connection, the present paper describes the method for direct organogenesis and subsequent regeneration and planting of the plantlets.

Materials and methods

The single and double varieties of tuberose (*Polianthes tuberosa* L.) were collected from Dindigul district. The bulbs were stored under heap of sand to avoid drying and pest infestation and were used whenever the explants were required. Radial cuttings of bulb segments numbering 9-12 were cut from each bulb. They were thoroughly washed in running water and in 0.2% tween 20 solutions followed by washing with sterilized distilled water thrice. The radial segments were then surface sterilized in 70% ethanol for 30 seconds and rinsed with sterilized distilled water for 3-4 times. Further sterilization was done with mercuric chloride 0.1% for six minutes and inoculated in MS medium supplemented with 0.8% agar, 3% sucrose, and deproteinised coconut water (15%) and with different concentrations of kinetin and BAP (1,2,3,4 mgl^{-1}). The cultures were incubated at a temperature range of 25 ± 2°C, light intensity of 2000-3000 lux, with 16h photoperiod, and at 75% relative humidity for direct organogenesis. After 25 days, the regenerated shoots transferred to MS medium supplemented with IBA and NAA respectively (1,2,3,4 mgl^{-1}) for root induction. Well rooted plantlets were transferred from test tubes to small containers filled with sterile vermiculite. At this stage, plants were initially covered with plastic bags (upto 15 days).

Results and discussion

In tuberose, all the explants failed to form callus when treated with different combination of growth regulators. But they readily produced either shoot or root based on the concentration of auxins and cytokinins added. The shoot formation from bulb segment was influenced by the nature and concentration of growth regulators added to the basal media (Table 1). Shoot formation was maximum (90%) at 3.0 mgl^{-1} of kinetin and it declined thereafter with further increase in the concentration. BAP also had enhanced shoot formation with the highest response of 85 per cent recorded at 3 mgl^{-1} of concentration. The time taken for shoot formation was earliest with the addition of kinetin at a concentration of 3 mgl^{-1} (15 days). Shoot production increased with increasing concentration of cytokinin upto 3 mgl^{-1} and there after declined. Length of shoots was also found to be influenced by the concentration of growth regulators added. The maximum length of 5.2 cm was produced at a concentration of 3.0 mgl^{-1} of K and the shortest was 2.9 cm produced at 1.0 mgl^{-1} of kinetin. Similar trend was observed due to addition of BAP but with a slight variation in the values.

Production of such adventitious plantlets without undergoing callusing phase was recommended to overcome the possibility of genetic change that occur in long term callus culture (Ziv *et al.* 1979). By this way of thought, regeneration of plantlets was successfully achieved from radial cuttings of bulb segments. The bulb segments were successful when cultured on MS media supplemented with kinetin at 3 mgl^{-1} concentrations. This response to an extent of 90% is in concordance with the report of Rao *et al.* (1991) in gladiolus.

The root formation from shootlets as influenced by nature and concentration of growth regulators added to the basal media was studied. IBA treated shoot lets of 2 cm in length responded well with 90% root formation at a concentration of 2.5 mgl^{-1} (Table 2). NAA also enhanced the root formation, the maximum response being 85% at 3.0 mgl^{-1}. In general, the increasing concentration of auxins beyond 2.0 mgl^{-1} exhibited gradual

Table 1. Effect of growth regulators on shoot formation from bulb segment in tuberose.

Growth regulators (mgl^{-1})	Culture response (per cent)	Time taken for shoot formation (days)	Mean number of shoot / explant	Mean length of shoot (cm)
MS medium alone	-	-	-	-
MS + K 1.0	65	20 ± 0.63	3 ± 0.70	2.9 ± 0.53
MS + K 2.0	80	17 ± 0.44	4 ± 0.63	3.8 ± 0.47
MS + K 3.0	90	15 ± 0.31	5 ± 0.83	5.2 ± 0.34
MS + K 4.0	75	22 ± 0.77	4 ± 0.54	2.4 ± 0.36
MS + BAP 1.0	60	23 ± 1.14	2 ± 0.89	2.5 ± 0.45
MS + BAP 2.0	70	19 ± 0.54	5 ± 0.44	4.3 ± 0.59
MS + BAP 3.0	85	17 ± 0.83	6 ± 0.31	3.0 ± 0.67
MS + BAP 4.0	65	22 ± 0.40	4 ± 0.70	3.6 ± 0.43

Table 2. Effect of growth regulators on root formation from shootlets in tuberose.

Growth regulators (mgl^{-1})	Culture response (per cent)	Time taken for root formation (days)	Mean number of roots / explant	Mean length of shoots (cm)
MS medium alone	-	-	-	-
MS + IBA 1.0	60	17 ± 0.83	5 ± 0.77	3.6 ± 0.39
MS + IBA 2.0	90	15 ± 0.64	6 ± 0.82	4.7 ± 0.31
MS + IBA 3.0	65	20 ± 0.39	4 ± 0.71	2.6 ± 0.48
MS + IBA 4.0	40	21 ± 0.48	3 ± 0.46	2.5 ± 0.41
MS + NAA 1.0	45	24 ± 0.59	4 ± 0.62	2.8 ± 0.60
MS + NAA 2.0	60	21 ± 0.40	4 ± 0.59	3.4 ± 0.38
MS + NAA 3.0	85	19 ± 0.94	5 ± 0.45	4.3 ± 0.21
MS + NAA 4.0	55	23 ± 0.62	3 ± 0.56	3.4 ± 0.52

reduction in root formation. As that of culture response, IBA at the concentration of 2.0 mgl^{-1} was found to be effective in hastening earlier rhizogenesis when compared to the other auxin tried (NAA 19 days). Increasing IBA beyond 2.0 mgl^{-1} delayed rhizogenesis.

Addition of IBA at concentration of 2.0 mgl^{-1} to the basal medium has produced effective and early rhizogenesis. At the same concentration, the number and length of root growth was greater with IBA at 2.0 mgl^{-1} concentrations.

From the above results, it could be clearly inferred that direct organogenesis can be adopted as a tool for *in vitro* multiplication in tuberose. Callus regeneration can be foregone by which time can be saved and purity of the material can be restored. Therefore, the protocol standardised for direct organogenesis can further be experimented on large scale for confirmation and exploitation to meet the growing demands of the planting material.

References

Ziv M 1986. *In vitro* hardening and acclimatization of tissue culture plants. In: Plant Tissue Culture and Its Agricultural Application (Eds) Withers L A, P G Alderson & Butter Worths, London, pp. 187-196.

Rao T M, S S Negi & R Doraswamy 1991. Micropropagation of gladiolus. Indian J. Hort. 48 (2): 171-176.

Session II

Crop Production

Use of coir compost as a component of nursery mixture for spices

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Abstract

Lack of quality planting material is a major constraint in spices production. Non-availability of sand and FYM and chances of disease spread from soil are causing problems for production of quality planting material. Hence an attempt is made to use decomposed coir compost (Terra Care) as a substitute for soil/sand/FYM in conventional nursery mixture. Three years results showed that Terra Care can be successfully substituted for soil or sand in conventional nursery mixture (soil:sand:FYM 1:1:1 ratio). Results further showed that soil:Terra Care in 80:20 ratio (w/w) with small quantity of diammonium phosphate can also replace sand/FYM in nursery mixture in spices nursery.

Key words: black pepper, cinnamon, coir compost, nursery mixture, nutmeg

Introduction

Spices play an important role in Indian economy. During 1999-2000 India exported 2,08,825 metric tonnes spices valued 1861.03 crore rupees (Spice Market Weekly, May 2000). Though India is known as land of spices, our productivity is lowest compared to other growing countries. Lack of quality planting materials and improper management are major constraints for spices production in our country (Sadanandan *et al.* 1998). Majority of spices are grown in South India where disposal of coir dust from coconut plantation / industry is a problem. It has been estimated that in India 7.5 million tonnes of coir pith is produced annually (Kamaraj 1994). It was reported that composting is an efficient way of byproduct management in plantations by reducing C:N ratio, bulkiness and increasing nutrient content (Biddappa *et al.* 1996). Further ,for production of quality planting materials of spices use of FYM and sand in nursery mixture becomes uneconomical due to non-availability. Continuous removal of fresh forest soil predisposes soil for erosion, there by threatening the soil productivity in the long run. Hence, an experiment was carried out with the objective to study the efficiency of decomposed coir compost (Terra Care) as a substitute for soil/sand/FYM in conventional nursery mixture for growing spices.

Materials and methods

Experiment-I

To study the effect of substitution of coir compost, decomposed coir compost supplied by M/s. Marson Biocare, Bombay by trade name Terra Care (TC) was used in place of soil/sand/FYM in conventional nursery mixture. Nursery experiment was conducted during 1997-99 with the following five type of nursery mixtures, (i) conventional mixture with soil :s and : FYM (1:1:1) (ii) TC : sand : FYM (iii) soil : TC : FYM (iv) soil : sand : TC, all in equal proportions and (v) TC alone. The above nursery mixtures were filled in poly bags of one-kg capacity and rooted black pepper cutting were planted. Two varieties of black pepper *viz.*, Panniyur - 1 and Karimunda were used with five replications each. Plants were allowed to grow for three months after which number of nodes, shoot and root length were measured and data subjected to statistical analysis.

Experiment – II

During 1999-2000 the treatments were modified as below.

(1) Soil:TC in 80:20 ratio (w/w)

(2) Sand:TC in 80:20 ratio

(3) Soil:sand:FYM in 1:1:1 ratio

Sand and soil+TC mixtures were enriched with 0.2 kg DAP/m^3 as P source. Above potting mixtures were filled in poly bag holding one kg each and planted with rooted black pepper (single node) cuttings, cinnamon and nutmeg seedlings. There were five replications. After six months, shoot length, root length and dry matter (DM) production were recorded. The nutrient composition of mixture, shoot and root were also determined by standard procedures (Jackson 1967, Hesse 1971) from which nutrient uptake was computed.

Results and discussion

Experiment –I Effect of Terra Care as substitute for soil/sand/FYM in conventional potting mixture on growth of black pepper cuttings.

The results obtained during 1997-98 and 98-99 by using Terra Care as a substitute for either soil, sand or FYM in conventional potting mixture on shoot and root length of black pepper cuttings are given in table 1 & 2 and that of dry matter production in Fig. 1, respectively.

Data presented in table 1 revealed that though substitution of sand by TC scored the highest shoot length for both varieties i.e., Karimunda and Panniyur-1 during both the years, the combination of soil : sand : FYM, TC : sand : FYM and soil : TC : FYM were all on par. Among treatments, use of TC alone followed by substitution of TC for FYM recorded the least shoot length. Substitution of soil by TC recorded the highest root length which was on par with substitution of sand by TC (Table 2). Similar to shoot length use of TC alone recorded the least root length. This means TC can neither be used alone nor in place of FYM. The combination of TC and sand might have produced better porosity and penetration of root and might be the reason for scoring highest root length. Regarding dry matter production the combination of TC, sand and FYM recorded the highest (Fig. 1).

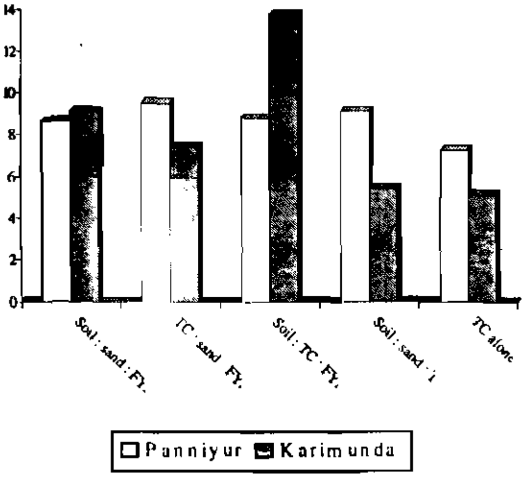

Fig. 1 Effect of Terra Care (TC) as nursery medium on dry matter production of black pepper cuttings

The results showed that TC can be successfully substituted either for soil or sand in conventional nursery mixture for production of black pepper cuttings. Use of TC in place of soil or sand will enhance more root penetration and reduce the chances of infection by inherent pathogen inoculum present in the soil. Further, TC can be substituted for sand in areas where availability of sand is scarce. The result also showed that TC alone cannot be used as nursery medium. This may be because of excess water holding capacity and less anchorage due to low bulk density of the medium, causing rotting of the roots.

Experiment -2

Results of combinations of soil / sand with TC in 80:20 (w/w) ratio with DAP as nursery mixture showed that availability of organic carbon, Bray's P, Mn and Cu was significantly superior in soil : TC and was lowest in sand:TC mixture. With regard to availability of soil K, Ca and Mg normal potting mixture with FYM was superior. Regarding availability of Fe, soil : TC and sand : TC were on par. Soil : TC and normal potting mixture were on par with regard to Zn availability (Table 3). This may be due to the contribution of these nutrients from FYM, soil and TC compared to sand. Saravanan & Basker (1997) also reported improvement in physico-chemical properties of potting medium due to incorporation of coir pith.

With regard to shoot length, ordinary potting mixture scored highest (56 cm) in pepper, soil : TC mixture scored highest (43) in cinnamon, where as in nutmeg both potting mixture and soil : TC were on par. Pepper scored significantly highest root length (35 cm) in soil : TC mixture followed by sand : TC mixture. Cinnamon scored highest root length (34 cm) in sand : TC mixture where as in nutmeg both sand : TC and ordinary potting mixture were on par and recorded highest root length. Regarding DM production, normal potting mixture produced maximum shoot dry matter in pepper and nutmeg where as sand : TC mixture produced maximum shoot DM in Cinnamon and was on par with soil : TC treatment. soil : TC mixture scored maximum root DM for pepper where as sand : TC scored maximum root DM in cinnamon and nutmeg (Table 4).

The plant nutrient composition and uptake by pepper,

Table 1. Effect of Terra Care (TC) as a nursery medium on shoot length (cm) of pepper seedlings

Treatment	Panniyur-1		Karimunda		Mean	
	97-98	98-99	97-98	98-99	97-98	98-99
Soil:sand:FYM	80	27	107	79	93	53
TC:sand:FYM	85	53	95	94	90	74
Soil:TC:FYM	86	73	99	124	93	99
Soil:sand:TC	34	65	34	57	34	61
TC alone	7	18	15	15	11	17
CD 5%	22	21	22	21	14	15

Table 2. Effect of Terra Care (TC) as a nursery medium on root length (cm) of pepper seedlings

Treatment	Panniyur-1		Karimunda		Mean	
	97-98	98-99	97-98	98-99	97-98	98-99
Soil:sand:FYM	37	26	41	22	39	24
TC:sand:FYM	42	34	44	32	43	33
Soil:TC:FYM	37	36	35	23	36	29
Soil:sand:TC	31	33	31	20	31	27
TC alone	28	19	15	21	22	29
CD 5%	10	6	10	6	5	4

Table 3. Effect of TC on soil nutrient availability of nursery mixture

Treatment	pH	OC %	Bray p	Ex. K	Ex. Ca	Ex. Mg	Fe	Mn	Zn	Cu
			(..........................			.mg/kg...				...........................)
Soil:TC	4.7	2.5	107	79	184	62	65	24	2.2	2.5
Sand:TC	5.1	0.8	60	36	195	83	61	6.7	1.9	1.5
Soil:sand:FYM	7.4	1.3	82	507	903	296	22	13	2.0	1.6
CD 5%	0.02	0.07	5.6	15	11	8.0	1.8	0.5	0.10	0.02

Table 4. Effect of TC on morphological growth and dry matter (DM) production of spices seedlings

	Length (cm)		Dry matter (gm)	
	Shoot	Root	Shoot	Root
Pepper				
Soil:TC	42	35	2.3	0.8
Sand:TC	36	31	1.6	0.76
Soil:sand:FYM	56	21	2.6	0.62
Cinnamon				
Soil:TC	43	25	1.8	0.47
Sand:TC	33	34	2.2	0.84
Soil:sand:FYM	25	18	1.2	0.50
Nutmeg				
Soil:TC	46	18	3.8	1.3
Sand:TC	32	23	3.0	2.0
Soil:sand:FYM	50	23	4.7	1.1
CD 5%	5.7	2.3	0.7	0.2

cinnamon and nutmeg as effected by composition of nursery mixture was also studied. Results showed that, in pepper and nutmeg, shoot N and K composition was highest for ordinary potting mixture and all treatments were on par in P content. In cinnamon soil : TC scored highest shoot N and P. In pepper root highest N concentration was in soil : TC, P in sand : TC and K in ordinary potting mixture. In cinnamon and nutmeg highest composition of root N and K was in ordinary potting mixture where as P concentration was highest in soil : TC and sand : TC treatment. This might be due to additional contribution of N and K from FYM and P from DAP which is used in TC combinations.

The N, P and K uptake of spices seedlings (pepper, cinnamon and nutmeg) are depicted in Fig. 2,3 and 4 respectively. In pepper shoot uptake of N and K was highest in ordinary potting mixture whereas in root N, P and K was highest for soil : TC mixture. Shoot uptake of P was highest in soil : TC mixture. For cinnamon shoot nutrient uptake was highest for soil : TC and was on par with sand : TC mixture. Root uptake in cinnamon was also highest for sand : TC mixture. This may be due to better penetration, growth and DM production of root in soil : TC mixture than in ordinar potting mixture. In nutmeg both shoot and root uptak of nutrients where highest in ordinary potting mixture

Results showed that though FYM is a better source c nutrients in potting mixture, Terra Care can be successfully substituted for sand or FYM in nursery mixture, provided little P source is mixed as external supplement. Warrier *et al.* (1998) also reported tha composted coir pith can be successfully used as rooting medium for crops. It was reported that soil : coi pith at 75 : 25 and 50 : 50 ratio (v/v) gave significar increases in yield of potted tomato plants (Baskar & Saravanan 1997). Savithri & Khan (1994) also suggested that coirpith can serve as important source o organic manure for agricultural crops.

From the study it can be concluded that, decompose coir compost (TC) can be successfully used for spice nursery in place of soil or sand in conventional nurser mixture, in equal proportion. It can also replace FYM provided, phosphorus source is added and mixed wit soil in 80 : 20 (w/w) ratio. Terra Care functions as good substitute material to replace FYM or sand wher the availability of them is scarce or uneconomical.

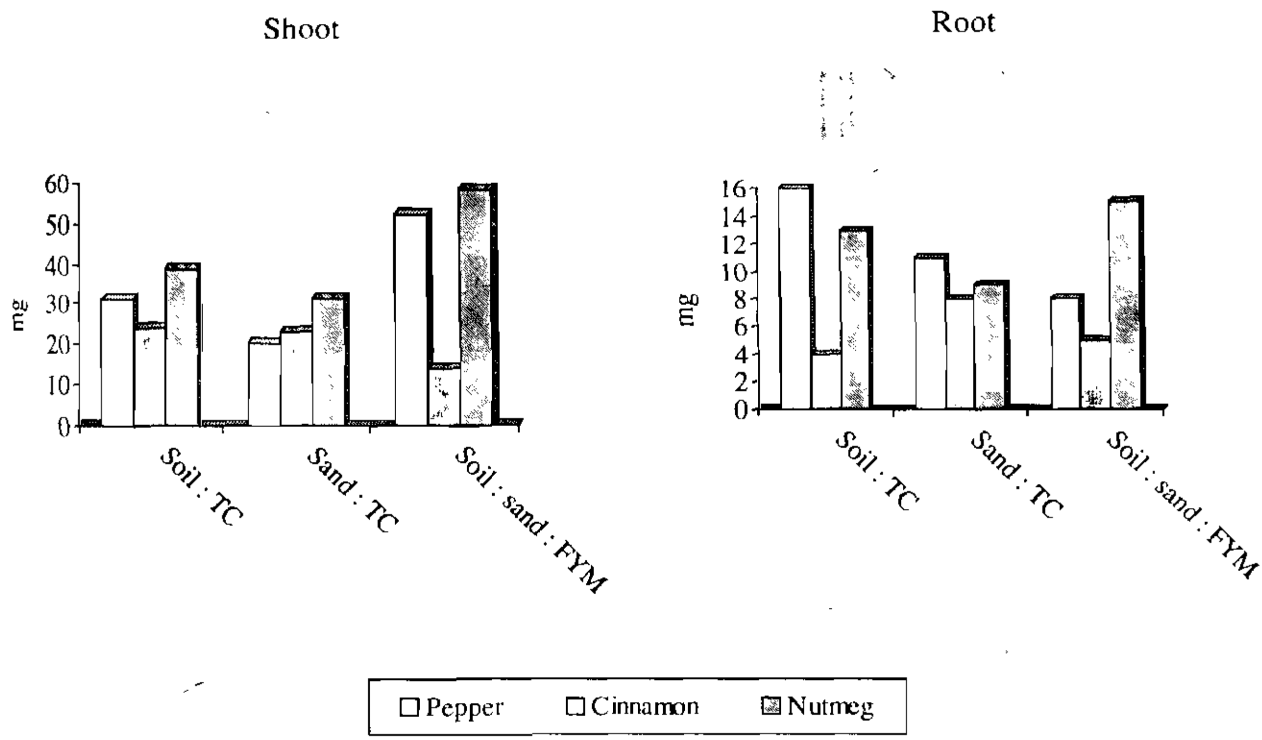

Fig. 2 Effect of Terra Care (TC) on N uptake in spices seedlings

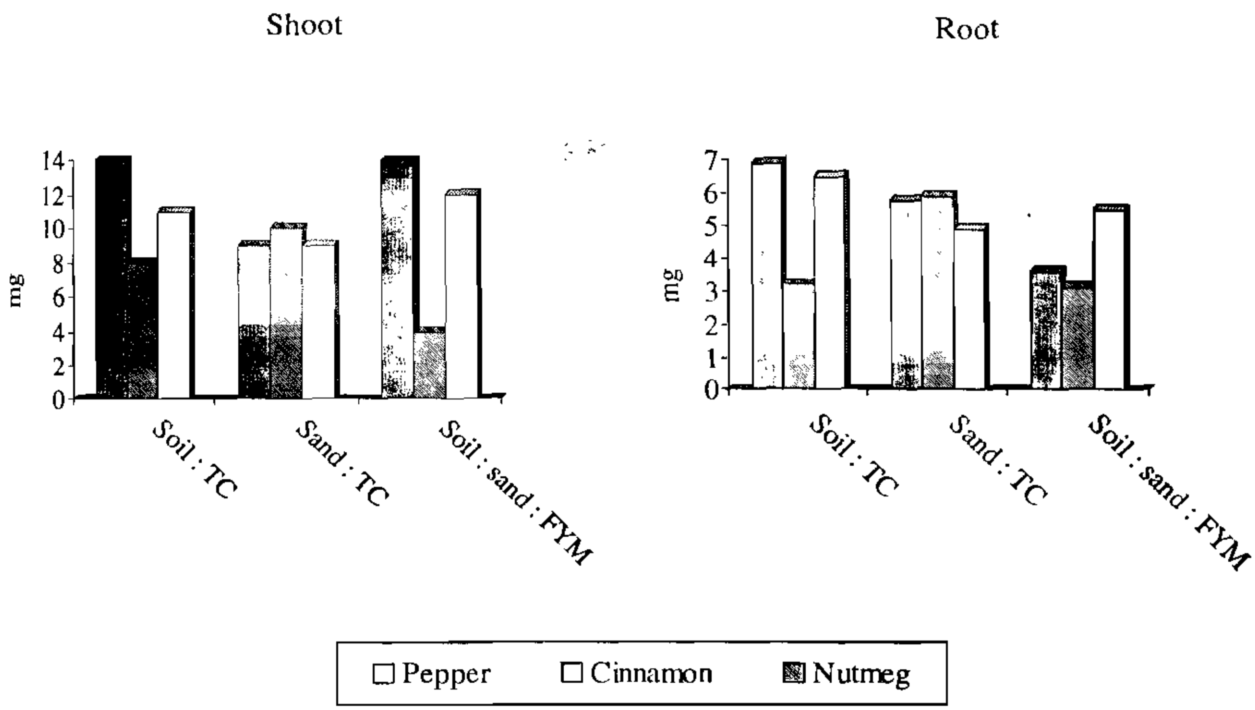

Fig. 3. Effect of Terra Care (TC) on P uptake in spices seedlings

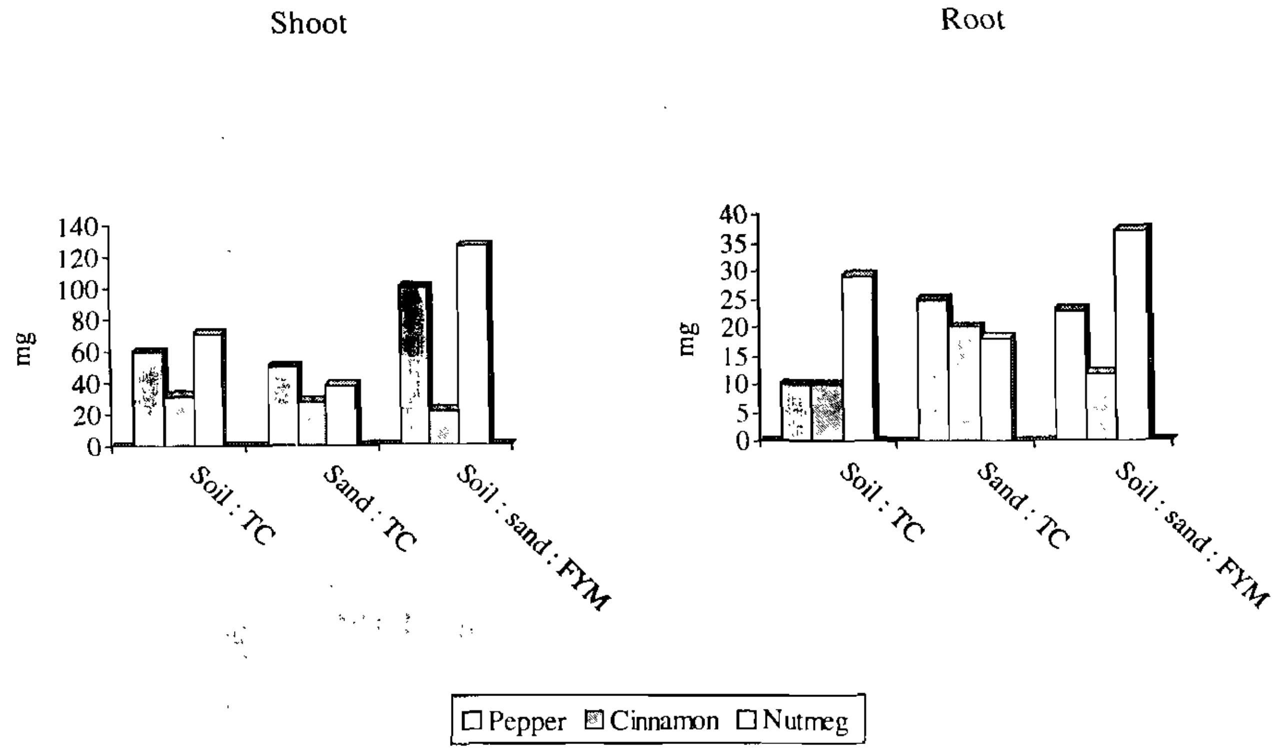

Fig. 4. Effect of Terra Care (TC) on K uptake in spices seedlings

References

Baskar M & Saravanan A 1997. Effect of coir pith based potting mixture and methods of fertilizer application to tomatoes. Madras Agric. J. 84 (8) : 476- 480.

Biddappa C, Upadhyaya A K, Hegde M R & Palaniswami C 1996. Organic matter recycling in plantation crops. J. Plantn. Crops 24(2) : 71-85.

Hesse P R 1971. Soil chemical analysis. John Murray (Publishers) Ltd. London, 520p.

Jackson M L 1967. Soil chemical analysis. Prentice Hall of India Pvt. Ltd. New Delhi. 498p.

Kamaraj C M 1994. Exportable coir products in Tamil Nadu. The Coconut Wealth 1(6) : 6-8.

Sadanandan A K, Kandiannan K & Hamza S 1998. Soil nutrient and water Management for sustainable Spices Production. In Proceeding National Seminar on Water and Nutrient Management for Sustainable Production Quality of Spices. Sadanandan A K, Krishnamurthy KS, Kandiannan K & Korikanthimath VS (Eds.) Indian Society for spices, Calicut, Kerala, India, pp 12-20.

Saravanan A & Basker M 1997. Changes in the properties of potting medium and yield of vegetable cowpea as influenced by coir pith and methods of fertilizer application. Madras Agric. J. 84(8) : 471-475.

Savithri P & Hameed Khan H 1994. Characteristics of coconut coir pith and its utilization in agriculture. J. Plantn. Crops 22(1) : 1-18.

Spice Market Weekly, 5th May 2000. Spice Board, Cochin XIII (18), p-1.

Warrier K E S, Kumaran K G A & Venkataraman K S 1998. A low cost rooting medium for macro propagation of Eucalyptus. Sylva Plus 6 (1) : 13.

Optimum percentage of allowable depletion of soil moisture in bush pepper

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Abstract

Black pepper (*Piper nigrum* L.) can also be raised as a self-supporting bush pepper by propagating from laterals. An experiment was conducted to find out allowable depletion of soil moisture in bush pepper planted in pots during 1997-1998 at college of Horticulture, Vellanikkara. There were four levels of soil moisture depletions viz. depletion of 25, 50, 75 and <10% (control) of available soil moisture. The experiment was laid out in a Completely Randomised Design and replicated six times. Number of branches, leaves, spike characters, berry yield, oleoresin and piperine content were significantly influenced by different soil moisture depletion levels. Maximum yield and oleoresin content were observed when the crop was irrigated at 50% soil moisture depletion . It is concluded that 50% soil moisture depletion is optimum for bush pepper.

Key words: bush pepper, oleoresin, soil moisture.

Introduction

Information on the optimum percentage of allowable depletion of soil moisture is used for scheduling irrigation in crops. In annual crops like pearl millet, finger millet and barley irrigation at 50% depletion of available soil moisture is recommended (Reddy & Reddy 1998). There are no reports available on the optimum percentage of allowable depletion of soil moisture in bush pepper (*Piper nigrum* L.) (pepper raised by laterals) which is grown mostly in irrigated condition. By virtue of its plant type, bush pepper can be grown in pots in terrace of buildings, apart from its natural habitat. It can also be grown easily in kitchen garden and homesteads. Recently there has been a lot of interest among traditional pepper growers both small and marginal farmers on bush pepper. Hence a study was conducted to determine the percentage of allowable depletion of available soil moisture for irrigation in bush pepper.

Materials and methods

Two year old bush pepper plants cv. Karimunda grown in pots (60 x 40 cm) filled with 10 kg sieved potting mixture were used for this experiment. Field capacity and wilting point of the potting media were determined. The available soil moisture in pots were allowed to deplete by 25, 50 and 75% before giving irrigation by gravimetric method. The number of days taken to deplete the available soil moisture to 25,50 and 75% respectively were calculated and irrigation was scheduled accordingly. In control (<10% depletion) plants were irrigated daily. In order to ensure the correct soil moisture status before irrigation under each depletion level, the soil moisture was estimated a day prior to the proposed date of irrigation. The optimum percentage of allowable depletion of soil moisture was determined by observing the growth and yield for four months (December-March). The experiment was laid out in a Completely Randomized Design and replicated six times.

Result and discussion

Growth and yield of bush pepper were influenced by the available soil moisture. Maximum number of leaves (Table 1) were observed at 50% depletion of available soil moisture followed by 25% depletion and it was least at 75% depletion of soil moisture. The leaf area was not significantly influenced at 90 days after treatment, due to different soil moisture depletion levels. Maximum number of branches were observed in plants irrigated when 50% of available water was depleted. Irrigating the plants at 25% depletion was on par with irrigation at 50% depletion. However, delaying the ir-

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Table 1. Effect of irrigation at different levels of soil moisture depletion on number of leaves, number of branches and leaf area of bush pepper

Soil moisture depletion (percent of available water)	Number of leaves (DAT)			Number of branches (DAT)			Leaf area (cm^2 $plant^{-1}$) (DAT)		
	30	60	90	30	60	90	30	60	90
25%	12.3[a]	12.7	10.6[a]	17.5[a]	17.0[a]	17.0[a]	310.6	279.8	245.5
50%	20.0[a]	16.7	16.3[a]	18.1[a]	17.7[a]	17.6[a]	463.6	367.1	385.6
75%	14.3[a]	8.5	7.8[b]	9.6[b]	9.2[bc]	8.9[bc]	338.6	331.7	269.0
<10%(Daily irrigation)	8.0[b]	8.5	10.0[a]	8.5[bc]	10.9[a]	9.4[b]	355.0	481.6	407.4

DAT-Days after treatment
Mean values followed by a common letter are not significantly different at 5% levels by DMRT. Mean values of number of leaves at 60 DAT, Leaf area at 30, 60 and 90 DAT are not significantly different at 5% levels by DMRT

Table 2. Effect of irrigation at different soil moisture depletion on root dry weight, shoot dry weight, root-shoot ratio and total dry matter production in bush pepper.

Soil moisture depletion	Root dry weight ($g.plant^{-1}$)	Shoot dry weight ($g.plant^{-1}$)	Total dry matter ($g.plant^{-1}$)	Root-shoot ratio
25%	2.5[ab]	6.0	12.6[b]	0.84
50%	8.3[a]	16.8	35.5[a]	0.65
75%	1.5[b]	8.0	12.3[b]	0.28
<10%(Daily irrigation)	3.3[ab]	8.3	17.2[b]	0.63

The means followed by a common letter are not significantly different at 5% levels by DMRT.
Shoot dry weight and root-shoot ratio are not significantly different at 5%l evels by DMRT.

rigation to 75% depletion of available water resulted in a drastic reduction in number of branches per plant.

Root dry weight and total dry matter production (Table 2) were more in plants irrigated at 50% soil moisture depletion and least in 75% depletion. Shoot dry weight and root - shoot ratio were not significantly influenced by irrigation at different soil moisture depletion.

Number of spikes on primary branches were not significantly influenced by soil moisture depletion, whereas the number of spikes on secondary branches recorded at one month stage was significantly influenced by soil moisture depletion. The number of spikes on tertiary branches was also significantly influenced due to the levels of soil moisture depletion at 30 days after treatment. Maximum number of spikes were observed on plants irrigated at 50% depletion of soil moisture and least in plants irrigated at 75% soil moisture depletion (Table 3).

Yield and quality of berries (Tables 4 & 5) were also influenced due to levels of soil moisture depletion. Total number of spikes harvested, compaction of spikes, green berry weight, dry berry weight, oleoresin were maximum in plants irrigated at 50% soil moisture depletion

Table 3. Effect of irrigation at different soil moisture depletion on production of spikes on primary, secondary and tertiary branches of bush pepper.

Soil moisture depletion	Number of spikes on primary branches (DAT)			Number of spikes on secondary branches (DAT)			Number of spikes on tertiary branches (DAT)		
	30	60	90	30	60	90	30	60	90
25%	4.9	1.6	2.3	4.4[b]	4.4	2.3	1.2[a]	0.0	0.0
50%	5.6	4.8	1.9	8.7[a]	5.7	2.6	2.3[a]	0.0	0.0
75%	3.9	0.8	1.2	3.3[b]	1.9	2.0	0.8[bc]	0.0	0.0
<10% (Daily irrigation)	4.1	1.0	1.0	3.0[b]	1.1	1.2	0.9[b]	00	00

DAT-Days after treatment

Number of spikes on primary branches at 30 DAT, number of spikes on secondary and tertiary branches at 60 and 90 DAT are not significantly different at 5% levels by DMRT.

The means followed by a common letter are not significantly different at 5% levels by DMRT.

Table 4. Effect of irrigation at different soil moisture depletion on yield characters in bush pepper.

Soil moisture depletion	*Total Number* of spikes harvested	*Length of* spikes	*Compaction of* spikes (No.of berries cm^{-1})	*Number of* berries on spike	*Volume of 100* berries (cc)
25%	9.0[b]	6.6[b]	33.2[b]	35.7[a]	5.0[b]
50%	17.8[a]	5.8[b]	40.9[a]	39.2[a]	7.5[ab]
75%	5.5[bc]	5.6[b]	25.0[c]	22.3[b]	3.7[b]
<10% (Daily irrigation)	11.0[b]	8.9[a]	26.1[c]	40.3[a]	11.7[a]

The means followed by a common letter are not significantly different at 5% levels by DMRT.

The hundred berry weight is not significantly different at 5% levels by DMRT.

Table 5. Effect of irrigation at different soil moisture depletion on yield and quality of berries in bush pepper

Soil moisture depletion	100 berry weight	Green berry weight	Dry berry weight(g)	Oleoresin(%)	Piperine(%)
25%	9.7	29.2[b]	7.5[a]	10.0[c]	2.9[a]
50%	9.0	41.2[a]	10.8[a]	13.5[a]	2.5[ab]
75%	9.3	16.5[c]	4.4[b]	9.0[d]	2.0[bc]
<10%	10.0	23.6[c]	6.1[a]	11.5[b]	2.2[b]

The means followed by a common letter are not significantly different at 5% levels by DMRT.

The hundred berry weight is not significantly different at 5% levels by DMRT.

and least was in 75% soil moisture depletion.

From the results it is evident that yield and quality characters of berries were favourably influenced by irrigation at 50% depletion of soil moisture. Daily irrigation or irrigation at 25% depletion were on par or inferior to irrigation at 50% depletion. Considering these results irrigation at 50% depletion of available soil moisture is recommended for bush pepper. Kerala Agricultural University recommends irrigation of black pepper vines at an IW/CPE ratio of 0.25 indicating low frequency of irrigation (KAU,1996). In many field crops like pearl millet, finger millet, barley (Reddy & Reddy 1998) and plantation crops like coffee (Awatramani *et al.*1973) irrigation at 50% depletion of available soil moisture is recommended for maximising yield.

References

Awatramani N A Cheriyan M & Mathew P K 1973. Sprinkler irrigation for coffee. II Studies on Robusta coffee . Indian Coffee 37(1) : 16-20.

Kerala Agricultural University 1996. Crops- Package of practices recommendations, Kerala Agricultural University, Vellanikkara pp 267.

Reddy S & and Reddy Y 1998. Efficient use of irrigation water. Kalyani Publishers. New Delhi. p 219-253.

Foliar nutrient diagnostic norms for optimising cardamom production

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Abstract

Cardamom (*Elettaria cardamomum* Maton) is one of the important export oriented spice crops of India. During 1999-2000 India exported 550 tonnes of cardamom valued Rs.276 million. A nutritional survey was carried out in major cardamom growing areas during 1993-98 and the data was used for developing foliar diagnostic (DRIS) norms for cardamom. The results showed that for optimising yield between 131 to 625 kg (dry) capsules/ha the index leaves should have nutrient concentrations of 1.26 to 2.81% N, 0.10 to 0.20% P, 1.1 to 3.4% K, 0.51 to 1.38% Ca, 0.18 to 0.31% Mg, 135 to 370 ppm Fe, 261 to 480 ppm Mn, 20 to 45 ppm Zn, 10 to 46 ppm Cu and 0.28 and 0.84 ppm molybdenum.

Key words: cardamom, DRIS norms, leaf nutrient levels, yield.

Introduction

Small cardamom (*Elettaria cardamomum* Maton.) is known as queen of spices. During 1998-99 it was cultivated in an area of 84,910 ha with the production 8790 tonnes in India (Anonymous 2000). The cultivation is mainly confined to evergreen rain forests of Western Ghats of South India (67% in Kerala, 24% in Karnataka and 7% in Tamil Nadu). During 1999-2000 India exported 550 tonnes of cardamom valued Rs. 276 million with an unit value of Rs. 502 kg^{-1} (Anonymous 2000 b). This emphasises the importance of cardamom in Indian economy.

In India, average productivity of cardamom is only 104 kg (dry) capsules per ha while it is over 250 kg per ha in Guatemala. One of the reasons for low productivity is poor nutrition and improper management. Cardamom is a heavy feeder of nutrients and grown in heavy rainfall areas where loss of nutrients through erosion and leaching is high. Besides, continuous cultivation in same piece of land results in poor growth and yield, necessitating application of balanced dose of nutrients for getting sustained yield (Anonymous 1989, Sadanandan *et al.* 1993). Foliar analysis can be used as a tool for assessing plant nutrient status, which guide to fertilizer recommendation (Walsh and Benton 1973). An attempt has therefore been made to standardize the optimum leaf nutrient levels in cardamom through diagnostic recommendation integration system (DRIS) (Sumner 1979).

Materials and methods

A plant nutritional survey was conducted during 1993-98 in major cardamom growing areas, *viz.*, Idukki district of Kerala and Coorg district of Karnataka. Youngest mature leaf (fifth pair) from terminals of newly emerged panicle bearing tillers (Korikanthimath 1994) were collected as index leaves, from 181 cardamom plantations, processed and analysed for different nutrients as per standard procedures (Jackson 1967). The yield data were collected from above plantations. The DRIS technique (Beaufils 1971, Sumner 1977, Bharghava & Chadha 1993, Sadanandan *et al.* 1996) was applied for developing norms for leaf nutrients. For development of DRIS norms, the gardens were divided into two groups as high and low yielders. For the purpose cardamom plantations yielding more than 130 kg/ha were considered as high yielders and less than that as low yielders.

DRIS is based on nutrient balance and indicate not only the nutrient most likely to be limiting at any stage of crop development, but also lists the nutrient elements in their orders of limiting importance on yield. For the purpose each parameter was expressed in as many forms as possible (N/DM, DM/N, N/P, P/N etc.). The mean of each sub population was calculated for various forms of expression. The variance ratios between yields of sub population for all the forms of expressions were taken for developing formulae for calculation of norms (Sadanandan *et al.* 1996).

Results and discussion

The mean and range of different nutrient concentrations in cardamom is presented in Table 1. The nitrogen concentration ranged from 1.26 to 2.81% with a mean of 2.04 and that of phosphorus from 0.10 to 0.20% with a mean of 0.15. Potassium concentration ranged from 1 to 3.4% with mean of 2.25% and of calcium from 0.60 to 1.38% with mean of 0.95%. Magnesium concentration ranged from 0.18 to 0.31 with mean of 0.25%. Iron concentration ranged from 135 to 370 ppm with mean of 253 ppm where as manganese concentration ranged from 261 to 480 with mean of 371 ppm. Zinc concentration ranged from 20 to 45 ppm with mean of 33 ppm and of copper from 10 to 46 with mean of 28 ppm. Molybdenum concentration ranged from 0.28 to 0.84 ppm with mean of 0.56 ppm. Yield of cardamom in surveyed plantations ranged from 25 to 625 kg/ha.

Leaf nutrient norms

The status of nutrients as deficient, low, optimum and high is presented in Table 2. As per the norms worked out, in cardamom leaf N, P, K, Ca and Mg status of less than 0.49, 0.04, 0.50, 0.20, and 0.10%, respectively, were deficient. Similarly Fe, Mn, Zn, Cu and Mo status less than 15, 60, 5, 5 and 0.05 ppm, respectively, were also deficient that may cause yield reduction to an extent of less than 50 kg/ha. A level of 0.5 to 1.25% N, 0.05 to 0.09% P, 0.51 to 1.0% K, 0.21 to 0.50% Ca, 0.11 to 0.17% Mg, 16 to 134 ppm Fe, 61 to 260 ppm Mn, 6 to 19 ppm Zn, 6 to 9 ppm Cu and 0.06 to 0.27 ppm Mo were considered to be low. From plantations having the above low nutrient status, yield level of 51 to 130 kg/ha can be realized. According to Mathewkutty *et al.* (1998) a low DRIS index for a nutrient seemed to be a poor indicator of the necessity of application of that nutrient, as application of some other nutrient could also improve the index. They also stated that DRIS does not offer an alternative method to critical level approach in coconut but may be used to supplement information on nutrient imbalances.

As per the norms, leaf having 1.26 to 2.81% N, 0.10 to 0.20% P, 1.1 to 3.4% K, 0.51 to 1.38% Ca, 0.18 to 0.31% Mg, 135 to 370 ppm Fe, 261 to 480 ppm Mn, 20 to 45 ppm Zn, 10 to 46 ppm Cu and 0.28 to 0.84 ppm Mo is optimum for producing optimum cardamom yield ranging from 131 to 625 kg/ha. In other words, for getting an optimum yield of 378 kg/ha indicator

Table 1. Mean and range of different nutrient concentrations in cardamom leaf.

Element	Unit	Mean	Range	
			Minimum	Maximum
N	%	2.04	1.26	2.81
P	"	0.15	0.10	0.20
K	"	2.25	1.00	3.4
Ca	"	0.95	0.60	1.38
Mg	"	0.25	0.18	0.31
Fe	ppm	253	135	370
Mn	"	371	261	480
Zn	"	33	20	45
Cu	"	28	10	46
Mo	"	0.56	0.28	0.84
Yield	Kg/ha	378	25	625

Table 2. Leaf nutrient norms for cardamom

Nutrient	Unit	Status			
		Deficient	Low	Optimum	High
N	%	< 0.49	0.50-1.25	1.26-2.81 (2.04)	2.81-3.60
P	"	< 0.04	0.05 -0.09	0.10 – 0.20 (0.15)	0.21 – 0.30
K	"	< 0.50	0.51 – 1.00	1.1– 3.4 (2.25)	3.5 – 4.9
Ca	"	< 0.20	0.21 – 0.50	0.51 – 1.38 (0.95)	1.39 – 1.78
Mg	"	< 0.10	0.11 – 0.17	0.18 – 0.31 (0.25)	0.32 – 0.40
Fe	ppm	< 15	16-134	135 – 370 (253)	371 – 490
Mn	"	< 60	61 – 260	261 – 480 (371)	481 – 690
Zn	"	< 5	6 – 19	20 – 45 (33)	46 – 60
Cu	"	< 5	6 – 9	10- 46 (28)	47 – 70
Mo	"	< 0.05	0.06 – 0.27	0.28 – 0.84 (0.56)	0.85 – 1.12
Yield	Kg/ha	< 50	51-130	131 -625 (378)	626 - 860

leaves of cardamom should contain the mean N, P, K, Ca and Mg status of 2.04, 0.15, 2.25, 0.95 and 0.25%, respectively. The optimum status of micronutrients for realising optimum yield is 253 ppm Fe, 371ppm Mn, 33 ppm Zn, 28 ppm Cu and 0.56 ppm Molybdenum. The data showed that the requirement of K is the highest (2.25%) among all other nutrients for obtaining the optimum yield. Many other workers also described cardamom as a heavy feeder of K and 52 and 9% of cardamom growing soils of Karnataka and Kerala, respectively, are low in K status (Sadanandan *et al.* 1993, Korikanthimath 1994). It was reported that (Anonymous 1989) one hectare of bearing cardamom plantation will take 25.97 kg N, 4.35 kg P, 52.11 kg K, 13. 96 kg Ca and 0.8 kg Mg per year and each kilogram of cardamom capsule remove 0.122 kg N, 0.014 Kg P, 0.2 kg K, 0.088 kg Ca and 0.023 kg Mg. This emphasises the importance of balanced manuring especially that of potassium for sustained production of cardamom.

From the DRIS norms worked out it was found that a status of 2.82 to 3.6% N, 0.21 to 0.30% P, 3.5 to 4.9% K, 1.39 to 1.78% Ca, 0.32 to 0.40% Mg, 371 to 490

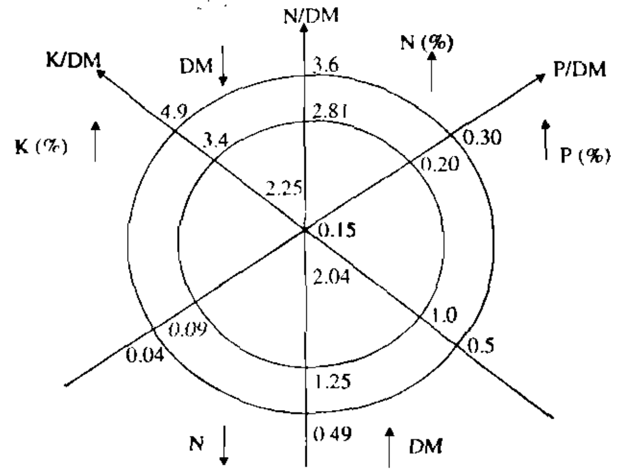

Fig. 1. DRIS chart for cardamom (leaf)

ppm Fe, 481 to 690 ppm Mn, 46 to 60 ppm Zn, 47 to 70 ppm Cu and 0.85 to 1.12 ppm molybdenum are considered to be high. The DRIS chart denoting the status *viz.*, deficient, low, optimum, high and excessive for major leaf nutrients arrived at is given in Fig. 1.

The study revealed the optimum leaf nutrient concentration based on which a balanced fertilization can be recommended to have a significant impact on cardamom production.

References

Anon 1989. Three decades of cardamom research at regional research station, Mudigere. Krishnamurthy K, Khan M M, Avadhani K K, Venkatesh J, Siddaramaih A L, Chakravarthy A K & Gurumurthy B R (Eds.), UAS Bangalore, 94p.

Anon 2000. Directorate of Economics and Statistics, New Delhi.

Anon 2000b. Spice Market Weekly, Spices Board, Cochin, 2000, XIII (18) : 1-2.

Beaufils E R 1971. Physiological diagnosis. A guide for improving maize production based on principles developed for rubber trees. Fertil. Soc. South Africa J. 1 : 1-28.

Bharghava B S & Chadha K L 1993. Leaf nutrient guide for fruit crops. In: Advances in Horticulture. Chadha K L & Pareek O P (Eds.), Malhotra Publishing House, New Delhi, 2 : 973 –1030

Jackson M L 1967. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 498 p.

Korikanthimath V S 1994. Nutrition of cardamom. In: Advances in Horticulture. Chadha K L & Rethinam P (Eds.), Malhotra Publishing House, New Delhi, 9(1) : 467-476.

Mathewkutty T I, Wahid P A & Tajuddin E 1998. Diagnosis and recommendation integrated system (DRIS) in coconut palm. J. Plant. Crops, 26(1) : 31-40.

Sadanandan A K, Korikanthimath V S & Hamza S 1993. Potassium in soils of cardamom (*Elettaria cardamomum* M.) plantations. In: Potassium for Plantation Crops. Mahatim Singh & Mishra M K (Eds.). Potassium Research Institute of India, Gurgaon, Haryana, p 89-101.

Sadanandan A K, Bharghava B S & Hamza S 1996. Leaf nutrient norms for black pepper (*Piper nigrum* L.) using DRIS. J. Plantn. Crops 24 (Suppl.) : 53-59.

Sumner M E 1977. Use of DRIS system in foliar diagnosis of crops at high yield levels. Commun. Soil Sci. Plant. Anal. 8 : 251-268.

Sumner M E 1979. Interpretation of foliar analysis for diagnostic purposes. Agron. J. 71 : 343-348.

Walsh L M & Benton J D (Eds.) 1973. Soil Testing and Plant Analysis. Soil Sci. Soc. Am., Madison, Wisconsin, USA.

Njallani green gold at cardamom productivity helm with precision farming techniques

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Abstract

Njallani green gold cardamom came into limelight during 1990s from a small grower's cardamom field near Kattappana in Idukki district, Kerala. This characteristic high yielding hybrid cardamom was out of an innovative search of Sri. Sebastian Joseph, Njallaniyil during late 1980s. In the process, planting ottachimban (single tiller) with emerging buds has since been emerged as a precious farming technique to reap higher yields for cardamom. The planting material of this cultivar was later used by many growers, and the success stories of the award winners of cardamom from the Spices Board indicated towards high cardamom productivity and achievable potential for productivity as somewhere near 2.5 - 3.0 tonnes of dry cardamom/ha. Their demonstarations further give us confidence to possibility of improving the present national productivity (125-175 kg/ha) to much higher levels.

Introduction

Cardamom (*Elettaria cardamomum)* is an important spice with domestic consumption as well as export demand from India. It is presently cultivated in Kerala, Karnataka and Tamilnadu in an area of about 70-75 thousand ha. with an annual production of 9,000-10,000 tonnes per year. To recognise and encourage growers to achieve substantial increase in productivity, Spices Board instituted cardamom awards in the year 1994-95. The award consists of one first prize worth Rs. 10,000 and two second prizes each worth Rs. 5,000 to be given with citations and certificates on the basis of productivity attained. The growers for the cardamom award are selected on the basis of claims filed and verified by an expert committee. From 1993-94 to 1999-2000 cardamom seasons, awared winners in Kerala mainly used Njallani Green Gold cardamom suckers as planting materials in preference to releasd cardamom varieties viz. ICRI-1, ICRI-2 and PV1 recommended suitable for cardamom growing tracts in Kerala.

Description of Njallani green gold cardamom

Njallani, now the popular cultivar is a vazhuka type hybrid cardamom characterised with semierect panicles. It is a tall herbaceous perennial with massive subterranean rhizome from which a number of succulent leafy stems (culm) develop. The collar portion of the culms has a charateristic purple colour, which is a distinguishing feature of this cultivar. During the vegetative phase of a mature culm. It produces 3 to 4 vegetative buds and during the reproductive phase equal panicles. Panicles emerging directly from swollen base of the culm are produced throughout the year and lasts for 12 to 18 months which is yet another characteristic feature of this cultivar. The panicles are sturdy to attain a length of about one metre and to bear around 25 racemes and each receme with around 15 capsules in cropping season.

Unlike other cultivars, Njallani is luxurious and robust in growth habit and very promising in yield perfromance. As this cultivar is propagated only vegetatively using single tillers with emerging buds there to as the planting material, the plants would be true to type but for the chances of segregation. Immature capsule shedding is rarely noticed. High percentage of capsule setting averaged around 12 receme is experienced. The size of the capsule is yet another promising feature, as a result, not less than 70% of the cured cardamom are retained in the 7 mm sieve while grading. The capsules have deep green in colour with thick husk.

Vegetative propagation

Cardamom is propagated both by seeds and vegetative means. The seedlings are raised from seeds of selected mother plants with desirable characters in yield and quality parameters. Cardamom being a highly cross pollinated crop, the seedling progeny often exhibits wide variations in vegetative and reproductive propagation for quite long. For vegetative propagation, the traditional practice was to use selected mother plants as a whole or part of it having a minimum of 4-5 mature tillers with adhering younger tillers as the planting material. This kind of propagation was not much encouraged earlier to avoid chances of spreading 'Katte' disease which was prevalent in all the cardamom growing tracts especially in Karnataka in alarming proprtions. The other reasons could be the economic life span of plants propagated through suckers is comparatively shorter, and the availability of elite materials for planting is always limited. Therefore, the farmers used to go in for about one or two year old seedlings raised in beds for planting. Of late, the preference of the growers in Kerala was towards about one year old seedlings raised in polybags, while the planters in Karnataka continued to use seedlings about one year old raised in beds.

Again, during late 1990s, the growers in Idukki district were mostly attracted towards a modified method of vegetative propagation which was proved successful from the holding of Sri. Sebastian Joseph, who came out with a desirable selection of vazhukka cultivar which is now popular as Njallani green gold. To multiply the limited elite material, individual mature suckers with an emerging bud were separated and planted in his field. The result of this method was quite encouraging and within a few years, substantial number of planting materials was made available for the early adapters.

Since the planting material used is single sucker, it is commonly called as 'Ottachimban' in Malayalam vernacular. As this planting practice was first introduced with 'Njallani', the farmers most often use the term 'Ottachimban' as a synonym of Njallani. Nevertheless, the practice of multiplication through Ottachimban would be successful in other cultivars too.

A mature tiller with the emerging sprouts is used as the planting material. The suckers planted in pits should be protected from the disturbance of wind by proper staking and tying, to ensure early and better establishment. But in six months time, it would develop into a clump having 8-10 tillers under proper management. Within an year, the number of tillers would be 15-20 and in another six months it may go up to 35-40. Economic yield could be obtained on completion of two years of planting of the suckers because of fast and robust growth.

Precision farming practices

Large sized pits (90 x 90 x 60 cm) with wider spacing (3 x 3 m, 3.5 x 3.5 m) under thin regulated overhead shade with irrigation facilities (sprinkler/drip/hose watering) are provided. Every plant is to be nursed with day-to-day care. Besides applying cattle manure/ cowdung slurry, neem cake/castor cake/ground nut cake, recommended doses of chemical fertilizers may be needed. Periodical weedings, thrashings, soil application /forking/mulching around the plants are resorted to. There must be monthly plant protection operations especially for controlling thrips. Njallani green gold cardamom cultivar exhibits responses towards high input uses/watering/cultural practices.

Cardamom productivity

The productivity of cardamom of the award winners from the Spices Board who used Njallani green gold cardamom is indicated below compared with national average during the period 1994-95 to 1999-2000 cropping season.

Year	Yield (Kg/ha) Award winners	Yield (Kg/ha) National average
1994-95 (First prize)	1035	113
1995-96 (Second prize)	1650	128
1996-97 (Second prize)	1087	125
1997-98 (First prize)	1925	149
1998-99 (First prize)	1875	135
1999-2000 (First prize)	2475	174

Conclusion

During the past few years, the productivity of cardamom in Kerala especially in Vandanmedu region in Idukki district has gone up remarkably. Towards this, the emergence of Njallani green gold during late 1980s and its multiplication through ottachimban (single tiller) as precision farming technique have played their own roles along with other contributing factors.

Distribution of Photosynthetically Active Radiation (PAR) and performance of ginger under arecanut shade

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Abstract

Ginger cv. Suprabha was grown as intercrop in an adult arecanut plantation (30 years old) at the Agricultural Research Station (Pepper), Sirsi, Karnataka and its performance was compared with those planted under open conditions. Ginger plants grown as intercrop were significantly taller than those under open conditions (pure crop) when measured 200 days after planting and had significantly lower number of functional leaves and tillers per clump. Interception of photosynthetically active radiation (PAR) by ginger was maximum at 110 DAP, both in open conditions (1.088 ly/min) and in the intercrop (0.788 ly/min). Percentage of PAR intercepted by ginger out of total PAR was the lowest at 170 DAP in both open (74.4%) and under arecanut shade (56.41%). Mean duration of ginger crop grown in open conditions was 184.5 days, while it was 198.5 days when grown as intercrop. Per plant yield of ginger under arecanut plantation was significantly higher (154.5 g) when compared to open conditions (118.8 g/plant). Individual rhizomes of ginger grown in arecanut plantation were slightly bigger (4.5 g/rhizome) than the crop grown in open (3.4 g/rhizome). Yield of arecanut was not affected due to intercropping with ginger during the two years study. However, there was slight improvement in the yield of arecanut (3.20 kg *chali*/palm) when compared to monocropping of arecanut (2.59 kg *Chali*/palm).

Key words : arecanut, ginger, intercrop

Abbreviations:

PAR = Photosynthetically Active Radiation,

IST = Indian Standard Time

DAP = Days After Planting,

Q_T = Total PAR at the top of the canopy,

Q_R = Reflected PAR from the crop canopy,

Q_S = PAR at ground level,

Q_I = Intercepted PAR by the crop,

RC =Reflection Coefficient of the crop canopy,

Introduction

The dry matter production is almost proportional to intercepted PAR during vegetative growth of plants (Gallogher & Boscoe 1978). Venation structure and orientation of arecanut leaves permit sizable amount of incoming solar radiation incident on the crown to penetrate underneath. Monteith (1969) considered distribution of radiation within plant community as the most important single element of microclimate.

Rhizomatic spices viz., ginger and turmeric are commonly intercropped in arecanut plantations. Reports of experiments from various locations in India in gen-

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eral indicated that, yield of arecanut is not adversely affected due to intercropping with seasonal crops (Abraham 1974, Singh *et al.* 1982 & Muralidharan 1990). Jayachandran *et al.* (1991) opined that ginger can be grown as intercrop where 25 to 50 per cent shade exists. Profitability of ginger under coconut plantations of Assam is also reported (Sarma *et al.* 1996). The present investigation is carried out to study the distribution of PAR and to assess the performance of ginger as intercrop in arecanut plantation in comparison with that of the sole crop grown in open, under hill zone (*Malnad*) conditions of Karnataka.

Materials and methods

The field trial was carried out at Agricultural Research Station (Pepper), Sirsi, Karanataka during 1994-95 and 1995-96. Ginger cv. Suprabha was grown in the interspace of arecanut plantation (as intercrop) and in open fields as sole crop under similar management conditions. Observations on various components of PAR were recorded at monthly intervals starting from 110 DAP, thrice in a day between 9.00 & 9.30 hr, 12.00 & 12.30 hr and 15.00 & 15.30 hr IST on clear days by use of a digital photometer (Lux meter DX1000). Mean values were worked out and expressed as langly/min. Radiation at the top of the canopy (Q_T) was measured by keeping the sensor in the horizontal position facing upwards. Reflected PAR (Q_R) was measured by keeping the sensor in horizontal position facing the canopy at 60 cm above while PAR at ground level (Q_S) was measured keeping the sensor in horizontal position facing upwards. Intercepted PAR (Q_I) was calculated according to the method suggested by Gallo & Davghtry (1986)

$$Q_I = Q_T - Q_R - Q_S$$

Reflection coefficient (RC) was computed by dividing Q_R with the Q_T.

Growth observations were recorded on ginger from 110 DAP at monthly intervals both under sole cropping and intercropping situations. Crop duration of ginger was calculated based on senescence and drying of foliage. Number of fruit bunches, number of nuts and processed nut yield (Chali) per palm were recorded on arecanut. Student's "t" test was used to know the significance between sole cropping and itercropping for growth and yield attributes.

Results and discussion

Distribution of PAR

The results (Table 1) indicated that, mean interception of PAR was higher in sole cropping than intercropping at all the stages of observations. In sole crop of ginger percentage of PAR intercepted (out of Q_T) decreased from 82.40 per cent at 110 DAP to 78.50 per cent and 74.40 per cent at 140 DAP, respectively. Corresponding values in intercropped ginger was 59.70 per cent, 74.10 percent and 56.41 per cent at 110, 140 and 170 DAP respectively. Mean PAR intercepted was maximum at 110 DAP, both in sole (1.088 ly/min) and in intercropped ginger (0.788 ly/min) while it was the lowest at 140 DAP in sole cropped ginger (0.818 ly/min) and at 170 DAP in intercropped ginger (0.695 ly/min). Performance of ginger as intercrop in arecanut plantation is also reported by Shankar & Swamy (1988). Mean RC values recorded on ginger grown under arecanut shade was lower through out the period of recording (0.074, 0.077 and 0.071 at 110, 140 and 170 DAP, respectively) than the corresponding values recorded in sole cropping situations (0.080, 0.101 and 0.114 at 110, 140 & 170 DAP, respectively). Thus, under reduced light, the interception efficiency of available light is higher due to the reduced canopy reflection. Muralidharan (1980) also observed efficient utilization of available energy by intercrops grown under shade. Howard (1992) mentioned that, mean RC for grain crops and green grasses were between 0.10 to 0.25 and 0.08 to 0.27, respectively.

Performance of ginger and arecanut

Ginger plants grown under arecanut were significantly taller only at 200 DAP, while number of tillers and leaves per clump were significantly higher during entire period of crop growth starting from 110 DAP (Table 2). However, there was no significant difference between intercrop and sole crop of ginger with respect to leaves per tiller except at 110 DAP though plants grown as sole crop recorded slightly higher number throughout. Dry weight of rhizomes was significantly higher under sole cropping when compared to intercropping and the difference came down at 200 DAP though it was significant. Increased plant height due to reduced light is also reported in ginger (Aclane & Quisumbing 1976, Jaswal *et al.* 1973). Reduction in number of tillers produced by plants grown under shade is also reported by Singh (1973) in cereals. Reduced dry weight of

Table 1. Mean PAR distribution/interception on ginger in open and as intercrop with arecanut .

Stage of crop (days after planting	Time (hrs)	Open crop/sole crop (PAR ly./min)					As intercrop with arecanut (PAR ly./min)					Intercepted PAR (% of Q_T open)	
		Q_T	Q_R	Q_S	Q_I	RC (Q_R/Q_T)	Q_T*	Q_R	Q_S	Q_I	RC (Q_R/Q_T)	SC	IC
	9.0 to 9.30	1.225	0.098	0.104	1.023	0.080	0.870	0.072	0.081	0.717	0.083	83.5	58.5
110	12.0 to 12.30	1.688	0.131	0.146	1.411	0.077	1.389	0.104	0.133	1.152	0.075	83.6	68.3
	15.0 to 15.30	1.049	0.090	0.132	0.827	0.085	0.616	0.038	0.084	0.494	0.062	78.8	47.6
	Mean	1.321	0.106	0.127	1.088	0.080	0.958	0.071	0.099	0.788	0.074	82.4	59.7
	9.0 to 9.30	0.813	0.083	0.103	0.627	0.102	0.762	0.070	0.111	0.581	0.092	77.1	71.5
140	12.0 to 12.30	1.314	0.134	0.143	1.037	0.102	1.222	0.094	0.163	0.965	0.078	78.9	73.4
	15.0 to 15.30	1.000	0.098	0.110	0.792	0.098	0.963	0.064	0.128	0.771	0.066	79.2	77.1
	Mean	1.042	0.105	0.119	0.818	0.101	0.982	0.076	0.134	0.772	0.077	78.5	74.1
	9.0 to 9.30	1.126	0.134	0.174	0.818	0.119	0.643	0.039	0.103	0.501	0.062	72.7	44.5
170	12.0 to 12.30	1.544	0.162	0.154	1.228	0.105	1.254	0.096	0.145	1.013	0.076	79.5	71.4
	15.0 to 15.30	1.026	0.124	0.198	0.704	0.121	0.673	0.047	0.054	0.572	0.070	68.6	55.8
	Mean	1.232	0.140	0.175	0.917	0.114	0.857	0.061	0.101	0.695	0.071	74.4	56.41

* Under normal light
IC = Intercrop
SC = Sole crop

Q_T = Total PAR on the top of the canopy
Q_R = Reflected PAR from the crop canopy
Q_S = PAR at ground level

Q_I = Intercepted PAR by the crop.
R_C = Reflection Coefficient of the crop

Table 2. Growth and development of ginger as intercrop in arecanut and as sole crop in open.

Growth characters	110 DAP			140 DAP			170 DAP			200 DAP		
	IC	SC	T(5%)	IC	SC	T(5%)	IC	SC	T(5%)	IC	SC	T(5%)
Plant height (cm)	34.50 (±1.73)	37.80 (±2.20)	1.89	36.30 (±2.50)	39.00 (±3.43)	0.91	39.50 (±1.45)	36.70 (±2.38)	0.78	40.70 (±2.91)	25.70 (±2.72)	2.91*
Functional tillers (No./clump)	7.13 (±0.56)	9.80 (±0.36)	3.11*	10.40 (±0.83)	15.90 (±1.00)	3.27*	10.80 (±0.97)	16.80 (±1.67)	2.39*	3.10 (±0.77)	8.40 (±1.38)	2.60*
Functional leaves (No./clump)	35.40 (±4.12)	80.20 (±7.93)	3.90*	98.60 (±8.55)	160.60 (±17.0)	2.52*	102.50 (±8.34)	175.0 (±10.6)	4.16*	13.80 (±1.80)	44.30 (±5.14)	4.34*
Leaves (No./tiller)	4.96 (±0.86)	8.10 (±1.02)	5.61*	9.49 (±0.72)	10.10 (±0.74)	1.64	9.50 (±1.23)	10.40 (±1.50)	1.14	4.40 (±0.89)	5.30 (±0.82)	1.29
Dry weight of rhizomes (g/plant)	—	—	—	4.60 (±0.54)	9.10 (±0.86	10.71*	5.10 (±0.73)	9.50 (±1.03)	9.42*	13.90 (±1.42)	16.30 (±1.68)	2.69*
Total dry weight (g/plant)	6.80 (±0.85)	13.80 (±1.94)	7.87*	15.20 (±1.42)	25.90 (±3.16)	7.59	—	—	—	—	—	—

Figures in parenthesis indicates deviations (±) from mean values.
* Significant at 5 % probability between intercrops (IC) and sole crops(SC)

Table 3. Performance of ginger and arecanut under intercropping and sole cropping situations.

Particulars	1994-95		1995-96		Mean		"T"
	IC	SC	IC	SC	IC	SC	value
I. Ginger							
Crop duration (Days)	207	189	190	180	198.5	184.5	——
Fresh yield (g/plant)	164.5	122.3	144.5	115.2	154.5 (±13.43)	118.8 (±6.78)	5.81*
Projected yield (t/ha) ++	6.58	12.23	5.78	11.52	6.18	11.88	——
III. Arecanut							
Fruit bunches/palm	2.53	2.43	2.86	2.67	2.70 (±0.13)	2.55 (±0.14)	1.97
Number of nuts/palm	490.5	400.1	516.2	437.2	503.35 (±34.35)	418.65 (±32.12)	1.39
Processed nut yield (i.e Chali kg/palm)	3.06	2.40	3.33	2.78	3.20 (±0.57)	2.59 (±0.53)	1.91

++ Ginger as intercrop, occupied in 40 per cent area of arecanut plantation.
* Significant at 5 % probability for mean values between intercrops (IC) and sole crops (SC).
Figures in parenthesis indicates deviations (±) from mean values.

rhizomes of ginger grown under arecanut shade, particularly during initial stages of rhizome initiation may be due to delayed rhizome initiation under reduced light.

Ginger crop grown under arecanut shade delayed in attainment of maturity and in showing symptoms of senescence resulting in increased mean crop duration by 14 days (Table 3). Oswald *et al.* (1994) reported delay in tuber initiation in sweet potato under shaded situation. Mean per plant yield of fresh rhizomes was significantly higher under arecanut shade (154.5 g/plant) when compared to ginger grown as sole crop (118.8 g/plant). Increased per plant yield of ginger under intercropping situations may be attributed to increased crop duration and it also indicates better performance of ginger under partial shade. Higher yield of ginger under partial shade (25 to 50%) was also reported by Aclane & Quisumbing (1976) and Jayachandran *et al.* (1991).

Yield observations recorded on arecanut indicated that, there is slight increase in mean number of nuts per palm and mean processed yield (i.e., *chali* kg/palm) due to intercropping with ginger successively for two years than in sole cropping though the difference was not significant. Studies reported by Abraham (1974) and Muralidharan (1990) also supported that intercropping in arecanut plantation is not harmful to the main crop.

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References

Abraham K J 1974. Intercropping in arecanut to build up farmer's economy. Arecanut & Spices Bull. 5 : 73-75.

Aclane F & Quisumbing E C 1976. Fertilizer requirement, mulch and light attenuation on yield and quality of ginger. Philippine Agric. 60 : 183-191.

Gallo K P & Davghtry C S T 1986. Technique for measuring intercepted and absorbed Photosynthetically Active Radiation in corn canopies. Agron. J. 78 : 752-756.

Gallogher T N & Biscoe P V 1978. Radiation absorption growth and yield of cereals. J. Agric. Sci. Cambridge. 91 : 47-60.

Howard J C 1992. General Climatology (4th Ed). Prentice Hall of India Private Limited, New Delhi.

Jaswal S C, Mishra V K & Verma K S 1993. Intercropping ginger and turmeric with popular (*Populus deltoides*). Agroforestry Syst. 22 : 111-117.

Jayachandran B K, Bai M M, Salam M A, Mammen M K & Mathew K P 1991. Performance of ginger under shade and open conditions. Indian Cocoa Arecanut Spices J. 15 : 40-41.

Monteith J L 1969. Light interception and radiative exchange in crop stands. In: Physiological Aspects of Crop Yield (pp. 271-292) (J D Eastin Eds.). American Society of Agronomy and Crop Science Society of America, Madison, Wisconsia.

Muralidharan A 1980. Biomass Productivity, Plant Interaction on Economics of Intercropping in Arecanut. Ph.D. Thesis. University of Agricultural Sciences, Bangalore.

Muralidharan A 1990. Intercropping in arecanut. J. Plantation Crops 17 : 25-28.

Oswald A, Alkamper J & Midmore D J 1994. The effect of different shade levels on growth and tuber yield of sweet potato. I Plant development. J. Agron. Crop Sci. 173 : 41-52.

Sarma R, Prasad S, Mohan N K & Medhi G 1996. Economic feasibility of growing some root and tuber crops under intercropping system in coconut garden. Hort. J. 9 : 167-170.

Shankar C R & Swamy M S 1988. Influence of light and temperature on leaf area index, chlorophyll content and yield of ginger. J. Maharastra Agric. Univ. 13 : 216-217.

Singh P M 1973. Effect of different levels of light intensity on vegetative growth of rice under controlled environment. Rice. 22 : 97-103.

Singh R K, Yadukumar N, Roy B K N & Roy A C 1982. Intercropping in areca gardens in North Bengal. Indian Fmg. 32 : 13-15.

Standardization of planting material with reference to the stages of sprouting in turmeric (*Curcuma longa* L.)

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Abstract

The study revealed that 14 days old sprouted rhizomes produced more vigorous growth than other treatment. The plant height, number of leaves per plant, leaf area, leaf area index and number of tillers per plant were significantly highest in the plants raised from 14 days old sprouted rhizomes. With regard to crop duration, the plants raised from 35 days old sprouted rhizomes matured 38 days earlier than the unsprouted rhizomes (control). Among the yield components, the number, length, fresh weight and dry weight of mother, primary and secondary rhizomes were significantly higher from 14 days old sprouted rhizomes as planting materials than the control. The 14 days old sprouted rhizomes also produced 27% more fresh rhizomes per hectare (40,133 kg) as compared to 31,508 kg in the control. There was no significant difference between the various planting materials in respect of curing percentage and curcumin content. But oleoresin and oil content were higher in the rhizomes developed from 7 and 28 days old sprouted rhizomes. However the estimated curcumin, oleoresin, and oil yield per hectare were highest in the rhizomes developed from the 14 days old sprouted rhizomes.

Key words: *Curcuma longa* L., curcumin, turmeric, yield.

Introduction

Turmeric is commonly propagated by rhizomes selected from the harvested crop. The type of rhizomes used for planting varies from region to region. In Andhra Pradesh, planting of mother rhizome is mostly preferred while the fingers are used for planting in Tamil Nadu. The information on the use of sprouted rhizomes needs to be standardized based on their growth and development, which will give an insight on the qualitative and quantitative yield of turmeric. The nature of morphological, physiological and quality changes in relation to the stage of sprouted planting material needs an intensive study. There is also need to manipulate the sowing practices to overcome the problem posed by water scarcity during the month of May when turmeric is usually planted. Hence a study on the sprouted planting material was under taken.

Materials and methods

The field experiment was carried out during the year 1997-98 to study the effect of different stages of planting material with respect to sprouting on growth, yield and quality parameters of turmeric at the college orchard, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The seed rhizomes of turmeric variety BSR-2 was collected from the Agricultural Research Station, Bhavanisagar. The experiment was laid out in Randomised Block Design and replicated four times.

Treatments

Uniform sized (15-20 g) primary rhizomes were selected and kept in nursery bed. Then they were covered with moist sand to induce sprouting at different days interval for each treatment except the control (T1). When the rhizomes start sprouting, the number of days were noted for each treatment. The seed rhizomes were sown in plots of size 1.8 x 1.35 m with a spacing of 45 x 20 cm.

T1 - Unsprouted primary rhizomes (Control)

T2 - 7 days old sprouted primary rhizomes

T3 - 14 days old sprouted primary rhizomes

T4 - 21 days old sprouted primary rhizomes

T5 - 28 days old sprouted primary rhizomes

T6 - 35 days old sprouted primary rhizomes

Observations on morphological, yield and quality characters were made and statistically analyzed (Panse & Sukhatme 1961).

Results and discussion

Plants grown from 14 days old sprouted rhizomes exhibited better growth as adjudged from plant height and number of leaves per plant compared to unsprouted rhizomes (Table 1). Plants raised from 14 days old sprouted rhizomes recorded encouraging plant height (110.85 cm) as against 85.79 cm in unsprouted rhizomes at 180 DAP. The same treatment had also recorded the highest number of leaves per plant (34.46) compared to other planting materials. The effect of 14 days old sprouted rhizomes was more pronounced in respect of leaf length and breadth at all the stages of observation. The increase in the plant height, number of leaves per clump may be attributed to the fact that more food material is made available during early growth period of the crop in 14 days old sprouted rhizomes. This is because of non disturbance of root system in seedling stage compared to 35 days old sprouted rhizomes in which root growth was more, so roots get disturbed at the time of planting.

The mean leaf length and breadth were maximum in the plants raised from 14 days old sprouted rhizomes while they were low in the plants raised from 35 days old sprouted rhizomes (Fig.1). The effect of different planting materials on leaf area was significant at all the stages of crop growth. The leaf area was highest (488.79 cm^2) in the plants grown from 14 days old sprouted rhizomes as compared to the leaf area (329.66 cm^2) in unsprouted rhizomes. A similar trend was observed in respect of leaf area index also. The maximum leaf area index (18.72) was observed in the plants which were grown from 14 days old sprouted rhizomes, as compared to control (9.44).

There was a significant difference between the various planting materials in respect of number of tillers per clump at all the stages of observation. At 240 DAP, 14 days old sprouted rhizomes produced the maximum (6.98) number of tillers as compared to 5.9 tillers per clump in control.

There was pronounced reduction in the crop duration due to the use of 35 days old sprouted rhizomes as planting materials. It recorded the lowest crop duration of 248 days as compared to the control (285). It is evident from this study, the crop duration can be reduced upto 38 days by using the 35 days old sprouted rhizomes for planting compared to unsprouted rhizomes. The reason for the reduced crop duration of 38 days may be the plants raised from 35 days old sprouted rhizome had already under gone the 35 days growth in nursery. Sinha (1969) also noted the sprouting potato seed tubers before planting accelerates maturity and the crop can be harvested a fortnight earlier than those

Table 1. Effect of planting materials on morphological characters of turmeric.

Treatment	Plant height (cm)	Number of leaves/clump	LAI	Tillers per clump	Crop duration	Crop stand
T1	85.79	25.76	9.44	4.46	285.75	89.83
T2	86.60	27.98	11.86	4.42	275.25	96.80
T3	110.85	34.46	18.72	5.15	268.00	96.13
T4	83.89	23.58	7.81	3.7	261.25	81.85
T5	71.4	18.63	5.48	3.38	255.25	71.48
T6	62.51	17.20	4.24	2.7	248.25	70.11
SE ±	1.59	0.77	0.42	0.17	1.18	1.69
CD at 5%	3.38	1.63	0.89	0.35	2.51	3.59

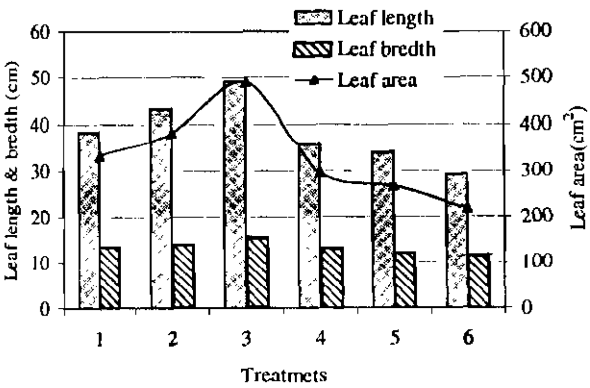

Fig. 1. Effect of presprouting on leaf area

grown from unsprouted tubers in potato. Similar findings were also reported by Hidalgo and Rojas (1986) and Johannes (1998) in potato. The crop stand also was higher (96.13%) in 14 days old sprouted rhizomes as compared to 89.83% in control at 90 DAP.

Much pronounced effects were obtained through the use of different planting materials on the number of mother, primary and secondary rhizomes per clump. The number of mother, primary and secondary rhizomes were high (5.54, 15.93 and 28.07, respectively) in the plants grown from 14 days old sprouted rhizomes as compared to control (3.85, 13.31 and 21.30, respectively).

There was a significant improvement in the fresh and dry weights of mother, primary and secondary rhizomes due to the use of 14 days old sprouted rhizomes as planting materials than the unsprouted rhizomes (control). Plants grown from 14 days old sprouted rhizomes produced the highest fresh weight of mother, primary and secondary rhizomes (126.83, 261.02 and 201.02 g, respectively) per clump as compared to the control (93.07, 222.48 and 161.85 g, respectively). A similar trend was observed in respect of dry weight of rhizomes also (Table 2).

The estimated fresh rhizome yield per ha also recorded maximum in the 14 days old sprouted rhizomes treatment (40133.28 kg) while it was 31508.28 kg in the control. The lowest rhizome yield per plot in the plants grown from 28 and 35 days old sprouted rhizomes was due to the poor crop stand resulting from the set-back of seedlings during transplanting on the respective days after sprouting.

There was no significant variation in respect of curing percentage between the various planting materials. However, rhizomes developed from 28 days old sprouted rhizomes recorded the highest curing percentage of 17.1%. Whereas, 14 days old sprouted rhizomes produced 7936 kg the cured rhizome yield per ha, as compared to 6419 kg in control.

Table 2. Effect of planting materials on yield characters of turmeric.

Treatment	Number of rhizomes in			Mother rhizome		Primary rhizome		Secondary rhizome		Estimated rhizome yield/ha	Curing percent
	Mother rhizome	Primary rhizome	Secondary rhizome	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight		
T1	3.85	13.31	21.30	93.07	16.09	222.48	37.52	161.85	26.77	31508.28	16.78
T2	4.26	14.18	23.20	98.40	17.03	234.85	40.06	175.30	29.23	34741.65	16.95
T3	5.54	15.93	28.07	126.83	21.59	261.02	44.229	201.02	33.32	40133.28	16.86
T4	3.99	12.58	20.26	92.68	16.01	214.80	37.64	164.23	27.34	25583.30	17.02
T5	3.63	12.08	16.56	68.88	12.01	149.97	25.87	111.02	20.95	21666.63	17.10
T6	3.00	11.58	15.59	52.78	9.13	120.60	20.52	95.10	15.78	18166.63	16.95
SE±	0.17	0.34	0.81	2.13	0.37	3.87	0.90	3.59	1.71	682.31	-
CD at 5%	0.37	0.72	1.73	4.53	0.79	8.26	1.92	7.65	3.66	1454.32	NS

Table 3. Effect of planting materials on quality characters of turmeric.

Treatment	Curcumin content	Oleoresin content	Essential oil content
T1	3.38	7.10	1.86
T2	3.34	7.68	1.89
T3	3.30	7.46	1.84
T4	3.37	7.13	2.04
T5	3.32	7.07	2.20
T6	3.37	6.97	2.11
SE ±	0.03	0.06	0.05
CD at 5%	NS	0.14	0.11

In quality aspects, there was no significant difference between the treatments in curcumin content (Table 3). Philip (1983) reported similar findings and he observed no significant variation among the planting materials with regard to the curcumin content. Rhizomes developed from 7 and 28 days old sprouted rhizomes contained higher oleoresin (7.68%) and oil (2.19%), respectively.

References

Anonymous 1968. American Spice Trade Association, Official analytical methods, 3rd edn. pp. 9-10.

Anonymous 1994. Crop production guide. Department of Horticulture and Plantation crops. Tamil Nadu. pp. 97-99.

Johannes G 1998. Prolonged presprouting. Practical trials on the preparation of seed tubers for the production of easly culinary potatoes. Institute *fur Kartoffelforschung*: 57-62.

Hidalgo O and J S Rojas 1986. Performance of whole and cut Pre sprouted seed (cv. Kennabec) used as planting material in the South Chile (Abstract). American Potato J. 63(8) : 432.

Panse VG and Sukhatme PV 1985 Statistical methods for agricultural workers. 4th ed. Indian Council of Agricultural Research, New Delhi.

Philip J 1983. Effect of different planting materials of growth, yield and quality of turmeric. Indian Cocoa, Arecanut, Spices J. 7(1) : 8-11.

Sinha M N 1969 Sprouting of seed potatoes and its significance in the production of the potato crop. Indian J. Agron. 14(1) : 71-77.

Effect of potassium fertigation on growth and yield of chilli under moisture stress conditions

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Abstract

Field experiment was conducted at Agronomy division, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore during *rabi* seasons of 1996-97 and 1997-98 to study the effect of K levels in inducing stress tolerance through different methods of fertigation in chilli. In general, irrigation given at 0.8 cumulative pan evaporation recorded significantly higher plant height, number of branches, leaf area index, leaf area duration and total dry matter during both the years. Yield and yield components followed the same trend. Fertilizer application methods had no significant influence either on growth or on yield parameters. Application of 150 per cent recommended potassium level producrd significantly higher total dry matter and dry fruit yield during both the years.

Key words: CPE, fertigation, potassium

Abbreviations:

CPE = Cumulative pan evaporation
LAI = Leaf area index
TDM = Total dry matter

Introduction

Though India stands first in area and production of chilli in the world, productivity is considerably low (Anon 1996). This low productivity in India and particularly in Karnataka is because chilli (for dry fruit) is grown mostly under rainfed conditions with uncertain soil moisture regimes. Hence, this limited supply of water necessitates a shift in the production objective from attaining potential yield $unit^{-1}$ of land to potential yield $unit^{-1}$ of water. Besides this objective, it is interesting to study the response of potassic fertilizers at rates above the normal to overcome the effect of moisture stress. Further, to increase the expense efficiency of both applied scarce water and costly nutrients, fertilizer application methods have also been studied under conventional furrow irrigation method. Considering the above facts, the present investigation was undertaken to assess the effect of irrigation and potassium levels under moisture stress conditions and fertigation on growth and yield of chilli.

Materials and methods

Field experiments were conducted at Regional Research Station, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bangalore to study the effect of potassium levels under moisture stress conditions in inducing stress tolerance through different methods of fertigation in chilli (*Capsicum annuum* L.) during *rabi* seasons of 1996-97 and 1997-98. The soil of the experimental site was red sandy loam with pH of 5.8 having low N (187.25 kg ha^{-1}), medium P_2O_5 (32.30 kg ha^{-1}) and K_2O (223.75 kg ha^{-1}) content. There were 12 treatment combinations laid out in factorial RCBD with three replications consisting of three irrigation levels (0.4, 0.6 and 0.8 CPE), two methods of fertilizer application (fertigation and conventional soil application of fertilizers) and two potassium levels (125% and 150% of recommended K_2O). Irrigation was scheduled at seven days interval according to the treatments after twenty days of transplanting. Cumulative pan evaporation (CPE) was worked out for seven days and was replenished according to the treatments. Measured quantity of water by using water meter of 2 inch size was conveyed through polythene lined main channel which had two buffer channels on either side of it to avoid lateral movement of water. Regarding fertilizer application methods, all the NPK fertilizers were applied to the soil as per the farmer's practice in one of the treatments. While in another treatment (fertigation) solutions of NPK fertilizers were applied to the irrigation water at the entry point of the irrigation channel to each of the plot at four equal splits viz., at the time of transplanting and 4, 8 and 12 weeks after transplanting. In both the treatments urea, single super phosphate and muriate of potash were used as source of N, P_2O_5 and K_2O respectively. The crop took a total duration of 180 days and was grown for its dry fruits. Ripened fruits were harvested in five different pickings and at the end total fruit yield ha^{-1} was computed. The experimental data was statistically analysed as per the procedure of Cochran & Cox (1965). Only pooled data is considered while discussing the results.

Results and discussion

Irrigation levels, significantly influenced dry fruit yield of chilli (Table 1). Weekly irrigation given at 0.8 times open pan evaporation registered maximum dry fruit yield (1328.57 kg ha^{-1}) (Table 2). This treatment was significantly superior to treatments receiving weekly irrigation at 0.6 (1244.51 kg ha^{-1}) and 0.4 (867.67 kg ha^{-1}) times cumulative pan evaporation. The main reason for better yield at higher levels of irrigation was improved soil moisture status, which always remained at the sufficiency range throughout the crop growth period. The results concur the findings of Ferreyra *et al.* (1985). The lowest fruit yield at 0.5 CPE may be attributed to more crop stress as it was evidenced by the lower soil moisture profile which showed that available water content was below 50 per cent throughout the crop growth stages. Because of this reason crop was heavily penalized which did curtail the productivity. Similar results were also observed with seed yield. Weekly irrigation given at 0.8 CPE recorded 38.38 and 12.99 per cent higher seed yield ha^{-1} over 0.4 and 0.6 CPE respectively.

Increase in total dry matter (TDM) production unit^{-1} area is a first step towards achieving higher yield. Hence, increase in the yield in the present study can also be related to the improvement in dry matter production. Improvement in the dry fruit yield ha^{-1} at 0.8 CPE may be related to higher dry matter production (37.09 g) and its major distribution in fruits (18.90 g) at grand growth period (120 DAT). The reduced TDM (21.96 g) in stressed treatment at 0.4 CPE caused a reduction in fruit yield. This reduction was consistent with a more limited water consumption. These results are in conformity with the findings of Hegde (1988) and Bandi (1994).

Further, the increase in yield and TDM production of chilli may also be related to improvement in growth parameters such as leaf area (1333.61 cm^2) and LAI (0.49) which are the indicators of active photosynthetic area when weekly irrigation was provided at 0.8 CPE. The improvement in these growth indices might be attributed to higher soil moisture status which enhanced the vegetative characters like number of primary branches (8.58 $plant^{-1}$) and plant height (65.25 cm).

Fertilizer application methods significantly influenced the dry fruit yield of chilli in the pooled analysis though there was a non significant difference between individual years (Table 2). Application of fertilizers through irrigation water i.e. fertigation registered maximum dry fruit yield (1161.16 kg ha^{-1}) which was significantly superior to soil application of fertilizers i.e., conventional method (1132.66 kg ha^{-1}). The increase in dry fruit yield was a reflection of fairly even distribution of applied nutrients within the soil profile down to the bottom of the plough layer and along the field in the direction of flow. These results are in agreement with the findings of Charles Black (1992). Economic yield is a part of the total biological yield of the crop. Hence, total dry matter production $plant^{-1}$ influenced the fruit yield. Generally there was slight improvement in the TDM $plant^{-1}$ with fertigation. Fertigation resulted in slightly higher TDM $plant^{-1}$ (30.67 g) besides, major portion of TDM was accumulated in fruits (16.29 g) which inturn make up the fruit yield ha^{-1}. The relatively lower TDM $plant^{-1}$ and its partitioning to fruits under soil application of fertilizers may be due to reduced availability of the nutrients and their uptake at later stages of crop growth as it received fertilizers only in two splits.

Further, the improvement in yield and TDM production can also be related to the influence of fertigation on growth parameters. Increased plant height (57.06 cm), number of primary branches (8.09 g), leaf area (1032.24 cm^2) $plant^{-1}$ and LAI (0.38) helped in the improved assimilation and translocation of photosynthates to growing fruits. Similar results were reported by Muirhead *et al.* (1985).

Application of 150 per cent recommended K_2O recorded significantly higher dry fruit (1176.51 kg ha^{-1}) and seed (371.87 kg ha^{-1}) yield ha^{-1}. Linear increase in the fruit yield with increase in potassium levels is in accordance with the general trend obtained elsewhere. The increased fruit yield can be related to the improvement in the TDM

Table 1. Growth traits of chilli as influenced by irrigation levels, methods of fertilizer application and potassium levels.

Treatment	Plant height (cm)			Number of primary branches plant^{-1}			Leaf area (cm^2)			LAI		
	1996-97	1997-98	Pooled	1996-97	1997-98	Pooled	1996-97	1997-98	Pooled	1996 97	1997-98	Pooled
Irrigation level (I)												
I1 : 0.4 CPE	39.81	34.65	37.23	5.00	4.82	4.76	543.50	715.84	629.67	0.20	0.27	0.23
I2: 0.6 CPE	58.97	57.96	58.46	7.15	7.87	7.51	1059.63	1154.03	1106.83	0.39	0.43	0.41
I3: 0.8 CPE	65.21	65.26	65.23	8.21	8.95	8.58	1128.37	1538.86	1333.61	0.42	0.57	0.49
SEm±	1.705	1.833	1.378	0.309	0.490	0.286	36.597	23.620	20.954	0.014	0.009	0.008
CD at 5%	5.002	5.337	4.041	0.905	1.437	0.840	107.326	69.268	61.452	0.040	0.026	0.023
Fertilizer application method (M)												
M1: Fertigation	49.86	47.69	48.78	6.32	6.38	6.35	795.77	1004.86	900.32	0.30	0.37	0.33
M2: Conventional method	59.47	57.55	58.51	7.25	7.84	7.55	1025.22	1267.62	1146.42	0.38	0.47	0.42
SEm±	1.393	1.497	1.125	0.252	0.400	0.234	29.881	19.285	17.109	0.011	0.007	0.006
CD at 5%	4.084	4.390	3.299	0.739	1.173	0.686	87.631	56.557	50.175	0.032	0.21	0.009
Potassium level (K)												
K1: 125% rec. K2O	56.21	54.17	55.19	6.88	7.27	7.08	915.41	1149.07	1032.24	0.34	0.43	0.38
K2: 150% rec. K2O	53.11	57.08	52.09	6.69	6.96	6.82	905.58	1123.42	1014.58	0.33	0.42	0.37
SEm±	1.393	1.497	1.125	0.252	0.400	0.234	29.881	19.285	17.109	0.011	0.007	0.003
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.009

NS = Non significant

Table 2. Fruit dry weight, total dry matter and fruit and seed yield of chilli as influenced by irrigation levels, methods of fertilizer application and potassium levels.

Treatments	Fruit dry weight			Total dry matter (g)			Dry fruit yield (kg ha^{-1})			Seed yield (kg ha^{-1})		
	1996-97	1997-98	Pooled	1996-97	1997-98	Pooled	1996-97	1997-98	Pooled	1996 97	1997-98	Pooled
Irrigation level (I)												
I1 : 0.4 CPE	13.25	11.91	12.58	22.94	20.98	21.96	822.00	913.27	867.64	240.29	265.92	256.11
I2: 0.6 CPE	16.67	16.87	16.62	31.22	32.45	31.84	1186.06	1302.96	1244.51	363.06	360.18	361.62
I3: 0.8 CPE	17.91	19.89	18.90	34.87	39.31	37.09	1296.11	1361.02	1328.57	407.68	423.58	415.63
SEm±	0.453	0.342	0.271	0.495	0.403	0.375	15.664	17.543	10.516	7.631	6.605	4.888
CD at 5%	1.327	1.004	0.794	1.451	1.183	1.098	45.937	51.449	30.840	22.378	19.370	14.336
Fertilizer application method (M)												
M1: Fertigation	14.86	14.47	14.67	27.51	27.94	27.73	1072.04	1162.56	1117.30	310.92	323.15	317.3
M2: Conventional method	17.02	17.77	17.40	31.84	33.88	32.86	1130.75	1222.28	1176.51	367.10	376.65	371.87
SEm±	0.369	0.279	0.221	0.404	0.329	0.306	12.790	14.324	8.586	6.230	5.393	3.951
CD at 5%	1.084	0.819	0.648	1.185	0.966	37.507	42.008	25.181	18.272	15.816	11.705	11.705
Potassium level (K)												
K1: 125% rec. K2O	16.21	16.37	16.29	29.99	31.36	30.67	1116.39	1205.93	1161.16	342.92	356.23	349.58
K2: 150% rec. K2O	15.67	15.87	15.77	29.36	30.47	29.91	1086.40	1178.91	1132.66	335.10	343.56	339.33
SEm±	0.369	0.279	0.221	0.404	0.329	0.306	12.790	14.324	8.586	6.230	5.393	3.991
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	25.181	NS	NS	NS

NS = Non significant

Table 3. Interaction effect of irrigation and potassium levels on total dry matter and dry fruit yield of chilli

Irrigation level (I)	Total dry matter (g)			Dry fruit yield (kg ha^{-1})		
	K_1	K_2	Mean	K_1	K_2	Mean
I1: 0.4 CPE	18.77	25.15	21.96	827.70	906.58	867.64
I2: 0.6 CPE	29.24	34.43	31.84	1204.28	1284.74	1244.51
I3: 0.8 CPE	35.17	39.01	37.09	1318.93	1338.21	1328.57
Mean	27.73	32.86		1117.30	1176.51	
	F.test	S.Em±	CD at 5%	F.test	S.Em±	CD at 5%
	*	0.530	1.553	*	19.362	56.615

K_1 = 125% rec. K_2O K_2 = 150% rec. K_2O

production $plant^{-1}$ (32.86 g) and its major distribution in the fruits (17.40 g) as potassium is involved in the fruit development and its size (Shahid Umar & Bansal, 1997). The improvement in the yield and TDM $plant^{-1}$ due to the application of 150 per cent recommended K_2O can further be related to significantly higher leaf area $plant^{-1}$ (1146.42 cm^2), LAI (0.38), plant height (58.51 cm) and number of primary branches (7.55 $plant^{-1}$).

Interaction effect of irrigation and potassium levels showed significant effect on dry fruit yield ha^{-1} and TDM $plant^{-1}$ (Table 3). Irrigation at 0.8 CPE with application of 150 per cent recommended K_2O recorded significantly higher dry fruit yield (1338.21 kg ha^{-1}) than the rest of the combinations but was on par with irrigation at 0.8 CPE with 125 per cent recommended K_2O and irrigation at 0.6 CPE with 150 per cent recommended K_2O. Even under severe moisture stress (0.4 CPE) application of 150 per cent recommended K_2O recorded significantly higher dry fruit yield (906.58 kg ha^{-1}) over 125 per cent (827.70 kg ha^{-1}). Similar trend was also noticed with TDM $plant^{-1}$. Potassium is a major osmo-regulatory agent in the cell vacuole. Hence, under moisture stress conditions, it lowers the osmotic potential and increases the solute concentration in response to water deficit which helps in extracting more water from the soil. The results are in agreement with the findings of Shahid Umar & Bansal (1997).

To conclude, weekly irrigation given to replenish 80 per cent CPE was beneficial under situations of adequate water availability. Whereas, under scarce water conditions (0.4 CPE), application of 150 per cent recommended K_2O produced higher yields. Even under conventional method of irrigation, application of fertilizers through irrigation water results in better yield compared to conventional soil application of fertilizers.

References

Anonymous 1996. Agril. Situation in India 46 : 767-772.

Bandi A G 1994. Effect of moisture stress on growth and yield of chilli under furrow and drip irrigation methods. Ph.D thesis submitted to University of Agril.Sciences, Bangalore.

Charles A Black 1992. Soil Fertility Evaluation and Control. Elsiever Publication Germany.

Cochran N G & Cox G M 1965. Experimental Designs, Asia Publishing House Bombay 2nd Edn. p.168-169.

Ferreyra K R, Selliesvao S G & Tosso J J 1985. Effect of different water levels on pepper-1: Influence of excess humidity. Irrigation Drainage abstr. 1267.

Hegde D M 1988. Irrigation and nitrogen requirement of bell pepper. Indian J.Agril.Sci. 58(9) : 668-672.

Muirhead M A, Melhuish F M & White R J G 1985. Comparison of several nitrogen fertilizers applied in surface irrigation systems: Crop response. Fert.Res. 6(2) : 97-109.

Shahid Umar & Bansal S K 1997. Effect of potassium application on yield and quality of water stressed groundnut. Fert. News 42(10) : 27-29.

Effect of soil solarization on chillies (*Capsicum annuum* L.)

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Abstract

Soil solarization is a hydrothermal disinfestation method based on covering the water saturated soil with transparent polyethylene sheet and thus increasing the soil temperature by solar energy. From the studies undertaken in the Cauvery delta region of Tamil Nadu during 1995 to 1997, it was found that there was an increase in soil temperature upto 10°C due to solarization. The use of 0.05 mm thick polyethylene sheet raised the temperature upto 3°C higher than 0.10 mm thick sheet. Solarization for 40 days produced desirable results. In all the four cultivars of chillies viz., G 4, K 2, CA 235 and Pusa Jwala which were sown in the nursery beds solarized for 15 days, there was enhanced germination, growth and vigour of the seedlings. Solarization of main field also resulted in better crop performance by recording higher yield with better expression of component characters in all the cultivars. Besides increased growth response, other beneficial effects of solarization as investigated were suppression of weed growth and reduction in fungal population in the solarized fields.

Key words: *Capsicum annuum* L., chillies, polyethylene covering, soil solarization, solar tarping

Introduction

Soil solarization is a technique of land preparation before planting and has claimed to be an integrated method of improving plant growth and yield. It is a process of hydro-thermal disinfestation accomplished by covering moist soil with transparent polyethylene film during hot weather period. This technique is adaptable in the productive areas of tropical belt of Tamil Nadu. In the agro climatic zone of Cauvery delta region where intense summer with bright sunshine is experienced for one or two months, effectiveness of the technique was tested to learn the response of chilli cultivars to the solarization treatment. A number of studies from different parts of the world had evinced interest in experimenting this technique on a variety of horticultural crops like bhendi (Bawazir *et al.* 1995), onion (Adetunji 1994), coriander (Herrera & Ramirez 1996) and lime (Stapleton & Garza- Lopez 1988).

Materials and methods

During January 1995, two nursery beds of 1 m width, 3m length and 15cm height were formed. One bed was irrigated and solarized with 0.05 mm thick transparent polyethylene sheet for 15 days. The other bed was maintained as non-solarized control. At the end of treatment period, the tarp was removed and lines were drawn across the beds at a spacing of 5 cm. Seeds of chillies cv. K 2 were sown sparsely along the lines drawn and were watered using rose can. Germination and growth of seedlings were monitored until transplantation. The difference in the performance of solarized seedlings was assessed based on the percentage improvement over the non-solarized seedlings. Simultaneously, main field was prepared for solarization. Individual plots of dimension 4 m x 3 m were laid out and seedlings were transplanted at a spacing of 45 cm x 45cm. This experiment was laid out in a randomised block design with three replications and with treatments comprising two levels of thickness of polyethylene sheets used (0.05 mm and 0.10 m) and three levels of treatment duration (20, 30, and 40 days). Besides, normal practice (non-solarized) and absolute control were maintained for comparison. During the treatment period, soil temperatures at 10 and 20 cm depths were recorded at five days interval using soil thermometers.

Subsequently, during 1996 and 1997, the effect of solarization on seedling growth of chilli cultivars were tested raising nursery beds of earlier mentioned dimension in a factorial randomised block design. The two factors comprised solarization treatment for 15 days using 0.05 mm thick polyethylene (S -solarized and S_0 non solarized) and varieties (V_1 - G 4, V_2 - K 2, V_3 -

CA 235 and V_4 - Pusa Jwala). The eight treatments were replicated thrice. Effect of mainfield solarization was conducted during 1996 and repeated during 1997 for different treatment duration (S_0 – non-solarized, S_1 -solarization for 20 days, S_2 -30 days, S_3 - 40 days) in the four mentioned varieties of chillies in a factorial RBD with three replications. During treatment period, soil temperatures were recorded at 5 days interval at 3 depths (5, 10 and 20 cm). Observations on plant characters were noted in all the 16 treatments. Data on weed control efficiency were found out using the formula stated under in the four treatments of solarization (S_0, S_1, S_2 and S_3) and subjected to statistical analysis.

$$\text{Weed Control Efficiency} = \frac{\text{Weed dry weight in control plot} - \text{Weed dry weight in treated plot}}{\text{Weed dry weight in con}} \times 100$$

To make a record of change in microbial population, soil samples were taken at 15 and 30 cm depths before treatment and immediately after solarization. Soil samples collected from all the plots after corresponding period of solarization were pooled together treatment-wise. From each samples, 10 g soil was taken for making suspension and cultured with different media following the dilution plate technique as suggested by Allen (1953). The number of fungal colonies developed on rose Bengal agar, bacterial colonies on soil extract agar and actinomycetes on Curter's agar were counted after two, four and ten days of inoculation respectively.

Results and discussion

Solarization of nursery beds for 15 days using 0.05 mm polyethylene sheet increased germination percentage and produced transplantable seedling of K2 variety, ten days earlier than the normal seedlings. The growth of the solarized seedlings was also improved as indicated by higher values for root length, shoot length, number of leaves, vigour index, chlorophyll and dry matter content as indicated in table 1.

Due to solarization of mainfield using 0.05 and 0.10 mm thick polyethylene sheets, the rise in soil temperature was 1 to 3°C higher due to 0.05 mm sheets. This result is in accordance with the finding of Katan (1981) and Horowitz *et al.* (1983) who had recommended thinner polyethylene tarp possibly due to its better radiation transmittance and persistence of heat energy in the soil remained for a longer period and was more effective in producing healthy plants of K 2 chillies. It could be ranked that the treatment with 0.05 mm thick sheet for 40 days, 0.05 mm thick sheet for 30 days followed by 0.10 mm thick sheet for 40 days were effective in order in the production of higher yield when compared with plants grown normally under regular practice as given in table 2.

Studies on response of four genotypes grown in solarized nursery beds indicated that irrespective of genotypes, all the solarized seedlings registered improved germination percentage and higher values for other growth parameters like root and shoot length, number of leaves, dry matter and chlorophyll content. The overall improvement brought about in the different growth parameters ultimately resulted in the better vigour index. It was substantial in the case of seedlings raised after solarization in almost all the four genotypes, in which the highest increase was recorded by Pusa Jwala (V_4) as indicated in table 3.

Similar solarization treatment using 100 gauge polyethylene tarp had produced healthy tobacco and tomato seedlings with simultaneous reduction in weeds as well as root knot nematodes (Anon. 1992).

Perusal of soil temperature recorded at 5 days interval during solarization of main field using 0.05 mm polyethylene at 5, 10 and 20 cm depths for various duration of covering indicated that the maximum rise in soil temperature was recorded at 5 cm depth. This rise in soil temperature reduced at deeper profile. It was in the order of 8.4, 7.8 and 55.4°C at 5, 10 and 20 cm depths, respectively during 1996 and 8.4, 8.2 and 7.6°C at respective depths during 1997. This is in accordance with the findings of Wajid *et al.* (1995) and Yucel (1995). The percentage number of occasions with highest soil temperatures (above 37°C) were more in 40 days treatment followed by 30 and 20 days treatments, respectively. In general, 4-6 weeks of treatment was considered enough (Stapleton & De Vay 1986). The rise in soil temperature was 8 to 10°C higher than air *temperature and the fluctuation reflected the actual prevailing* weather condition as stated earlier by Standifer *et al.* (1984).

The performance of all four genotypes was superior in the treatment S_3 (solarized for 40 days) followed by S_2 (solarized for 30 days) and it was poor in non-solarized control, S_3. As a measure of good responder, the

Table 1. Effect of solarization on K 2 chilli seedlings.

Character	Mean value		Percent increase or decrease over control
	Solarized	Non-solarized	
Germination per cent	92.50	84.80	9.08
Shoot length (cm)	22.38	18.20	22.97
Root length (cm)	4.95	4.12	20.15
Number of leaves per seedling	7.20	5.80	24.14
Vigour index	2528.03	1169.54	51.42
Chlorophyll content	1.32	1.02	30.36
Dry matter content	0.18	0.14	34.97
Days taken to attain transplantable stage	25.00	35.00	40.00

Table 2. Effect of solarization on the vegetative and yield parameters on K 2 chillies (1995).

Treatment	Plant height (cm)	Number of primary branches	Number of fruits per plant	Number of seeds per fruit	Yield (kg ha^{-1})	Bio-mass production (kg ha^{-1})
T_1 (0.05 mm; 20 days)	36.99	7.47	68.20	27.27	860.87	1453.59
T_2 (0.05 mm; 30 days)	52.32	9.53	80.53	36.93	1525.55	2665.62
T_3 (0.05 mm; 40 days)	55.75	10.60	88.47	38.33	1601.07	2955.34
T_4 (0.10 mm; 20 days)	36.27	7.07	64.60	26.67	823.34	1355.11
T_5 (0.10 mm; 30 days)	43.39	8.47	72.33	28.53	1023.68	1527.34
T_6 (0.10 mm; 40 days)	46.48	9.33	76.40	32.47	1357.43	2312.71
T_7 (Normal practice)	45.95	9.27	73.47	29.47	1333.25	2020.65
T_8 (Control)	33.02	6.52	51.87	22.53	724.07	1266.40
S.Ed	0.97	0.30	0.79	0.48	33.68	74.49
CD (P=0.05)	2.08	0.65	1.70	1.03	72.23	159.78
CD (P=0.01)	2.88	0.90	2.36	1.43	100.24	221.75

difference in values between S_0 and S_3 was found out in individual genotype for all the characters and the results revealed that Pusa Jwala (V_4) was the best responder for yield and yield contributing characters like plant height, number of primary branches, number of fruits (Table 4) and total biomass produced. Other remarkable genotype was G 4 (V_1). The variety K 2 reciprocated better for the characters, days to 50 per cent flowering. For the biochemical characters like ascorbic acid content and capsaicin content of fruits,

Table 3. Effect of solarization on the vigour index of chilli seedlings.

Year	1996			1997		
Variety/ Treatment	S	S_0	Mean	S	S_0	Mean
V_1 (G 4)	2945.51	2166.01	2555.76	2880.16	2071.64	2475.90
V_2 (K 2)	2297.84	1743.58	2020.71	2172.85	1679.44	1926.15
V_3 (CA 235)	1415.61	1068.19	1241.90	1378.49	1082.26	1230.37
V_4 (Pusa Jwala)	3788.26	2717.98	3253.12	3517.20	2886.63	3201.92
Mean	2611.80	1923.94		2329.53	2087.65	
Factor	S	V	S x V	S	V	S x V
S.Ed.	56.98	80.59	113.97	57.91	81.89	115.81
CD (P=0.05)	22.22	172.87	244.45	124.21	175.65	248.41
CD (P=0.01)	169.63	239.92	339.25	172.38	243.78	344.74

Table 4. Effect of duration of solarization on ascorbic acid content of red ripe fruit and capsaicin content of dry fruits (mg $100g^{-1}$) in chillies.

Year	1996				1997			
	Ascorbic acid content							
Treatment/ Varieties	S_0	S_1	S_2	S_3	S_0	S_1	S_2	S_3
V_1	179.70	187.48	199.45	208.53	197.02	206.23	210.48	217.73
V_2	152.60	166.52	173.55	183.47	162.00	168.27	176.52	184.77
V_3	215.80	228.47	246.00	259.49	239.01	251.24	263.49	276.70
V_4	209.90	221.53	228.60	244.51	226.00	236.26	241.51	258.80
Mean	188.75	200.50	211.50	223.50	206.00	215.25	222.50	233.75
Factor	S/V		S x V		S / V		S x V	
S.Ed.	39.24		78.47		43.37		86.75	
CD (P=0.05)	80.13		160.25		87.18		174.36	
	Capsaicin content							
V_1	225.49	231.20	238.24	245.00	227.74	231.01	247.00	263.20
V_2	115.51	120.30	139.26	152.01	117.73	126.01	141.00	156.23
V_3	136.48	155.23	162.23	175.00	143.76	157.00	170.01	188.30
V_4	142.52	151.27	158.27	164.01	140.77	154.00	162.01	170.27
Mean	154.50	164.25	174.25	184.00	156.75	167.00	180.00	194.25
Factor	S/V		S x V		S / V		S x V	
S.Ed.	4.17		8.34		5.15		10.30	
CD (P=0.05)	8.52		17.03		10.52		21.04	

Table 5. Effect of duration of solarization on number of primary branches and number of fruits per plant in chillies.

Year	1996				1997			
	Primary branches							
Treatment/ Variety	S_0	S_1	S_2	S_3	S_0	S_1	S_2	S_3
V_1	8.60	9.80	11.60	13.33	8.41	9.76	11.65	13.65
V_2	8.27	9.47	10.47	12.53	8.37	9.40	10.64	12.26
V_3	6.47	7.73	9.33	10.87	6.59	7.73	9.30	10.46
V_4	9.33	11.20	13.33	15.60	9.33	11.67	12.37	15.57
Mean	8.17	9.55	11.18	13.08	8.18	9.64	11.22	12.99
Factor	S/V		S x V		S / V		S x V	
S.Ed.	0.06		0.12		0.10		0.20	
CD(p=0.05)	0.12		0.25		0.20		0.41	
	Fruits per plant							
V_1	81.33	95.54	108.33	118.72	80.42	94.35	95.30	116.20
V_2	78.75	90.40	98.78	105.35	78.49	90.53	87.75	104.46
V_3	53.58	68.58	77.75	89.46	50.73	67.58	70.57	97.85
V_4	88.36	107.38	125.75	142.61	83.60	106.57	118.43	137.65
Mean	75.51	90.23	102.65	114.04	73.31	89.76	93.01	114.05
Factor	S/V		S x V		S / V		S x V	
S.Ed.	0.65		1.31		0.78		1.57	
CD(p=0.05)	1.32		2.63		1.57		3.15	

Table 6. Effect of solarization on weed control efficiency.*

Treatment	Weed control efficiency at 30 days		Weed control efficiency at 60 days	
	1996	1997	1996	1997
S_1	18.89 (25.73)	12.71 (20.86)	19.88 (26.43)	19.75 (26.38)
S_2	53.73 (47.14)	52.10 (46.20)	70.75 (57.26)	73.43 (58.97)
S_3	86.18 (68.18)	81.74 (64.73)	83.708 (66.19)	83.66 (66.16)
S.Ed.	0.88	1.49	1.16	0.52
CD (p=0.05)	2.15	3.65	2.84	1.28

* Numbers in parenthesis indicate transformed values

Table 7. Influence of solarization on the population of fungi, bacteria and actinomycetes in the experimental field.

Treatment	Population g^{-1} of moisture free soil					
	Fungi x 10^4		Bacteria x 10^6		Actinomycetes x 10^5	
	1996	1997	1996	1997	1996	1997
S_0	8.59	8.74	14.83	15.26	4.92	5.87
S_1	8.41	8.56	13.97	14.91	5.99	5.96
S_2	7.39	7.00	13.82	14.87	6.12	6.07
S_3	5.64	5.93	13.69	13.99	6.20	6.26
S.Ed.	0.45	0.43	0.60	0.59	0.31	0.33
CD (p=0.05)	1.31	1.29	NS	NS	NS	NS

CA 235 (V_3) was the best responder though it was the least responder for the biometric character as presented in the table 5. It is apparent from the results that chillies had shown increased growth response (IGR) due to solarization. A number of studies have shown that plant growth had improved in solarized soil (Stevens *et al.* 1994, Eltez & Tuzel 1994) as they were apparently free of weeds, pathogens and nematodes.

The spectacular effect of soil solarization is well pronounced due to the appreciable control of weeds (Silvereira 1994) and reduction in fungal population (Cartia 1987). Observation on weed control efficiency and shift in microbiota revealed the superiority of the treatment S_3 followed by S_2 as indicated in the tables 6 and 7.

Destruction of microbes in the soil system is a disadvantage when we consider the favourable micro organisms. Research should be focussed to strengthen the availability of beneficial micro organisms in the solarized soil. In the recent scenario of international horticulture, the incorporation of toxic chemicals to the soil either as weedicide or fungicide can be effectively brought down through the use of soil solarization process, which will add value to the produce.

References

Adetunji I A 1994. Response of onion to soil solarization and organic mulching in semi arid tropics. Scientia Horticulture 60 (1-2) : 161-166.

Allen O N 1953. Experiments in Soil Bacteriology. Burgers Publications. Minnepolies. pp. 240.

Anonymous 1992. Soil Solarization. Gujarat Agricultural University. Anand. pp. 1-4.

Bawazir A A, Rowaished A K, Bayounis A A & Ai-Jounaid A M 1995. Influence of soil mulching with sawdust and transparent polyethylene on growth & yield of okra and on weed control. Arab. J. Pl. Prot. 13 (2) : 89-93.

Cartia G 1987. Results of soil solarization in Sicily. Diefesa delle piante 10 : 189-194.

Eltez R Z & Y Tuzel 1994. The effects of soil solarization on glass house tomato growing. Acta. Hort. 366 : 339-344.

Herrera F & Ramirez C 1996. Soil solarization and chicken manure additions on propagule survival of *Cyperus rotundus, Rottboellia cochinchinensis* and *Bidens pilosa.* Agronomia – Mesoamericana 7 (1) : 1-8.

Horowitz M, Regev Y & Herzlinger G 1983. Solarization for weed control. Weed Sci. 31 : 170-179.

Katan J 1981. Solar heating (solarization) of soil for control of soil borne pests. Ann. Rev. Phytopathol. 19 : 311-336.

Silvereira H L, Calxinha M.L, Gomez R & Thomas J M 1994. Solarization of the soil, for weeds and production. Maitrise des adventices parvoie non chimique. Communication de la quatrieme conference international L.F. D.A.M. DiJon, France. pp. 141-148.

Standifer L C, Wilson P W & Sorbert R P 1984. Effect of solarization on soil weed seed population. Weed Sci. 32 : 569-573.

Stapleton J J & De Vay J E 1986. Soil solarization : a new non-chemical approach for management of plant pathogens and pests. Crop Prot. 5 : 190-198.

Stapleton J J & Garza-Lopez J G 1988. Mulching of soils with transparent (solarization) and black polyethylene films to increase the growth of annual and perennial crops in south western Mexico. Trop. Agric. 65 (1) : 29-33.

Stevens C, Khan V A, Wilson M A, Collins D J, Brown J E, Lu JY & Jones R J 1994. Comparative effects of soil solarization and other agriplastic mulch systems on increased growth response of Floracle tomato. Proceedings of 25th national agricultural plastic congress. Lexington, USA. pp. 156-161.

Wajid S M A, Shenoi M M & Sreenivasa S S 1995. Seed bed soil solarization as a component of integrated disease management in FCV tobacco nurseries of Karnataka. Tobacco Res. 21 (12) : 58-65.

Yucel S 1995. A study on soil solarization combined with fumigant application to control *Phytophthora* crown blight (*Phytophthora capsici* Leonian.) on peppers in the East Mediterranean region of Turkey. Crop Prot. 14 (8) : 653-655.

Effects of dates of sowing and spacing on growth and yield in fenugreek (*Trigonella foenum - graecum* L.)

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Abstract

An experiment was conducted to study the effects of dates of sowing and spacing on growth and yield in fenugreek (*Trigonella foenum - graecum* L.). The crop sown on first July responded significantly by recording the maximum plant height (56.27 cm), more number of branches and leaves (10.08 and 126.42, respectively), minimum number of days to 50 per cent flowering (34.11), more dry weight (16.12 g), more number of pods per plant and seeds per pod (50.95 and 15.43, respectively) and significantly increased seed yield (23.88 q/ha) which was followed by 15th July sown crop. Closer spacing (15 x 15 cm) produced higher seed yield, while wider spacing (30 x 30 cm) recorded the maximum growth and yield parameters except the seed yield per hectare.

Key words: fenugreek, growth, sowing, spacing, yield

Introduction

Fenugreek (*Trigonella foenum - graecum* L.) is an anuual herb, belonging to the family papilionaceae. Its origin lies between Iran and North Inda, but it is widely growth in India, China, Africa, Russia, Greece, Egypt, Pakistan, Bangladesh, Hungary, Argentina, France, Morocco and Lebanon. In India, it is grown in an area of 40,000 hectares. The uses of fenugreek are multifarious.It is used as medicine , spice and condiment. The fresh tender leaves and stems are consumed as curried vegetables alone or in combination with potato and other vegetables. Fenugreek seeds are greatly valued for their medicinal properties. An infusion of seeds is given to treat small pox and dysentery and also used in colic, flatulence, diarrhoea, dyspesia, loss of appetite, chronic cough, dropsy, enlargement of liver and spleen, rickets, gout and diabetes. The roasted seeds are used substitute for coffee also in pickles and curry powder.

The crop is commonloy grown during *kharif* and *rabi* seasons. To meet its ever increasing demand as a spice, condiment and medicinal products, it is required to be cultivated on a large scale and hence systematic efforts to develop its production technology are essential.

Materials and methods

The experiment was conducted at the Horticulture Research Station, University of Agricultural Sciences, GKVK, Bangalore during 1996-97. The trial was laid out in a Split Plot Design (Sundaraj *et al.* 1972) with three replications consisting of six dates of sowing (15th june, 1st July, 15th July, 1st September, 15th September and 1st October) as the main plots and three spacings (15 x 15 cm, 30 x 15 cm and 30 x 30 cm) as the sub plots. The net plot size for all the treatments was 1.5 x 1.2 m. The healthy seeds collected were sown in the furrows and kept in moist condition. The plots were applied with 50 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare. The full dose of P_2O_5 and K_2O along with half dose of N were applied at sowing and remaining half of N was applied after four weeks of sowing. The plots were kept weed free by hand weeding. Irrigation was given soon after sowing and then twice a week for four weeks and subsequently at weekly intervals depending on the moisture level in the soil. Proper plant protection measures were taken up to combat the pest and diseases. Observations were recorded on both growth and yield parameters.

Results and discussion

Proper sowing time and plant density for better growth and yield is of interest. The result of the present investigation on the effect of sowing dates and spacing on growth and yield in fenugreek and their implication on plant growth and yield parameters are discussed here and the data presented in Tables 1 and 2.

Table 1. Effect of dates of sowing and spacing on growth parameters in fenugreek.

Treatment	Plant height (cm)	No. of branches	No. of leaves	Days taken to 50% fl.	Dry wt. /plant (g)
Main treatments (date of sowing)					
15 th June (D1)	47.201	5.687	55.589	38.000	8.633
1st July (D2)	56.267	10.084	126.419	34.111	16.122
15th July (D3)	45.478	6.998	115.567	39.000	15.244
1st September (D4)	40.333	7.303	32.389	38.778	12.878
15th September (D5)	35.519	6.980	86.111	38.556	11.867
1st October (D6)	33.922	6.416	82.667	39.556	11.233
F-test	**	**	**	**	**
SEm ±	1.338	0.388	5.836	0.365	0.776
CD at 5%	4.216	1.223	18.388	1.149	2.446
Sub-treatments (spacing)					
15 cm x 15 cm (S1)	41.567	5.971	71.924	37.889	12.750
30 cm x 15 cm (S2)	41.793	7.063	81.967	30.000	13.825
30 cm x 30 cm (S3)	46.000	8.701	95.679	38.000	14.414
F-test	**	**	**	NS	**
SEm ±	0.736	0.181	2.815	0.184	0.179
CD at 5%	2.149	0.529	8.218	0.538	0.522
Interactions					
D1 S1	43.990	4.337	44.557	37.333	5.850
D1 S2	44.557	5.663	40.543	38.000	9.133
D1 S3	53.057	7.060	81.667	38.667	10.917
D2 S1	56.867	8.240	106.623	35.667	14.700
D2 S2	54.423	9.883	126.123	34.333	16.400
D2 S3	57.510	12.130	146.510	32.333	17.267
D3 S1	44.767	5.733	110.533	38.333	14.900
D3 S2	42.867	7.060	116.933	39.333	15.400
D3 S3	48.800	8.200	119.233	39.333	15.433
D4 S1	41.500	5.477	20.167	37.667	12.200
D4 S2	40.167	7.073	36.000	38.667	12.767
D4 S3	39.333	9.360	33.000	40.000	13.667
D5 S1	30.113	6.570	68.667	38.000	10.600
D5 S2	34.777	6.507	91.000	38.667	11.667
D5 S3	41.667	7.863	98.667	39.000	13.133
D6 S1	32.167	5.467	73.000	40.333	10.233
D6 S2	33.9676	6.190	80.000	39.000	11.133
D6 S3	35.633	7.590	95.000	38.667	12.333
F-test	*	NS	NS	**	*
SEm ± (A)	1.803	0.444	6.896	0.451	0.438
SEm ± (B)	1.983	0.531	8.109	0.518	0.855
CD at 5% (A)	5.263	-	-	1.317	1.280
CD at 5% (B)	6.016	-	-	1.572	2.659

NS = Non significant, * = Significant, ** = Highly significant

A = Sub plot means at same level of main plot, B = Main plot means at same or different levels of Sub plot.

Table 2. Effect of dates of sowing and spacing on yield parameters in fenugreek.

Treatment	No. of pods/plant	No. of seeds/pod	Test wt. (1000 seeds) (g)	Seed yield/ plant (g)	Seed yield/ plot (g)	Seed yield /ha (q)
Main treatments (date of sowing)						
15 th June (D1)	26.191	14.070	12.077	4.427	267.188	8.893
1st July (D2)	50.952	15.430	22.183	9.877	606.562	23.881
15th July (D3)	37.564	15.500	12.374	7.338	451.304	16.716
1st September (D4)	18.176	11.620	10.610	2.264	133.977	4.963
15th September (D5)	21.147	11.150	10.573	2.578	150.924	5.588
1st October (D6)	11.976	11.430	12.777	1.830	105.552	3.910
F-test	**	**	**	**	**	**
SEm ±	2.663	0.232	0.143	0.577	31.651	1.115
CD at 5%	8.391	0.733	0.451	1.818	99.727	3.513
Sub-treatments (spacing)						
15 cm x 15 cm (S1)	22.362	12.090	11.395	3.223	387.346	14.347
30 cm x 15 cm (S2)	27.049	13.180	12.676	4.448	270.868	9.715
30 cm x 30 cm (S3)	33.791	14.330	12.227	6.486	194.539	7.914
F-test	**	**	NS	**	**	**
SEm ±	0.982	0.126	0.143	0.217	11.299	0.621
CD at 5%	2.866	0.368	-	0.634	32.981	1.813
Interactions						
D1 S1	18.733	12.870	11.777	2.653	318.470	11.797
D1 S2	26.763	14.130	11.843	4.483	268.873	8.060
D1 S3	33.077	15.200	12.270	6.143	184.220	6.823
D2 S1	45.427	15.030	10.540	7.250	869.943	32.220
D2 S2	47.237	15.170	12.980	9.280	556.860	20.623
D2 S3	16.193	16.700	13.497	13100	329.882	18.800
D3 S1	30.597	14.630	11.877	5.310	637.027	23.593
D3 S2	39.403	15.400	11.877	7.193	431.620	15.983
D3 S3	42.693	16.470	13.280	9.510	285.267	10.567
D4 S1	13.767	10.700	10.127	1.493	179.543	6.650
D4 S2	17.903	11.570	10.377	2.113	126.850	4.700
D4 S3	24.057	12.590	10.613	3.187	95.537	3.540
D5 S1	16.220	9.620	10.193	1.530	186.933	6.923
D5 S2	19.887	10.790	10.540	1.863	135.707	5.020
D5 S3	27.333	14.040	12.183	4.340	130.133	4.820
D6 S1	9.430	09.690	11.863	1.100	132.160	4.897
D6 S2	11.103	12.040	13.207	1.757	105.300	3.900
D6 S3	15.393	12.570	13.603	2.633	79.197	2.933
F-test	NS	*	NS	**	**	*
SEm ± (A)	2.405	0.309	0.632	0.532	27.676	1.522
SEm ± (B)	3.309	0.343	0.536	0.722	38.890	1.669
CD at 5% (A)	-	0.902	-	1.553	80.786	4.441
CD at 5% (B)	-	1.038	-	2.215	119.491	5.045

NS = Non significant, * = Significant, ** = Highly significant

A = Sub plot means at same level of main plot, B = Main plot means at same or different levels of Sub plot.

The plant height significantly differed with the dates of sowing. The first July sown plants were taller (56.27 cm) than the plants sown on other dates. Sudheendra (1993) and Ramesh (1994) have observed similar response in celery and kalmegh, respectively. The first July sown plants produced more number of branches (10.08), more number of leaves (126.42), minimum number of days to 50 per cent flowering (34.11), higher dry weight (16.12 g), more number of pods per plant (50.95), number of seeds per pod and seed yield per plant (9.88 g) compared to other dates of sowing. This may be due to the fact that early sown plants received a longer and favourable weather conditions (rainfall 26.5 mm, temparature 18.6-26°C) during the crop growth period wich might have helped in a better response to the growth and yield of fenugreek. Ramesh *et al.* (1989) have obtained similar results in isabgol.

The wider spacing (30 x 30 cm) recorded superior values with regard to plant height (46.00), number of branches (8.70), number of leaves (95.68), dry weight of plant (14.41 g), number of pods per plant (33.79), number of seeds per pod (14.33) and seed yield per plant (6.49 g). While the closer spacing (15 x 15 cm) was found to record significantly higher seed yield per plot (387.35 g) and per hectare (14.35 q). This could be due to the reason that, the widely spaced plants could accumulate more dry matter through proper growth and development by better utilization of nutrients, moisture, light etc. The higher seed yield in closely spaced plants over widely spaced ones could be due to the increased number of plants per unit area. Similar results were found by Ghosh *et al.* (1981) in black cumin, Randhawa *et al.* (1984) in *Ammi majus* and Singh and Kewalanand (1984) in fenugreek.

Interaction between dates of sowing and spacing differed significantly with respect of growth and yield parameters. Among the treatments, the best combination was, the first July sowing with 30 x 30 cm (wider) spacing, which recorded the maximum plant height (57.51), higher number of branches (12.13), more number of leaves (146.51), minimum days to 50 per cent flowering (32.33), maximum dry weight of plant, number of pods per plant, seed per pod and seed yield per plant. Perhaps, the congenial weather conditions together with less competition for moisture, nutrients and sunlight among the widely spaced plants must have helped them in putting faster growth and development and helping in boosting the production potential. Whereas, the combination of first July sown crop with 15 x 15 cm (closer) spacing recorded significantly high seed yield per plot and per hectare over the other combinations. The possible reason for higher yields may be due to the accommodation of more number of plants per unit area along with congenial weather conditions prevaling during the crop growth period. These results are in confirmity with Gill & Sharma (1986) in honey plant and Ghosh *et al.* (1981) in black cumin.

From the present investigations, it can be concluded that, fenugreek should be sown on first July and at a spacing of 15 x 15 cm to obtain better growth and maximum yield under Bangalore conditions.

References

Ghosh D, Roy K & Mallick S C 1981. Effect of fertilizers and spacing on yield and other characters of black cumin (*Nigella sativa* L.). Indian Agric. 25 (3) : 191-197.

Gill B S & Sharma J S 1986. Effect of rate and time of nitrogen application on seed yield of *Ammi majus*. Indian perfume 30(1) : 262-264.

Ramesh P M 1994. Standardization of cultural practices in Kalmegh (*Andrographis paniculata* Nees.). M.Sc. Thesis, Univ. Agric. Sci., Bangalore.

Ramesh M N, Farooqi A A & Thilak S 1989. Influence of sowing date and nutrients on growth and yield of Isabgol (*Plantage ovata* Forsk). Crop Res. 2(2) : 169-174.

Randhawa G S, Mahey R K, Sidhu B S & Saini S S 1984. Growth & yield of *Ammi majus* under different plant and row spacing. Sci. Cult. 50(4) : 131-133.

Singh J N & Kewalanand 1984. Effects of dates of sowing, row spacing & nitrogen levels on the grain yield of fenugreek. Indian drugs 21(2) : 536-540.

Sudheendra S 1993. Influence of sowing dates & nutrients on growth, yield & essential oil content in celery (*Apium graveolents* L.). M.Sc. thesis, Uni. Agric. Sci., Bangalore.

Sundaraj N, Nagarau S, Venkataramu M N & Jaganath M K 1972. Design and analysis of field experiments. Published by University of Agricultural Sciences, Bangalore.

Yield and nutrient uptake by some spice crops grown in sodic soil

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Abstract

Field experiments were conducted to evaluate the prospects of growing coriander (*Coriandrum sativum* Linn*)* and fennel (*Foeniculum vulgare* Mill) in a partially reclaimed sodic soils at Banthra Research Station of National Botanical Research Institute, Lucknow, U.P., India. Coriander var. *Haritima* was grown at 20 ESP (exchangeable sodium percentage) with four doses of N i.e. 0, 30, 60, and 90 kg ha^{-1} and three doses of P i.e. 0, 25 and 50 kg ha^{-1} forming in all 12 treatments arranged in a factorial randomized block design (RBD) with four replications. Fennel (var. *local)* was grown at 30 ESP, also with four doses of N (0, 40, 80, and 120 kg ha^{-1}) and three doses of P (0, 25, and 50 kg ha^{-1}) comprising of 12 treatments laid in a factorial RBD with three replications. Results showed that the treatment N3P2 i.e. 90 kg ha^{-1} N and 50 kg ha^{-1} P was the best and produced 37% higher seed yield over control in case of coriander. The treatment of N2P1 i.e. 80 kg ha^{-1} N and 25 kg ha^{-1} P yielded the highest and produced 67% greater seed yield in case of fennel. The values of mineral composition of seeds were greater than the stover (plant part) in both the species. However, the concentration of N in the seed and Na in the plant part of fennel were higher than the coriander crop. In general, the nutrients uptake were higher by the stover than by the seed in both the spices. The study indicated that a large amount of Na accumulated and removed by the stover of fennel indicating its capacity to endure moderate degree of sodic tolerance. Analysis of soil done before sowing and after harvest of these spices crops revealed a marked decrease in soil pH and ESP and an increase in exchangeable Ca and organic carbon contents under fennel crop whereas coriander crop did not show any remarkable change in sodic soil attributes except an increase in organic carbon.

Key words: coriander, fennel, nutrient uptake, spices, sodic soil, yield

Introduction

Coriander (*Coriandrum sativum* Linn) and fennel (*Foeniculum vulgare* Mill) are important crops grown extensively in India. Besides meeting home demands they are exported fetching fair amount of foreign exchange. The sodic wastelands particularly partially reclaimed or having moderate sodicity, if used for cultivation may increase production, provided appropriate agrotechnology is developed without deteriorating effect in their quality. In India about 57% of the geographical land is facing the problem of degradation due to erosion including wind and water, salinity, alkalinity and urbanization etc. There is nearly 1.25 m ha land that is sodic in nature in Uttar Pradesh alone. Presently a great deal of information is documented in the literature on the tolerance of sodicity of many cereals, oil seed and vegetable crops (Abrol & Bhumbla 1979, Singh *et al.* 1981, Singh & Abrol 1985). However, little is known about the performance of spice crops in degraded lands. Available information indicates that main contributing factors for yield of coriander and fennel are time of sowing, spacing, irrigation and fertilizers like nitrogen , phosphorus and sulphur (Gill & Samra 1986, Ahmed *et al.* 1988, Bhati *et al.* 1989, Bhati 1990, Maurya 1990, Lal *et al.* 1997, Singh 1999). Sodic soils are generally low in N and P, and information on responses of spice crops to these nutrients on such soil is still lacking . Hence, the present study is conducted with the objectives to know the effect of different doses of N and P fertilizers on yields and nutrients composition and to assess ameliorative effect of these crops when grown in sodic soil of Gangatic alluvial plains of U.P.

Materials and methods

Field experiments were conducted at Banthra Research Station of National Botanical Research Institute, Lucknow. The area lies between $26^0 40'$-$26^0 45'$

N latitude and 80° 45'- 80° 53' E longitude on the Lucknow -Kanpur highway at an elevation of 129 m above the mean sea level. The meteorological parameters indicate that the climate of the area is semi arid, subtropical and monsoonic. It receives an average annual rain fall of 872 mm. The mean maximum temperature of 39.1° C reaches in the month of May and the mean minimum temperature 7.6° C reaches in the month of January indicates a seasonal climate. Site soil belong to fine silty, mixed, active, calacareous, hyperthermic family of Aeric Halaquepts The soil is partially reclaimed by biological measures (Khoshoo 1987) and having silt loam texture in the surface. Soil pH varies from 8.6 to 9.0 with low to medium status of organic carbon (0.574%). The soil is also very low in available phosphorus (8 kg ha $^{-1}$) and high in available potassium.

Two spice crops of *Coriandrum sativum* Linn and *Foeniculum vulgare* Mill were grown at about 20 and 30 ESP (Exchangeable sodium percentage) an index of sodicity . The experiment of *C.sativum* was laid out in a factorial randomized block design with four doses of nitrogen i.e. No-0, N1- 30 , N2- 60 and N3- 90 kg ha $^{-1}$ and three doses of phosphorus i.e.Po-0, P1-25 and P2-50 kg ha^{-1}. The variety *Haritima* was sown @ 15 kg ha^{-1} in the first week of October at 50 cm x 20 cm apart in a bed size of 5 m x 4 m with four replications . Normal cultural practices were followed. The irrigation was given as and when required. The crop was harvested in the month of April.

The experiment of *F.vulgare* was also laid in a factorial randomized block design with four levels of nitrogen i.e. 0 , 40 , 80 and 120 kg ha^{-1}and three levels of phosphorus i.e. 0 , 25 , and 50 kg ha^{-1}. The *local* variety of fennel was sown @ 12 kg ha^{-1} in the last week of October at 50 cm x 30 cm distance in a plot size of 4 m x 3 m with three replications. General cultural practices were followed and irrigation was given as and when required. The crop was harvested in the month of May.

Observations on the seed and stover yields of both the crops were recorded at harvest. Seed and stover yields data were subjected to analysis of variances (Panse & Sukhatme 1961). Samples of stover and seeds were oven dried at 65° C and weighed separately. These samples were ground, oven dried and analyzed for total N using macro kjeldahl method with a Tecator Kjeltec Auto1030 Analyser. For P, K, Na, Ca, and Mg 1 g sample was digested in a nitric and perchloric acid following wet digestion method (Richards 1954). Phosphorus was determined by a colorimetric procedure using vanadomolybdophosphoric yellow colour method and K, Na and Ca by flame photometer. Mg was determined by atomic absorption spector photometer (Richards 1954). The uptake of nutrients by these crop was calculated by multiplying the total dry matter and their concentration of each element of stover and seed separately.

To study the changes in soil chemical characteristics of sodic land due to cultivation of these crops, soil samples were collected from 0-15 cm depth before sowing and after harvest of these crops. These were homogenized, passed through a 2 mm sieve and were analyzed. Standard methods of analysis were followed for pH, EC (Electrical conductivity in 1:2 soil water ratio), organic carbon, total nitrogen, $CaCO_3$, exchangeable cations (Na^+, K^+, Ca^{++} and Mg^{++}), and exchangeable sodium percentage (ESP) (Jackson 1967).

Results and discussion

Effect of fertilizer

There was no significant difference between the treatments in *C. sativum* but they were significant in *F. vulgare* crop grown in sodic soil. Table 1 shows that the treatment N_3P_2 i.e. application of 90 kg N and 50 kg P_2O_5 ha^{-1} produced the maximum yield of about 16.4 q ha^{-1} and 28.0 q ha^{-1} of seed and stover, respectively, by coriander. This was followed by treatment N_2P_2 i.e. application of 60 kg N and 50 kg P_2O_5 ha^{-1} showing the yield of seed 15 q ha^{-1} and stover 25.8 q ha^{-1}. Results indicated that the increase in seed yield over the control was 37% at N3P2 level and it was 25% at N_2P_2 level. Thus, application of 60 kg N and 50 kg P_2O_5 ha^{-1} would be some what economical for growing of coriander in sodic soils. These results are in agreement to the mean yield of seed and stover obtained on normal soil that ranges from 14 to 18 q ha^{-1} and from 21.3 to 37.4 q ha^{-1}, respectively with the use of different doses of fertilizers (Maurya 1990, Tomar *et al.* 1994, Lal *et al.* 1997).

Yields of seed (CD=1.64 q ha^{-1}) and stover (CD=2.29 q ha^{-1}) increased significantly with increasing dose of N by *F.vulgare* crop grown in sodic soils. The significant response of seed yield was obtained at N_2P_0 i.e. 80 kg N ha^{-1} showing 56% higher seed yield than control. However, the treatment of N_2P1 i.e. 80 kg N and 25 kg P_2O_5 ha^{-1}was the best indicating about 67 % increase

Table 1. Effect of fertilizer N and P applications on seed and stover yield of *C. sativum* and *F. vulgare*.

	C.sativum Yield (q ha^{-1})		*F. vulgare* Yield (q ha^{-1})	
Treatment	Seed	Stover	Seed	Stover
N0P0	12.0	20.5	6.3	8.8
N0P1	13.3	21.0	6.4	9.0
N0P2	13.6	23.3	7.2	10.1
N1P0	11.3	19.4	8.4	11.7
N1P1	12.5	21.5	8.8	12.3
N1P2	14.4	24.6	9.3	12.9
N2P0	12.6	21.5	9.8	13.7
N2P1	12.2	20.8	10.4	14.6
N2P2	15.0	25.8	10.6	14.8
N3P0	13.0	22.1	10.9	15.3
N3P1	13.1	25.5	11.2	15.7
N3P2	16.4	28.0	11.5	16.2
CD(P=0.05)	5.03	8.55	1.64	2.29

in seed yield over control. Thus, combined effect of N and P has definite influence on yield in both the crops because of their low status in sodic soils (Garg 1987) (Table 1). The corresponding yield of stover at N2P0 treatment was 12.9 q ha^{-1} and at N2P1 it was 14.6 q ha^{-1}. In our study seed yield of fennel produced on sodic soils is slightly low in comparison to the yield of seed obtained on good soil that ranges from 14 - 24 q ha^{-1} as influenced by application of fertilizers (Ahmed *et al.* 1988, Bhati *et al.* 1989, Bhati 1990, Sharma & Prasad 1990).

Nutrient concentration and uptake

The data on nutrient concentration of plant (stover) and seed indicated a wide variation by the two crops studied. The mineral composition of seed, in general, was greater than the plant part in both the species. However, the differences in the concentration in *F.vulgare* were more prominent than that of *C.sativum* (Fig. 1). The mineral composition of latter species is within the desirable range except for some minor variations in the concentration of seed N and Na in comparison to the values reported for its normal growth and yield on the unproblematic soils (Pruthi 1976, Wealth of India 1950). In the absence of nutrient concentration standards for satisfactory growth and yield of former species, it is difficult to evaluate its nutrient status. However, the concentration of N in the seed and Na in the plant of fennel were greater than the values reported for good soils (Pruthi 1976).It is generally observed that when plant is grown in saline/sodic soil conditions the mineral composition of it is altered and the growth of it suffers more due to ion imbalance stress. Hence, the ability of a given species to assimilate the nutrient under stress would provide a better index of salt tolerance capacity than those which suffers from these attributes (Garg & Khanduja 1976). Therefore, such species which are capable of assimilating the nutrient elements to a comparable level to those growing on normal soil would be able to overcome the effect of nutrient imbalance due adverse soil conditions. On this account these species have the potential of growing in sodic soils. However, there is a need to establish standards of nutrient status of these spices on normal soils which may form the basis for comparisons. In general, nutrient uptake were higher by the stover than by the seed in both the crops except for N and P in *F.vulgare* grown in sodic soil, probably caused by higher accumulation of soluble sodium in the exchange complexm (Fig. 2). The uptake of N, P and K by the stover of *C.sativum* are not much affected by the sodicity of soil as their values were within the range observed on normal soil that shows the variation from 27 - 31 kg ha^{-1}N, 3-14 kg ha^{-1} P and 31- 76.8 kg ha^{-1} K (Rao *et al.* 1983, Lal *et al.* 1997). It is interesting to point out that under sodic conditions a large amount of Na was accumulated in the stover (32 kg ha^{-1}) of *F.vulgare*. This may be ascribed primarily to the higher concentration of Na in the plant (Fig. 1). Thus, it appears that fennel has the capacity to transport much of absorbed Na from root and retained in the plant parts (Graifenberg *et al.* 1996). Plants differ in their ability to accumulate or exclude Na ions when grown in saline/ sodic stress conditions.In our study this salt (Na) inclusion mechanism in the plant tissue of fennel does not affect growth and development. Therefore, it leads to postulate that fennel crop has potential to endure moderate degree of sodic tolerance.

Amelioration of sodic soil

Soil samples analyzed before the experiment and after the harvest of spices crops grown in sodic soils are presented in Table 2. The results show that there are

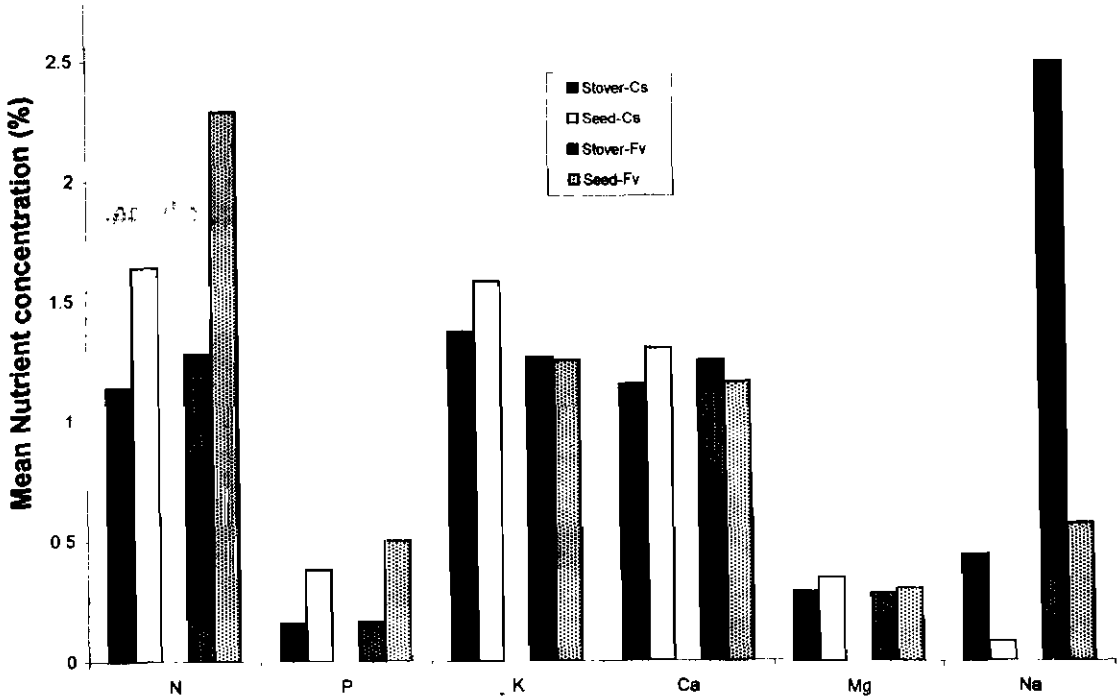

Fig. 1. Mean nutrient concentration in stover and seed of Coriandrum sativum (Cs) and Foeniculum vulgare (Fv) grown in sodic soils.

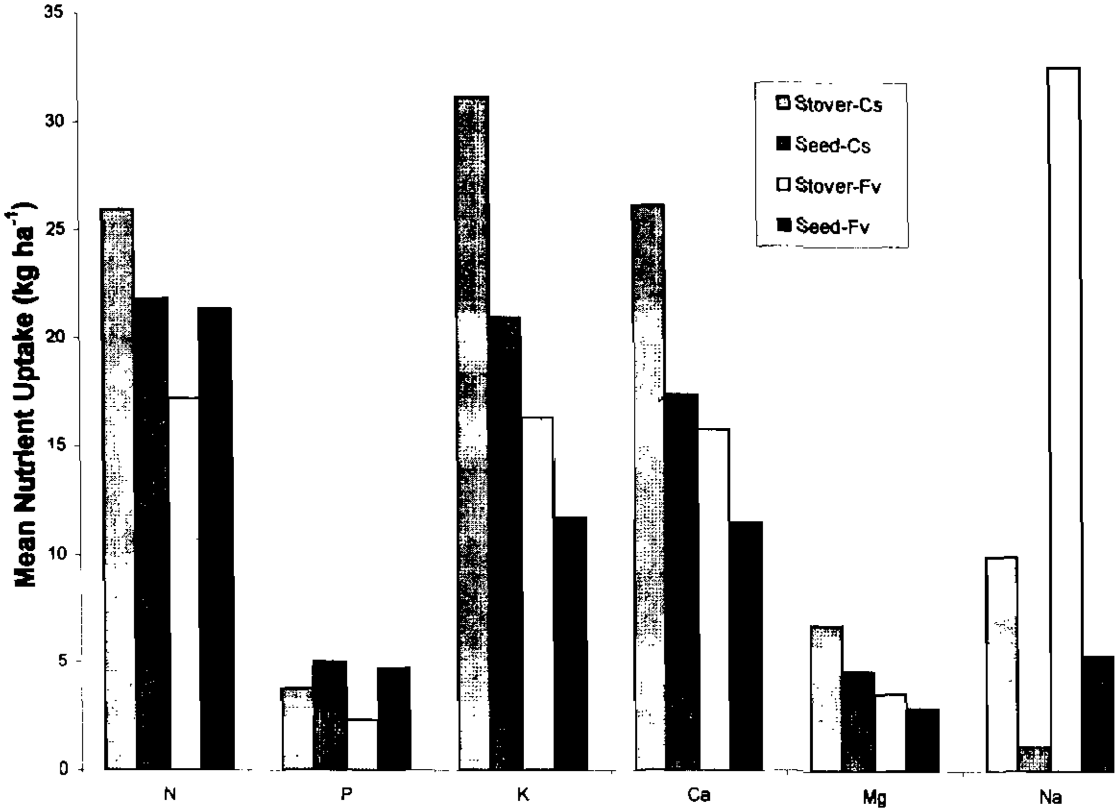

Fig. 2. Mean nutrient uptake in stover and seed of *Coriandrum sativum* (Cs) and *Foeniculum vulgare* (Fv) grown in sodic soils.

Table 2. Analysis of surface soil (0-15cm) under *Coriandrum sativum* and *Foeniculum vulgare* grown in sodic soils (values are means of three determinations with standard deviation)

Treatment	pH 1:2	EC dSm-1	OC %	$CaCO_3$ %	Na	K (c mol kg^{-1})	Ca	ESP
Coriandrum sativum								
Before sowing	8.6	0.31	0.21	1.45	3.48	0.78	6.0	20.3
	±0.10	±0.002	±0.003	±0.001	±0.02	±0.025	±0.023	±0.2
After harvest	8.5	0.25	0.46	1.71	3.27	0.72	7.5	18.8
	±0.05	±0.001	±0.002	±0.001	±0.01	±0.02	±0.15	±0.35
Foeniculum vulgare								
Before sowing	9.2	0.35	0.15	1.75	5.3	0.51	5.0	31.0
	±0.15	±0.001	±0.002	±0.002	±0.03	±0.015	±0.10	±3
At harvest	8.9	0.34	0.77	1.98	3.1	0.82	8.3	19.0
	±0.10	±0.002	±0.003	±0.002	±0.02	±0.10	±0.15	±0.75

least changes in soil attributes especially in pH and exchangeable sodium percentage (ESP) of soil except a slight increase in organic carbon contents after the harvest of coriander crop. After the harvest of fennel crop there were reduction in soil pH by about 0.3 unit and ESP by about 36% in the surface soil. Correspondingly there were increases in exchangeable Ca and decrease in exchangeable Na values indicating its replacement by divalent Ca ions. This phenomenon may be discemible to exceptionally higher uptake of sodium by the shoot.Such improvement in sodic soils have been observed in crops like vetiver, sugar beet and other tree crops (Anwar *et al.* 1996, Garg 1986, 1998).

Thus, it may be concluded that fennel crop could be considered moderate by sodic tolerant and has potential for improvement of sodic soils also.

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References

Abrol I P & Bhumbla D R 1979. Crop responses to differential gypsum application in a highly sodic soils and tolerance of several crops to exchangeable sodium under field conditions. Soil Sci.127 : 79-85.

Ahmed A, Farooqi A A & Bojappa K M 1988. Effect of nutrients and spacing on growth, yield and essential oil content in fennel (*Foeniculum vulgare* Mill). Indian Perfumer 32 : 301-305.

Anwar M, Patra D D & Singh D V 1996. Influence of soil sodicity on growth, oil yield and nutrient accumulation in vetiver (*Vetiveria zizaniodes*). Ann. Aridzone 35 : 49-52.

Bhati M S, Dixit V S & Bhati D S 1989. Effect of nitrogen fertilization and stage of umbel picking on quality attributes and economics of fennel (*Foeniculum vulgare*). Indian Perfumer 33 : 174-177.

Bhati D S 1990. Effect of stage of umbel picking and nitrogen fertilization on fennel (*Foeniculum vulgare*). Indian J Agron. 35 : 375-379.

Garg V K & Khanduja S D 1976. Nutritional status of some fruit trees grown on normal and alkali soils. Scientia Hort. 5 : 243-247.

Garg V K 1986. Varietal differences in sugar beet yield and quality due to soil exchangeable sodium. J.Indian Soc. Soil Sci. 34 : 572-576.

Garg V K 1987. Soil chemical appraisal In: T N Khoshoo (Ed) Ecodevelopment of Alkaline Land Banthra - A Case Study (pp 15-18) NBRI, CSIR, PID New Delhi.

Garg V K 1998. Interaction of tree crops with a sodic soil environment: Potential for rehabilitation of degraded environments. Land Degrad. Develop. 9 : 81-83.

Gill B S & Samra J S 1986. Effect of rate and time of nitrogen application on the seed yield of fennel (*Foeniculum vulgare*). Indian Perfumer 30 : 261-264.

Graifenberg A, Botrini L, Giustiniani L & Lipucci Di Paola M 1996. Salinity affects growth, yield and elemental concentration of fennel. Hort Sci. 31 : 1131-1134.

Jackson M L 1967. Soil Chemical Analysis. Prentice Hall of India, New Delhi.

Khoshoo T N (Ed) 1987. Ecodevelopment of Alkaline Land Banthra - A Case Study. NBRI, CSIR, PID, New Delhi.

Lal H, Rathore S V S & Dadhwal K S 1997. Seed quality and nutrient uptake by coriander as influenced by irrigation and Mixtalol spray. J. Indian Soc. Soil Sci. 45 : 230-234.

Maurya K R 1990. Effect of date of sowing on yield and essential oil content in coriander (*Coriandrum sativum* L). Indian Perfumer 34 : 60-182.

Panse V G & Sukhatme P V 1961. Statistical Methods for Agricultural Workers I.C.A.R, New Delhi.

Pruthi J S 1976 .The Land and the People: Spices and Condiments. National Book Trust of India, New Delhi.

Richards L A (Ed) 1954. Diagnosis and Improvement of Saline and Alkali Soils, US Dept.Agric Handb No.60 .

Sharma R N & Prasad R 1990. Nitrogen and irrigation requirement of fennel. Indian J. Agron. 35 :449-451.

Singh S B & Abrol I P 1985. Effect of exchangeable sodium percentage on growth,yield and chemical composition of onion and garlic. J.Indian Soc. Soil Sci. 33 : 358-361.

Singh S B, Chhabra R & Abrol I P 1981. Effect of exchangeable sodium on the yield chemical composition and oil content of safflower and linseed. Indian J. Agric. 5 : 885-891.

Singh M 1999. Effect of doses and sources of sulphur application on oil content, seed and oil yield and quality of coriander (*Coriandrum sativum* L) Cv. S-33 on alfisols.

Tomar S S, Gupta K P, Abbas M & Nigam K B 1994. Effect of irrigation and fertility level on growth and yield of coriander (*Coriandrum sativum*). Indian J. Agron. 39 : 442-447.

Wealth of India 1950. A Dictionary of Indian Raw Materials and Industrial Products Vol.II pp.347-350. CSIR, Govt of India Press, New Delhi.

Yield attributes, seed, essential oil yield and oil content of coriander (*Coriandrum sativum* L.) as influenced by the graded levels of nitrogen, sulphur and zinc nutrition in red sandy loam soils

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Abstract

A field experiment was carried out on coriander (Cv. CIMPO S-33) in various combinations of N, S and Zn to achieve higher yields during *rabi*, 1996 with three levels of nitrogen at 0, 40 and 80 kg per hectare combined with two levels each of sulphur (0 and 12 ppm ha^{-1}) and zinc (0 and 2.5 ppm ha^{-1}). Besides, the recommended dose of phosphorus and potassium @ 30 kg per hectare each were applied at the time of sowing. The number of seeds per plant, seed weight per plant and stover yield were improved and resulted in higher seed yield. The magnitude of response obtained at $N_0S_0Zn_0$ level, the seed yield ranged from 543 kg ha^{-1} to 2088 kg ha^{-1} at $N_{40}S_{12}Zn_{2.5}$ level which further expidated to 2306 kg ha^{-1} at $N_{80}S_{12}Zn_{2.5}$ level indicating synergistic effect of N, S and Zn nutrients application. The essential oil yield of coriander enhanced significantly due to combined application of N, S and Zn ranging from 3.9 kg ha^{-1} ($N_0S_0Zn_0$) to 23.06 kg ha^{-1} ($N_{80}S_{12}Zn_{2.5}$) followed by 18.79 kg ha^{-1} ($N_{40}S_{12}Zn_{2.5}$). The essential oil content of 1 per cent was hallmark of combined application of N_{80}, S_{12} and $Zn_{2.5}$ compared to 0.700 per cent without nutrient application.

Key words : CIMPO S-33, coriander, *Coriandrum sativum* L., essential oil yield, essential oil content, seed yield

Introduction

Coriander (*Coriandrum sativum* L.) is cultivated commercially for its fruits which have a fragrant odour and pleasent aromatic taste. The odour and taste is due to the presence of an essential oil consisting d-Linalool which is used for flavouring liquors, perfumes, soap, tobacco and pharmacentical preparations etc. (Dimri & Narayana 1992).

In spite of large scale production of coriander seeds in a recent years, little atempt has been made to produce coriander seed for essential oil purpose in our country which has export value. This may be due to less oil content in indigenous seed material unlike Bulgarian seleetion (CIMPO S-33) and little attention has been paid towards manurial application. With this in view, the present investigation was under taken in Alfisol to study the effect of N, S and Zn on seed yield, essential oil yield and content of coriander under irrigated condition.

Materials and methods

A field experiment with cv. CIMPO S-33 was conducted during *rabi*, 1996 at University farm, UAS, GKVK, Bangalore. Soils were sandy loam, acidic (pH 5.90), electrical conductivity (0.04 dSm cm^{-1}), organic carbon (0.27%). The soil was low in available nitrogen (123 kg ha^{-1}), sulphur (4.6 ppm) and 0.49 ppm DTPA extractable zinc. The soil was well drained. The treatment consisted of three levels of nitrogen, (0, 40 and 80 kg N ha^{-1}), 2 levels of S (0 and 12 ppm) and 2 levels of Zn (0 and 2.5 ppm) and were replicated thrice. The nitrogen was applied in three splits as urea/ DAP. But, entire recommended dose of P_2O_5 and K_2O @ 30 kg ha^{-1} each were applied as diammonium phosphate and muriate of potash. The sulphur and zinc were applied in the form of elemental sulphur and zinc sulphate as it is cheap and readily available. Coriander (CIMPO S-33) was grown as test crop. Soil was analysed before commancement of the study by following standard procedures as outlined by Jackson (1973).

Table 1. Influence of nitrogen, sulphur and zinc levels on seed weight (g) per plant, number of seed $plant^{-1}$ and stover yield ($kg\ ha^{-1}$) of coriander.

Treatment		Seed weight (g) $plant^{-1}$	Number seed $plant^{-1}$	Stover yield ($kg\ ha^{-1}$)
Main effect				
Nitrogen	N_0	13.92	2983	2321
	N_{40}	23.41	3407	2840
	N_{80}	26.68	3876	2927
Sulphur	S_0	12.54	2720	2087
	S_{12}	30.08	4124	3305
Zinc	Zn_0	15.90	2847	2342
	$Zn_{2.5}$	26.77	3997	3050
Interaction effect				
$N_0S_0Zn_0$		2.93	1907	1192
$N_0S_0Zn_{2.5}$		15.40	3047	2503
$N_0S_{12}Zn_0$		12.83	2787	2469
$N_0S_{12}Zn_{2.5}$		24.50	4193	3121
$N_{40}S_0Zn_0$		8.07	2327	1639
$N_{40}S_0Zn_{2.5}$		17.23	3183	2661
$N_{40}S_{12}Zn_0$		28.30	3717	3361
$N_{40}S_{12}Zn_{2.5}$		40.03	4399	3698
$N_{80}S_0Zn_0$		11.37	2467	2051
$N_{80}S_0Zn_{2.5}$		20.53	3387	2476
$N_{80}S_{12}Zn_0$		31.90	3877	3339
$N_{80}S_{12}Zn_{2.5}$		42.90	5772	3841

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
N	0.282	0.827	28.2	82.7	26.21	76.86
S	0.230	0.675	23.0	67.5	21.40	62.76
Zn	0.230	0.675	23.0	67.5	21.40	62.76
N x S	0.399	1.169	39.9	116.9	37.07	108.70
N x Zn	0.399	NS	39.9	116.9	37.07	108.70
S x Zn	0.326	NS	32.6	95.4	30.26	88.75
N x S x Zn	0.563	NS	56.4	165.3	52.42	153.74

NS =Non significant

Nitrogen levels
N_0 - No Nitrogen
N_{40} - 40 kg N ha^{-1}
N_{80} - 80 kg N ha^{-1}

Sulphur levels
S_0 - No sulphur
S_{12} -12 ppm sulphur

Zinc levels
Zn_0 - No zinc
$Zn_{2.5}$ - 2.5 ppm zinc

Results and discussion

Number of seeds per plant

It is evidenced from Table 1 that there was improvement in number of seeds which was quite marked to the levels of N and their combinations were highly significant. The lowest seed number (1907) was obtained without application of nutrients ($N_0S_0Zn_0$). It was further stepped upto 5772 by application of 80 kg N conjunction with S_{12} and $Zn_{2.5}$ which was followed by $N_{40}S_{12}Zn_{2.5}$ (4399).

Seed weight per plant

It was significantly influenced by N, S and Zn applications (Table 1). The lowest seed weight 2.93 g was obtained without any nutrients application. It was further raised to 40.03 g at $N_{40}S_{12}Zn_{2.5}$. However, the highest seed weight per plant obtained was 42.90 g at $N_{80}S_{12}Zn_{2.5}$ level (Bhat and Sulikeri 1992).

Stover yield

Stover yield of coriander significantly improved by combined application of nitrogen, sulphur and zinc. The lowest stover yield of 1192 kg ha^{-1} was obtained at $N_0S_0Zn_0$ level (Table 1). It was further pushed to 1639 kg ha^{-1} at N_{40} level without nitrogen and sulphur application. But by incremental addition of N_{80} in conjunction with sulphur and zinc upto 12 and 2.5 ppm stover yield was rose to 3840 kg ha^{-1}. It was followed by $N_{40}S_{12}Zn_{2.5}$ (3698 kg ha^{-1}). Thus results indicated the preponderance of nutrition of zinc and sulphur to the coriander.

Seed yield

There was perceptable improvement in grain yield either due to levels of N or S or Zn or their combinations (Table 2). The differences in the yield due to levels of nitrogen, sulphur and zinc and their interaction effects were significant. The magnitude of response obtained at $N_0S_0Zn_0$ level ranged from 543 kg ha^{-1} to 2306 kg ha^{-1} with $N_{80}S_{12}Zn_{2.5}$ whereas at $N_{40}S_0Zn_0$ level it was varied from 638 kg ha^{-1} to 2088 kg ha^{-1} at $N_{40}S_{12}Zn_{2.5}$. The possible reason for increased seed yield is due to supplemental application of N, S and Zn nutrients. Further, a spurt increase in the seed yield was noticed by application of sulphur in conjunction with nitrogen and zinc which may be due to active role of sulphate (SO_4^{2-}) in the synthesis of organic S-compounds. Besides, application of Zn is closely involved in N-metabolism of the coriander (Surendra *et al.* 1994).

1000-seed weight

Similar trend of lesser magnitude was quite evident without nutrients nurishment (Table 2). The lowest recorded value of 1000-seed weight was 700 mg at $N_0S_0Zn_0$. Whereas, at N_{80} level in conjunction with S and Zn application, the highest test weight of 850 mg was recorded, which was followed by $N_{40}S_{12}Zn_{2.5}$ (830 mg). Thus, the results indicated influence of preponderance of nutrition of zinc and sulphur to coriander as evidenced by Bhat & Sulikeri (1992).

Essential oil yield

It is observed from Table 3, that the essential oil yield enhanced significantly not only with N application but also by combining with zinc and sulphur which varied from 3.90 kg ha^{-1} at $N_0S_0Zn_0$ to 23.06 kg ha^{-1} ($N_{80}S_{12}Zn_{2.5}$). It is evident from the results that incremental addition of N, S and Zn has spectacular influence on essential oil yield of coriander. The possible reason for increased yield in oil was due to increase in number of umbels/umblets per plant, 1000-seed weight, seed yield per unit area due to treatments effect and partially due to added nutrients of sulphur and zinc to impoverished soil which is reflected by increase in essential oil percentage of coriander oil. The spurt increase in the oil yield is due to intimate involvement of sulphur information of sulphydryl group which involves in bio-synthesis and sulphonation of essential oil.

Essential oil content

It is evidenced from the Table 3 that the lowest per cent essential oil content was 0.700 at $N_0S_0Zn_0$. The highest percent essential oil content was 1.00 per cent due to combined application of 80 kg ha^{-1} nitrogen, sulphur and zinc at 12 and 2.5 ppm, respectively. The results indicated the synergestic effect of N, S and Zn in enhancing the essential oil content. The possible justification for enhancement in the essential oil content is due to increased level of S and Zn with 80:30:30 kg NPK per hectare might have favourable effect on promoting the essential oil content of coriander. As sulphur is the constituent of co-enzyme (CoA-SH) which involved in biosynthesis of essential oil content.

Table 2. Effect of levels of nitrogen, sulphur and zinc on 1000-seed weight (mg) and seed yield (kg ha^{-1}) of coriander.

Treatment		1000-seed weight (mg)		Seed yield (kg ha^{-1})
Main effect				
Nitrogen N_0		745		1295
N_{40}		777		1659
N_{80}		793		1769
Sulphur S_0		738		1167
S_{12}		805		1981
Zinc Zn_0		752		1248
$Zn_{2.5}$		792		1901
Interaction effect				
$N_0S_0Zn_0$		700		543
$N_0S_0Zn_{2.5}$		740		1172
$N_0S_{12}Zn_0$		750		1490
$N_0S_{12}Zn_{2.5}$		790		1972
$N_{40}S_0Zn_0$		720		638
$N_{40}S_0Zn_{2.5}$		760		1913
$N_{40}S_{12}Zn_0$		800		1998
$N_{40}S_{12}Zn_{2.5}$		830		2088
$N_{80}S_0Zn_0$		730		782
$N_{80}S_0Zn_{2.5}$		780		1955
$N_{80}S_{12}Zn_0$		810		2034
$N_{80}S_{12}Zn_{2.5}$		850		2306
	S.Em±	CD at 5%	S.Em±	CD at 5%
N	3.41	9.45	4.91	14.40
S	2.17	6.01	4.01	11.76
Zn	2.17	6.01	4.01	11.76
N x S	4.10	11.36	6.95	20.37
N x Zn	4.10	11.36	6.95	20.37
S x Zn	3.41	9.45	5.67	16.63
N x S x Zn	6.19	17.16	9.82	28.81

NS = Non significant

<u>Nitrogen levels</u>
N_0 - No Nitrogen
N_{40} - 40 kg N ha^{-1}
N_{80} - 80 kg N ha^{-1}

<u>Sulphur levels</u>
S_0 - No sulphur
S_{12} -12 ppm sulphur

<u>Zinc levels</u>
Zn_0 - No zinc
$Zn_{2.5}$ - 2.5 ppm zinc

Table 3. Essential oil yield (kg ha^{-1}) and oil content (%) of coriander as influenced by levels of nitrogen, sulphur and zinc

Treatment	Essential oil yield (kg ha^{-1})	Essential oil content (%)
Main effect		
Nitrogen N_0	9.74	0.746
N_{40}	13.32	0.783
N_{80}	14.82	0.813
Sulphur S_0	8.42	0.717
S_{12}	16.83	0.844
Zinc Zn_0	9.55	0.750
$Zn_{2.5}$	15.70	0.811
Interaction effect		
$N_0S_0Zn_0$	3.90	0.700
$N_0S_0Zn_{2.5}$	8.20	0.717
$N_0S_{12}Zn_0$	11.10	0.767
$N_0S_{12}Zn_{2.5}$	15.78	0.800
$N_{40}S_0Zn_0$	4.47	0.700
$N_{40}S_0Zn_{2.5}$	14.03	0.733
$N_{40}S_{12}Zn_0$	15.98	0.800
$N_{40}S_{12}Zn_{2.5}$	18.79	0.900
$N_{80}S_0Zn_0$	5.60	0.717
$N_{80}S_0Zn_{2.5}$	14.34	0.733
$N_{80}S_{12}Zn_0$	16.27	0.800
$N_{80}S_{12}Zn_{2.5}$	23.06	1.000

S.Em±	CD at	S.Em± 5%	CD at	5%
N	0.236	0.692	0.011	0.033
S	0.193	0.565	0.009	0.027
Zn	0.193	0.565	0.009	0.027
N x S	0.334	0.979	0.016	0.047
N x Zn	0.334	0.979	0.016	0.047
S x Zn	0.273	0.799	0.013	0.039
N x S x Zn	0.472	1.384	0.023	0.069

NS = Non significant

<u>Nitrogen levels</u>
N_0 - No Nitrogen
N_{40} - 40 kg N ha^{-1}
N_{80} - 80 kg N ha^{-1}

<u>Sulphur levels</u>
S_0 - No sulphur
S_{12} -12 ppm sulphur

<u>Zinc levels</u>
Zn_0 - No zinc
$Zn_{2.5}$ - 2.5 ppm zinc

References

Bhat V R & Sulikeri G S 1992. Effect of nitrogen, phosphorus and potassium on seed yield and yield attributes of coriander (*Coriandrum sativum* L.). Karnataka J. Agric. Sci. 5(1) : 26-30.

Dimri B P & Narayana M R 1992. Cultivation of coriander (Var. CIMPO S-33) in India. Farm Bull No. 23, CIMAP, Lucknow.

Jackson M L 1973. In Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Surendra S, Tomar Gupta K P, Mohd Abbas & Nigam K B 1994. Effect of irrigation and fertility levels on growth and yield of coriander (*Coriandrum sativum*). Indian J. Agron. 39(3) : 442-447.

Production methods for aromatic plants in South India

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Abstract

Aromatic plants are of immense commercial potential in south India. Though several improved production technologies for these crops have been developed, it becomes increasingly important that a strategy should be evolved for future in order that all the inputs in the production systems can be carefully balanced while not interfering with the natural ecosystems. This requires a strategy that takes into account productivity, sustainability and at the same time commercial viability since these products will attract increasing attention for both internal trade and exports. Researches conducted at CIMAP, field station, Bangalore during the past two decades had thrown light on various aspects of production technology. They include (1) Identification and rectification of nutrient deficiencies (2) Optimum management of nutrients (3) Optimum use of water and its efficient interaction with nutrients (4) Development of cropping systems which include components of aromatic crops and food crops. Also, several studies made have given opportunity to understand the phenomenal changes in soil fertility parameters in a long run. Combination of organics and inorganics have greatly improved the efficiency of production systems. The results of studies on the above will be discussed. Thus focussing on future strategies to combine appropriate production methods will help the productivity and agronomic viability of aromatic crops in south India.

Key words : aromatic plants, essential oils, production methods.

Introduction

Aromatic plants form a very important group of plants for diversification of commercial agriculture in south India. These plants yield essential oils of varied chemical constitutions. Essential oils and their products are widely used in flavour, perfume and pharmaceutical industries and more recently in aromatherapy. India has been a pioneer in the production of several essential oils. India produces nearly 16000-20000 tonnes of essential oils valued at nearly Rs.1000 crores. Essential oils and their products worth Rs. 700 crores are exported to the world markets. South India has been a traditional home for several essential oil bearing plants. Red soil regions in the semi-arid tropical parts of south India sustain production of a variety of essential oils. Recent trends of commercial agriculture and the need for sustainable production systems has placed great demand for evolving appropriate production methods for various crops. Since aromatic plants are viewed as alternatives in the diversification programme of commercial agriculture and in production systems in marginal lands and watershed areas, there is a need to develop a strategy for future in order that sustainable production systems are developed for these crops.

During the past nearly 20 years, several studies were made at CIMAP, Field Station, Bangalore on improved production methods for several commercially important aromatic crops. Some of the important commercial aromatic crops are: Java citronella (*Cymbopogon winterianus*), lemongrass (*Cymbopogon flexuosus*), palmarosa (*Cymbopogon martinii* var. motia), scented geranium (*Pelargonium graveolens*), davana (*Artemisia pallens*), coriander (*Coriandrum sativum*), rosemary (*Rosmarinus officinalis*), patchouli (*Pogostemon cablin*), *Eucalyptus citriodora*, *Tagetes minuta* etc. In this paper, results of research on production methods of these crops are discussed in detail.

Nutrient management

Identification and rectification of nutrient deficiencies form basic components of production technology of aromatic plants. Usually, red soils are medium to low in soil fertility with emerging deficiencies of certain secondary and micro nutrients. Mostly, these soils are deficient in nitrogen and therefore several experiments were conducted to study the response pattern to applied nitrogen. The results have shown that all the aromatic crops under study have responded significantly to applications of N with the result that the essential oil

Table 1. Response pattern of aromatic crops to N and their N recovery

Crop (kg/ha/yr)	N dose over control	% Improvement (%)	N recovery	Reference
Java citronella	400	81.7	<20	Prakasa Rao *et al.* (1983_b) Prakasa Rao *et al.* (1985_b)
Lemongrass	100	58.7	29-38	Prakasa Rao *et al.* (1985_c)
Palmarosa	240	49.0	38-54	Prakasa Rao *et al.* (1985_a) Prakasa Rao *et al.* (1989)
Geranium	240	69.2	18-60	Prakasa Rao *et al.* (1988)
Davana	150	54.9	32-54	Prakasa Rao *et al.* (1983_c)
Coriander	50	29.9	12-21	Prakasa Rao *et al.* (1983_a)
Rosemary	300	60.5	-	Prakasa Rao *et al.* (1999_b)
Tagetes minuta	*50*	*68.4*	-	*Prakasa Rao et al. (1999_a)*

Table 2. Efficient N management techniques (test crop: Java citronella)

Techniques	% improvement over conventional method	Reference
Split application	16	Prakasa Rao *et al.* (1988_c)
Urea supergranules	12-15	Prakasa Rao *et al.* (1984)
Neem cake coated urea	25	Prakasa Rao *et al.* (1985_b)
DCD-treated urea	31	Prakasa Rao and Puttanna (1994)
Fe-deficiency correction	36	Puttanna *et al.* (1993)
Combination of organics and inorganics	33	Puttanna and Prakasa Rao (1997)

production could be enhanced by 30 to 82% with the application of nitrogen fertilizers (Table 1). While N fertilizers are added to a production system, it is important that their use efficiency has to be studied in order to understand the pathways of movement of this element in light soils such as red soils. With frequent irrigations, the nutrient which is predominantly found in NO_3 form is subject to leaching losses which can contribute to pollution of ground water. Also, some of the inorganic nitrogen is lost as ammonia gas through the process of volatilization which can be reduced by placement. These losses not only render production systems uneconomical but also create environmental pollution. Studies made at CIMAP, Field Station, Bangalore have revealed very low recoveries of nitrogen by these crops (Table 1). Several methods for efficient management of nitrogen fertilizers in aromatic plants have been evolved for these crops in order to minimise nitrogen losses as well as economise N use (Table 2). Use of nitrification inhibitors such as neem cake, dicyandiamide, benzotriazole, split application of N, combination of organics and inorganics etc., have greatly enhanced N use efficiency by these crops. Such methods can potentially improve the economics of these production systems. Sometimes under intensive cultivation of these aromatic crops with high nitrogen applications and frequent irrigations, it is possible that deficiencies of some other nutrient elements can render the production system unviable. For instance, iron deficiencies can reduce responsiveness of Java citronella

Table 3. Phosphorus and potassium deficiencies in aromatic crops

Crop	P (%) in leaves		K (%) in leaves		% reduction in oil content
	Normal	Deficient	Normal	Deficient	
Lemongrass	0.08	0.06	1.21	0.42	4
Palmarosa	0.23	0.18	1.35	1.44	7
Patchouli	0.23	0.09	1.96	1.07	14
Cinnamon	0.09	0.05	1.30	0.81	33

(Source : Prakasa Rao *et al.* 1996)

Table 4. Interaction effect of P and K applications on essential oil yields of palmarosa

P level (kg P/ha/yr)	Essential oil yield (kg/ha/6 havests) K level (kg K/ha/yr) 0	33.3	66.6
0	33.0	42.2	39.2
17.5	41.0	36.0	44.2
35.0	47.1	44.2	41.7
52.5	36.8	48.4	55.8
	L.S.D. (P=0.05)=10.6		

Source : Prakasa Rao *et al.* (2000)

to N applications (Puttanna *et al.* 1993) and rectification of the deficiency by $FeSO_4$ spray enhanced essential oil yields by nearly 36%. Similarly, deficiencies of phosphorus and potassium were observed in crops such as lemongrass, palmarosa, patchouli and cinnamon (Table 3). These deficiencies can reduce the yields and also alter the content and chemical constitution of the essential oils (Prakasa Rao *et al.* 1996). Also, it was found that perennial aromatic grass, palmarosa develops P and K deficiencies in a long run as shown by a recent study (Prakasa Rao *et al.* 2000). This study has shown that palmarosa responds to applications of phosphatic (120 P_2O_5 kg/ha/yr) and potassic (80 K_2O kg/ha/yr) fertilizers and interestingly the interactions were significant (Table 4). In such perennial crops, depletion of soils of P and K takes place which requires rectification to maintain the productivity of the systems as well as the fertility of the soil. Use of spent material of citronella in the cultivation of citronella improved the organic matter status of soils (Puttanna & Prakasa Rao 1997). It is also important to understand the nutrient removal pattern by aromatic crops either in pure or in intercropping systems. The data collected over several years (Table 5) has shown that these crops when intercropped with food or fodder crops, remove large quantities of nutrients necessitating proper management of soil fertility. Thus optimum management of nutrient forms a basis in proper production methods of aromatic plants.

Table 5. Increase in nutrient removal by improved cropping systems

Cropping system	% increase in nutrient removal over pure crop			Reference
	Nitrogen	Phosphorus	Potassium	
Citronella + cowpea based rotation	177	140	91	Prakasa Rao *et al.* (1988$_a$)
Citronella + greengram based rotation	77	64	41	
Geranium + cowpea	30	-	-	Prakasa Rao *et al.*(1986)
Geranium + blackgram	20	-	-	
Palmarosa + blackgram based rotation	60	41	28	Prakasa Rao *et al.* (1994)
Palmarosa + sorghum based rotation	57	109	24	

Water management and its interaction with nutrients

Hitherto, very little work has been done on understanding water requirements and its management in aromatic crops. In red soils of semi-arid tropics, water is one of the limiting factors for successful production of aromatic crops. CIMAP, field station, Bangalore has generated information on categorisation of aromatic crops based on their suitability to irrigated and rainfed conditions. Crops such as Java citronella, geranium, davana, coriander, patchouli, rosemary, *Tagetes minuta* have to be necessarily cultivated under irrigated conditions for deriving economic yields whereas crops such as palmarosa, lemongrass, *Eucalyptus citriodora,* cinnamon, *Bursera delpechiana* can be cultivated under rainfed conditions. However, data generated subsequently has shown that in order to derive maximum production benefits from these crops, appropriate management of water is important. The water requirements of crops such as Java citronella was found to be as high as 1750 mm for 2 years and water use efficiency ranged from 0.20 to 0.28 l oil/ha/mm^{-1} (Singh *et al.* 1996$_c$). The consumptive use of water of geranium (*Pelargonium graveolens*) varies betwseen 70-95 cm/yr (Singh *et al.* 1996$_b$). However, this requirement varies with the depth of irrigation water and by optimising the depth to 30mm, the consumptive use could be restricted to 82.5 cm/yr. Research carried out on scheduling of irrigation on some important aromatic crops has yielded useful results. For example, irrigating citronella at 0.8 IW : CPE ratio or –60 kPa soil matric potential (Singh *et al.* 1996$_a$) or irrigating geranium at 0.5 IW : CPE ratio has yielded maximum essential oils (Singh *et al.* 1996$_b$). However, in production systems, single factor effects do not give complete understanding of the crop growth. Therefore, studies were initiated to find the interactions of water and nutrients of some of the important aromatic crops. Java citronella can respond to applications of high doses of N (400 kg/ha/yr) at –40 kPa soil matric potential (Singh *et al.* 1996$_a$) and similarly, at this level of N, 25 mm depth of irrigation has given the maximum benefit. In case of geranium, combination of irrigation at 0.5 IW : CPE ratio and N at 100 kg/ha/yr has resulted in the maximum essential oil yields (Singh *et al.* 1996$_b$). Adopting improved irrigation methods such as broad bed and furrow method in citronella (Singh *et al.* 1996$_c$), alternate furrow irrigation in geranium and patchouli (Prakasa Rao *et al.* 1998) have saved considerable water to an extent of 30-50% thus improving the water use efficiency tremendously. Some of the salient features of water management studies on some important aromatic crops are presented in Table 6.

Cropping systems

With dwindling arable land and increased demand for food and related crops, it seems that more land area

Table 6. Water management studies in some important aromatic crops

Crop	Water requirement	Irrigation Schedule	Improved methods	Interaction with	Reference
Java citronella	2450 mm/ 2 yrs	at 0.8 IW/CPE or –40 kPa soil matric potential	Broadbed and furrow method	nitrogen Significant	Singh *et al.* ($1996_{a,c}$)
Scented geranium	825 mm/yr	at 0.50 IW/CPE ratio	Alternate furrow method	Significant	Singh *et. al.* (1996_b), Prakasa Rao *et al.* (1998).

Table 7. Cropping systems in aromatic crops

Intercropping system	Improvement in land use efficiency	Reference
Java citronella+(cowpea-fingermillet)	46%	Prakasa Rao *et al.* (1988_a)
Scented geranium +blackgram	33%	Prakasa Rao *et al.* (1986)
Palmarosa +black gram	15%	Prakasa Rao *et al.* (1994)

will not be available exclusively for cultivation of crops such as aromatic crops. Therefore, a strategy has to be worked out incorporate these crops into the regular agricultural systems in order that more land use efficiency can be achieved while maintaining the basic agricultural production systems. Several studies were made at CIMAP, field station, Bangalore on the performance of intercropping systems involving some aromatic crops and food/fodder crops. Encouraging results were obtained where land use efficiencies have tremendously improved from 15 to 46% (Table 7). For instance, in Java citronella, intercropping of crop rotations involving food crops has resulted in increasing the land area efficiency in terms of Area Time Equivalency Ratio by 21 to 46% (Prakasa Rao *et al.* 1998). Similarly, the improvement in land use efficiency in palmarosa was 9-24% (Prakasa Rao *et al.* 1994) and in geranium from 29-33% (Prakasa Rao *et al.* 1986). In most of these studies, it has been possible to derive bonus yields of food/fodder crops over and above the normal yields of perennial aromatic crops, thus making the production systems more economically viable. However, such systems place a greater demand on soil nutrients necessitating replenishment of soil nutrients by external additions either through inorganic or organic forms. It is possible to design appropriate intercropping systems involving aromatic and food crops in south India to meet needs of aromachemical industries as well as food requirements.

Residue management

Most of the aromatic crops are steam distilled to derive essential oils and often the residue left is bulky and can be considered as an agricultural waste. Several studies were made at CIMAP, field station, Bangalore to characterize and utilise such wastes. For example, citronella spent grass has been shown to retard the release of N from urea (Puttanna & Prakasa Rao 1993) and it has substantially improved the yields of these crops in a field study where as much as 150 kg/ha/yr could be saved while maintaining the production levels (Puttanna & Prakasa Rao 1997). Similarly, use of palmarosa spent material has helped to conserve soil under rainfed conditions and its incorporation in soil has increased the yields of palmarosa yields as much as 30% (Prakasa Rao *et al.* 2000). The distillation residues could be converted into nutrient rich vermicompost (unpublished data) and also citronella spent material was found to be useful in mushroom production (CIMAP 1997). Thus it is possible to recycle and find alternate uses of residues derived from aromatic plants which help to sustain fertility, productivity of the soil in the long run as well as to utilise in diversified activities such as mushroom, vermicompost production.

New crops

It is a continuous endeavour to introduce and acclimatize new aromatic crops and to standardise agro-and distillation technologies for them. Recently, crops such as rosemary (Prakasa Rao *et al.* 1999_b) and *Tagetes minuta* (Prakasa Rao *et al.* 1999_a) have been agronomically and chemically evaluated in a typical red soil in Bangalore. Their field distillation methods have also been successfully standardised for the production of these oils for commercial acceptability. Thus development of production methods dynamically will help greatly to design strategies for sustainable and economically viable systems where aromatic plant production could take place without disturbing the ecosystem as well as production of agricultural crops.

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References

CIMAP 1997. Central Institute of Medicinal & Aromatic Plants, Lucknow Annual Report (1996-97) p. 142.

Prakasa Rao E V S, Gopinath C T & Ganesha Rao R S 1998. Alternate furrow irrigation for geranium (*Pelargonium graveolens*) and patchouli (*Pogostemon cablin*). J. Med. Arom Pl Sci. 20 : 1036-1037.

Prakasa Rao E V S, Narayana M R, Singh M & Puttanna K 1983_b. Effect of N, P, K fertilizers on growth, yield and nutrient uptake in Java citronella (*Cymbopogon winterianus* Jowitt.) Z. Acker & Pflanz (J. Agron. & Crop Sci.) 152, 279 : 283.

Prakasa Rao E V S, Singh M & Ganesha Rao R S 1985_c . Effect of N, P and K fertilizers on growth, yield and nutrient uptake in lemongrass (*Cymbopogon flexuosus*). Intern J. Trop. Agri. 3(2) : 123-127.

Prakasa Rao E V S, Singh M & Ganesha Rao R S 1986. Effect of nitrogen fertilizer on geranium (*Pelargonium graveolens* L. Her. ex. Ait.) cowpea and blackgram grown in sole cropping and intercropping systems. *Intern. J. Trop. Agri.* 4 (4) : 341 - 345.

Prakasa Rao E V S, Singh M & Ganesha Rao R S 1988_b. Effect of plant spacings and nitrogen levels on herb and essential oil yields and nutrient uptake in geranium (*Pelargonium graveolens* L. Her. ex. Ait.)Intern. J. Trop. Agric. 6(1-2) : 95-101.

Prakasa Rao E V S, Singh M, Ganesha Rao R S & Ramesh S 1985_b. Effect of urea and neem cake coated urea on yild and concentration and quality of essential oil in Java citronella (*Cymbopogon winterianus* Jowitt). J. Agric Sci. Cambridge 104 : 477 - 479.

Prakasa Rao E V S, Singh M, Narayana M R & Chandrasekhara G 1984. Relative efficiency of prilled urea and urea-supergranules in Java citronella (*Cymbopogon winterianus* Jowitt). Fertilizer Res. 5 : 435 - 437.

Prakasa Rao E V S & Puttanna K 1994. Evaluation of dicyandiamide treated urea in Java citronella. J. Indian Soc. Soil Sci. 42(1) : 54-59.

Prakasa Rao E V S, Singh M & Chandrasekhara G 1988. Effect of nitrogen application herb yield, nitrogen uptake and nitrogen recovery in Java citronella (*Cymbopogon winterianus* Jowitt.) Indian J. Agron. 33 (4), 412-415

Prakasa Rao E V S, Ganesha Rao R S & Puttanna K 2000. Studies on *in situ* soil moisture conservation and additions of phosphorus and potassium in rainfed palmarosa (*Cymbopogon martinii* var motia) in a semi-arid tropical region of India. European J. Agron. (in press).

Prakasa Rao E V S, Ganesha Rao R S & Ramesh S 1996 Changes in content and composition of some essential oils due to possible deficiencies of phosphorus and potassium in a red soil region of Bangalore. Pafai J. Oct-Dec : 25-27.

Prakasa Rao E V S, Gopinath C T, Ganesha Rao R S & Ramesh S 1999$_b$. Agronomic and Distillation Studies on Rosemary (*Rosmarinus officinalis* L.) in a Semi-Arid Tropical Environment. J. Herbs, Spices & Med. Plants 6(3) : 25-30.

Prakasa Rao E V S, Singh M & Ganesha Rao R S 1988$_a$. Intercropping studies in Java citronella (*Cymbopogon winterianus* Jowitt.) Field Crops Res. 18 : 279-286.

Prakasa Rao E V S, Singh M & Ganesha Rao R S 1983$_c$. Effect of N and plant spacings on davana (*Artemisia pallens* Wall.) Intern. J. Trop. Agric. 1(3) : 187-192.

Prakasa Rao E V S, Singh M & Ganesha Rao R S 1994. Performance of intercropping systems based on palmarosa (*Cymbopogon martinii* var motia). Indian J. Agric. Sci. 64(7) : 442-445.

Prakasa Rao E V S, Singh M, Ganesha Rao R S & Narayana M R 1989. Response of palmarosa (*Cymbopogon martinii* (Roxb.) Wats. var. motia) to farmyard manure and nitrogen. Indian J. Agron. 34 (3), 376 - 378.

Prakasa Rao E V S, Singh M, Ganesha Rao R S and Rajeswara Rao B R 1985$_a$ Effect of plant spacing and application of nitrogen fertilizer on herb and essential oil yields of palmarosa (*Cymbopogon martini* Stapf.var.motia). J. Agric. Sci. Cambridge 104, : 67-70.

Prakasa Rao E V S, Singh M, Narayana M R, Ganesha Rao R S and.Rao B R R 1983 Fertilizer studies in coriander (*Coriandrum sativum L*) J.Agric. Sci. Cambridge. 100 : 251- 252.

Prakasa Rao E V S, Syamasundar K V, Gopinath C T & Ramesh S 1999$_a$. Agronomical and Chemical Studies on *Tagetes minuta* Grown in a Red Soil of a Semiarid Tropical Region in India. J. Essent. Oil Res. 11 : 259-261.

Puttanna K & Prakasa Rao E V S 1993. Mineralisation of nitrogen and ammonia volatilisation from urea in presence of citronella spentgrass in red soils. In Sehgal *et. al.* (eds) Red and Lateritic soils of India. National Bureau of Soil Survey & Land Use Planning Publ. 37 p. 268-270.

Puttanna K & Prakasa Rao E V S 1997. Effect of incorporation of citronella spentgrass in a sandyloam soil on nitrogen economy and yield of citronella (*Cymbopogon winterianus* Jowitt.). J. Indian Soc. Soil Sci. 45(4) : 835-837.

Puttanna K, Narayana M R & Prakasa Rao E V S 1993. Bicarbonate - induced iron chlorosis in Java citronella. Commun. Soil Sci.Plant Anal. 24(19&20) : 2545-2551.

Singh M, Chandrasekhara G & Prakasa Rao E V S 1996$_a$. Oil and herb yields of Java citronella (*Cymbopogon winterianus* Jowitt.) in relation to nitrogen and irrigation regimes. J. Essential Oil Res. 8 : 531-534.

Singh M, Chandrasekhara G, Ganesha Rao R S & Prakasa Rao E V S 1996$_b$. Effect of irrigation and levels of nitrogen on herb oil yields of geranium (*Pelargonium graveolens* L. Her.ex. Ait) in semi-arid tropical India. J. Ess.Oil Res. 8 : 653-656.

Singh M, Ganesha Rao R S & Prakasa Rao E V S 1996$_c$ Effect of depth and method of irrigation and nitrogen application on herb and oil yields of Java citronella (*Cymbopogon winterianus* Jowitt.). J.Agronomy & Crop Science 177 : 61-64.

Cultivation of geranium (*Pelargonium* spp.) in the hilly regions of Tamilnadu

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Abstract

Geranium (*Pelargonium* spp.) is cultivated for the essential oil obtained from the herb. It is cultivated as a perennial crop under rainfed conditions in Nilgiris (Udhagamandalam) and Palani hills (Kodaikanal) regions of Tamilnadu. Central Institute of Medicinal and Aromatic Plants developed important agrotechnologies for improving the productivity of this crop. The salient features of a series of experiments conducted on spacing, response to fertilizers, varietal suitability and after harvest practices are discussed. The agrotechnology developed by this institute resulted in the stable economic yield to the tune of 25-30 kg/ha under rainfed conditions in the hilly regions of Tamilnadu.

Key words: geranium, fertilizer dosage, oil yield, production technology

Introduction

The essential oil of geranium is obtained by steam distillation of the tender parts (leaves and stems) of *Pelargonium* sp. It is a versatile essential oil with a fine rosy odour and stable in slightly alkaline medium. Commercial rhodinol ex- geranium forms part of many high-grade perfumes (Douglas 1969). France, China, Belgium, Spain, Morocco, Reunion islands are the major producers of geranium oil in the world. The world production of this oil is estimated to be around 175-200 tons with China leading the production with about 80 tons of the oil.

Cultivation of geranium in Tamilnadu

French christian priests introduced geranium to Yercaud in the Shevroy Hills (near Salem in Tamilnadu). During 1953, the Government Cinchona Department introduced the crop to Nilgiris and Anamalai Hills. The soils and climate of Nilgiris (Udhagamandalam in Tamilnadu) was found to be relatively more suitable for this crop. Geranium was introduced to lower Palani Hills (Kodaikanal) by the same department during early seventies. By 1975 the area occupied by geranium had extended up to 200 ha in Nilgiris and 32 ha in Palani Hills (Swami *et al.* 1959). Due to the efforts of Geranium Growers Associations in Nilgiris and Palani Hills, by 1983-1984 the area under this crop was about 952 ha in Nilgiris and 450 ha in Palani hills (Sastry & Sushilkumar 1999). The production also reached upto 20 tons/year from a meager 3-4 tons in the early seventies. However, subsequently for reasons given below, including the handing over of cinchona lands to TanTea for cultivation of tea , the area under geranium cultivation decreased substantially. (a)The variety that rapidly spread in the area

(citronellol rich, known as Algerian, Tunisian or Kodaikanal Local type) gave low oil yields of around 10 kg/ha. (b)The oil produced was purchased by the local traders during the early eighties at low sale price of around Rs 500/kg only. (c)The infrastructural facilities for the distillation of the oil did not develop and eucalyptus distillation stills were used., consequently the quality of oil produced was poor, (d) High incidence of wilt and nematode diseases decreased the productivity. (e) All the above factors adversely affected the margin of profit.

To commercialize this crop and to produce economically viable yields Central Institute of Medicinal and Aromatic Plants initiated a project for development of this crop. The research findings of the institute's field station at Kodaikanal are presented here.

Research findings

1. Varieties/Chemotypes

In recent years on account of the research and devel-

Table 1. Some important chemical constituents of different chemotypes available at Kodaikanal

Particulars	Per cent content in the oil		
	Hemanthi	Bipuli	Kunthi
Citronellol	51.0	26.2	12.5
Geraniol	2.0	22.1	44.9
Linalool	1.5	14.7	7.3
Isomenthone	10.9	6.9	7.3

opment and extension activities of this institute (CIMAP), the geranium cultivation is again on the rise. CIMAP has made available three cultivars (distinctly different chemotypes) using which the old cultivated populations are getting replaced in the Nilgiri area. The chemical constituents of the oils of the three types are presented in the Table 1. Variety Hemanthi is rich in citronellol, variety Kunthi is rich in geraniol and variety Bipuli is rich in both geraniol and citronellol. These are comparable to different oils available in the international trade.

2. *Quality assessment of the oil*

The oil content in the three varieties in different months of the year in Kodaikanal was studied and the data is presented in Table 2. Oil content was low in winter months and it was high during summer months in all the three varieties. Oil content was low in variety *Hemanthi compared to Kunthi and Bipuli.*

The chemical composition of the oils in different months is presented in Table 3. Low night temperature resulted in low geraniol content in the essential oil of Hemanthi whereas in higher geraniol content in the essential oils of both Bipuli and Kunthi(Sastry & Sushilkumar 1999).

3. *Nursery and Season*

Geranium is planted during June to November depending on the rainfall in the hill regions as it is grown as a rainfed crop. Nursery is raised during March-April for June-July planting and during July-August for North-East monsoon plantings. Medium wood cuttings from healthy plants are taken for nursery and dipped in 100 ppm of IBA solution for 15-20 minutes. They are planted in 1x3 m raised beds. The rooted plats will be available for planting in 75-90 days after planting (Narayana *et al.* 1986).

Table 2. Per cent oil content in the herbage of three chemotypes of geranium harvested at different times in 1997 at Kodaikanal, Tamilnadu, India during different months.

Month	Per cent essential oil content in the herbage		
	Hemanthi	Bipuli	Kunthi
January	0.13	0.20	0.21
February	0.15	0.25	0.21
March	0.14	0.14	0.22
April	0.14	0.19	0.25
May	0.14	0.33	0.31
June	0.25	0.33	0.27
July	0.20	0.25	0.27
August	0.12	0.20	0.28
September	0.20	0.25	0.20
October	0.12	0.25	0.20
November	0.13	0.25	0.23
December	0.12	0.20	0.21
Mean	0.15	0.24	0.24
S.E.+	0.04	0.05	0.04

4. *Population and Fertilizer management*

A spacing of 60x 45 cm was found to be ideal for Kodaikanal conditions. In a set of experiments conducted during 1986-88 it was observed that a fertilizer dose of 120:60:60 N: P: K kg/ha gave 46% higher yield (Table 4) than control (Rao *et al.* 1990) In another experiment conducted during 1996-98 it was observed application of 150 kg N/ha resulted in 50-65 % (Table 5) increase yield over no nitrogen application (Sastry *et al.* 1999). Foliar spray of urea (2%) and /or foliar spray of soluble fertilizer (NPK 19:19:19) at 2% after each harvest increased the yield by 10 to 48 % depending on the season.

5. *Weed control*

Spraying of glyphosate at 0.2% after each harvest resulted in control of weeds without any damage to the crop. This resulted in saving about 2/3rd of the expenditure on weeding.

6. *Harvesting and distillation*

Experiments conducted to find the contribution of the plant parts to the essential oil it was found that tender leaves contribute most to the biomass and they contain

Table 3. Effect of the harvest time on the chemical composition of the essential oil distilled from the crops of the different varieties

	Chemical constituent (per cent)											
	Hemanthi				Bipuli				Kunthi			
Month	G	C	L	IS	G	C	L	IS	G	C	L	IS
January	2.0	42.5	3.2	11.6	31.9	23.4	7.0	6.7	47.3	11.0	12.3	8.2
February	1.4	52.9	1.1	7.5	27.2	22.5	7.1	4.8	41.3	11.9	13.0	6.2
March	2.3	49.5	1.8	7.3	24.5	23.2	9.8	4.2	39.9	12.5	16.0	6.7
April	4.0	47.0	3.2	6.8	21.1	27.0	11.1	5.4	33.0	10.0	23.6	8.1
May	3.9	46.8	2.9	7.1	22.0	24.0	10.4	5.8	22.0	24.0	10.4	5.8
June	2.0	51.0	1.5	10.9	22.1	26.2	14.7	6.9	44.9	12.5	7.3	7.3
July	2.8	52.6	1.3	9.6	35.0	21.2	9.8	5.7	41.8	10.1	9.1	7.4
August	3.4	48.9	1.8	10.2	28.7	21.8	10.4	6.6	48.0	8.9	9.3	6.9
September	2.0	48.4	3.0	13.5	22.9	24.2	13.6	8.6	26.4	9.5	5.3	4.9
October	3.6	51.3	1.7	9.1	29.6	23.1	9.8	5.7	44.0	13.2	9.7	7.6
November	4.0	50.2	1.8	9.1	29.9	21.9	8.3	6.6	39.9	11.4	19.6	8.6
December	5.8	46.1	2.8	12.1	35.0	19.0	9.1	6.2	47.3	10.7	10.0	7.2
Mean	3.1	48.9	2.2	9.6	27.5	23.1	10.1	6.1	39.65	12.14	12.13	7.08
S.E.+	1.2	3.0	0.8	2.2	5.0	2.1	2.3	1.1	8.38	3.96	5.25	1.06

G = Geraniol, C = Citronellol, L = Linalool, IS = Isomenthone

Table 4. Total biomass (t/ha) and essential oil yield(t/ha) of geranium at different locations in relation to NPK fertilization

Nutrient levels,	Total biomass yield			Total essential oil yield		
Kg/ha	Hyderabad	Bangalore	Kodaikanal	Hyderabad	Bangalore	Kodaikanal
Nitrogen						
0	24.2	30.2	31.8	48.6	67.7	30.1
60	29.0	30.4	39.4	57.2	67.2	38.0
12030.6	33.0	46.6	62.0	73.6	45.7	
C.D(P=0.05)	5.7	02.9	00.7	12.2	05.3	04.7
Phosphorus						
0	29.7	30.7	36.7	56.1	68.2	36.6
26	28.1	31.7	41.8	55.8	70.9	38.8
C.D(P=0.05)	NS	N.S	00.5	N.S	N.S	N.S
Potassium						
0	28.1	31.7	38.4	55.3	70.8	35.9
50	28.0	30.6	40.2	56.6	68.3	39.9
C.D(P=0.05)	N.S	N.S	00.5	N.S	N.S	03.2

Table 5. Total herb yield(t/ha) in two different chemotypes as influenced by different levels of nitrogen during 1997-98

	Herb yield (t/ha)						
	1997			1998			
	June	October	Total	January	July	October	Total
Chemotypes							
Hemanthi	06.5	10.3	17.0	01.9	17.1	06.3	23.6
Bipuli	05.5	10.2	15.7	02.1	17.1	06.1	24.8
C.D (P=0.05)	00.7	NS	01.1	NS	NS	NS	NS
N-levels,Kg/ha							
0	05.0	08.4	13.5	01.0	10.0	04.7	15.7
75	06.5	09.4	16.3	01.9	14.0	05.6	17.3
150	06.1	10.8	16.8	02.1	18.3	07.4	27.9
225	06.2	10.3	16.4	02.1	18.3	06.8	27.2
300	06.2	10.7	16.7	02.9	20.8	06.3	30.1
C.D (P=0.05)	NS	01.2	01.7	00.4	01.3	00.2	01.4

Table 6. Essential oil composition of different chemotypes in relation to position of leaf.

Leaf no			Hemanthi				Bipuli			Kunthi		
	G	C	L	IS	G	C	L	IS	G	C	L	IS
1.00	5.22	51.37	2.57	7.82	37.50	19.73	13.93	5.77	56.93	9.70	4.39	5.51
2.00	4.27	52.91	2.74	8.27	33.06	20.77	12.58	5.13	43.52	11.88	10.41	6.14
3.00	2.26	55.27	1.94	7.92	29.55	21.98	14.58	4.90	33.36	17.00	11.99	6.34
4.00	0.47	51.64	2.40	8.47	22.10	23.87	19.98	6.87	27.28	16.66	9.71	5.24
5.00	0.77	37.21	5.96	6.73	29.04	25.78	9.16	5.99	32.99	8.73	3.59	4.07

G = Geraniol, C = Citronellol, L = Linalool, IS = Isomenthone

Table 7. Chemical constituents (Per cent) of the geranium oil as influenced by heaping and keeping the herb for different periods of times after harvest (Chemotype Kunthi)

Constituent	Hours after harvesting (heaped) Per cent				
	0	3	6	12	24
pinene	0.02	0.03	0.00	0.02	0.00
pinene	0.02	0.29	0.45	0.61	0.00
Cis rose oxide	0.74	0.69	0.30	0.04	0.00
Trans rose oxide	0.00	0.06	0.00	0.37	0.00
Menthone	0.03	0.35	0.63	0.39	0.00
Iso menthone	5.57	4.99	5.47	6.59	2.42
Linalool	11.86	8.66	9.79	7.93	3.87
Citronellol formate	3.33	3.58	3.34	4.07	2.22
Geraniol formate	6.07	1.19	1.49	2.01	2.67
Terpinol	0.25	1.80	0.00	0.00	1.38
Citronellol	13.92	8.92	6.86	8.29	7.77
Geraniol	41.93	40.12	45.78	43.93	16.34
Geraniol tigilate	0.79	0.06	1.07	0.70	0.13
Eudesmol	4.13	4.75	4.75	3.82	1.51
P.E.tigilate	0.41	0.67	0.92	0.61	0.10

the maximum oil (Table 6). Similarly harvesting the herb at the time of flower initiation was found to produce better quality of oil. Late harvesting resulted in drastic reduction of geraniol content of the oil. It was also observed that the herb should distilled with in three hours after harvest. Storing or heaping the herb resulted in drastic reduction in the geraniol content of the oil (Table 7).

7. Yield

It was observed that on an average about 20-25kg oil can be obtained per hectare.

The technology developed by The Central Institute of Medicinal and Aromatic Plants, Lucknow and its Field stations has successfully demonstrated that it is possible to cultivate and obtain economic yield of cultivate geranium under rainfed conditions in the hilly regions of Tamilnadu.

References

Douglas J S 1969. Essential oil crops and their uses.World Crops. 21(1):49-54.

Narayana M R, Prakasa Rao E V S , Rajeswara RaoB R & Sastry K P 1986. New agronomic practices of growing geranium in South India. In :Plantation crops (p 339-342). Oxford-IBH Publishing Co., New Delhi,

Rao B R R , Sastry K P, Rao E V S P & Ramesh S I 1990. Variation in yield and quality of geranium (*Pelargonium graveolens* L'Hert) under varied climatic and fertility conditions. J.Essen.Oil Res. 3 : 73-79.

Sastry K P, Sushil Kumar, Radhakrishnan Karuppaiyan & Sahul Hameed Mumtaz Saleem.1999. Agronomic assessment of the oil yield in two chemotypes of geranium at different levels of nitrogen. Presented as a poster during the "National seminar on the research and development in aromatic plants : current trends in biology, uses, production and marketing of the essential oils " held at CIMAP, Lucknow during 30-31st July, 1999.

Sastry K P & Sushil Kumar 1999. Current status of the cultivation of Geranium in Tamilnadu. Presented as a poster during the XVI Biennial seminar of PAFAI held at Jaipur during 17-18th, January, 1999.

Sastry K P & Sushil Kumar 1999. Quality of essential oils from three cultivars of geranium *Pelargonium graveolens* grown in the sub tropical agroclimate of Kodaikanal Hills. Presented as a poster during the XVI Biennial seminar of PAFAI held at Jaipur during 17-18th, January 1999.

Swamy A G , Sreshta N J & Kalayanasundaram S 1959. Cultivation of scented geranium (*Pelargonium graveolens*)on the Nilgiris. Indian Perfumer 3(2) : 3-5.

Prospects of cornmint (*Mentha arvensis* L. f. *piperascens* Malinv. ex Holmes) cultivation in South India

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Abstract

India is the leading producer and exporter of cornmint oil and its products such as menthol crystals, dementholised oil, mint terpenes etc. The cultivation of cornmint or menthol mint or Japanese mint (*Mentha arvensis* L.f. *piperascens* Malinvaud ex Holmes; Family : Lamiaceae) is largely confined to northern and north western India. Recent investigations and farmers' experiences have shown that south Indian States of Andhra Pradesh and Tamil Nadu are suitable for commercial cultivation of cornmint. In Andhra Pradesh, under semi-arid tropical climatic conditions, the crop can be planted almost through out the year, unlike in north India, where it is planted during January - February months. Menthol mint can be grown on red as well as black soils. The first harvest can be performed in about 100 days without loss in yield or quality of the essential oil. Subsequent harvests can be obtained at 45-60 day intervals depending on agroclimatic conditions and crop management. More than 3 harvests can be taken in a crop cycle. A farmer has taken as many as 7 commercial harvests in a crop cycle of 17-18 months with 63.5 t ha^{-1} biomass yield and 271.5 kg ha^{-1} essential oil yield. In Tamil Nadu, Japanese mint crop grown in a farmer's field and harvested at full bloom (120 days duration) yielded 20.0 t ha^{-1} biomass yield and 100 kg h^{-1} essential oil yield in one harvest. The quality of the essential oil produced in south India is comparable to that of north India. Due to more number of harvests, greater biomass and essential oil yields of cornmint and higher returns are possible in south India. Owing to the short duration of the harvests, it is also possible to introduce this crop in existing crop rotations or intercrop it in other agricultural / horticultural / spice / medicinal and aromatic crops. Currently, farmers are growing this crop in more than 500 acres in Andhra Pradesh and the area is increasing. If the industry is interested, south India can be used as an attractive and advantageous alternative area for commercially cultivating cornmint in the 21st century. The necessary agrotechnology for cultivating this crop in Andhra Pradesh has been developed.

Key words : cornmint, *Mentha arvensis*, mentha oil, mint.

Introduction

Cornmint or menthol mint or Japanese mint (*Mentha arvensis* L.f. *piperascens* Malinvaud ex Holmes; Family : Lamiaceae) was introduced into India from Japan. Within a span of four and half decades, India has become the largest producer of mint oil and its products namely, menthol, mint terpenes, dementholised oil etc. surpassing the production level of China. The cultivation of this crop is concentrated in the States of Uttar Pradesh, Punjab and Haryana. The performance of the crop was first tested in 1985 in the semi-arid tropical climate of Hyderabad, Andhra Pradesh (Rajeswara Rao & Singh 1988) based on the earlier reports on other mint species (Rajeswara Rao *et al.* 1983, 1984). Inspite of its good performance, commercial cultivation of the crop could not be started due to the low oil price (Rs. 150 kg^{-1}) prevailing at that time. The sudden increase in the oil price (Rs. >1000 kg^{-1}) in the late 1990's led to initiation of commercial cultivation in Andhra Pradesh. Currently more than 500 acres is under cultivation of this crop in Andhra Pradesh. This paper reviews the experimental work done on this crop in south India.

Materials and methods

Seven field experiments were conducted in the red sandy loam soils of low to medium fertility status and slightly acidic to neutral in pH in the semi-arid tropical climate of Hyderabad, Andhra Pradesh and in Chennai. Two of the experiments were performed in farmers' fields, while others were made in Central Institute of

Medicinal and Aromatic Plants Field Station, Hyderabad and Acharya N.G. Ranga Agricultural University, Hyderabad. The treatments included were different genotypes, propagating materials, planting dates, spacings, N levels, P levels, intercropping with rose-scented geranium and harvest schedules. In all these experiments, the crop was raised following normal agricultural practices, weeded manually and irrigated frequently to avoid moisture stress at any stage of crop growth. The above ground shoot biomass was harvested and recorded as biomass yield. Representative shoot samples were distilled either in the laboratory using Clevenger trap or in the field distillation unit to estimate essential oil concentration in the plant samples. The essential oil yield was computed by multiplying biomass yield with oil concentration and specific gravity of the oil.

Two more field studies were carried out by collecting different plant parts namely, whole herb, shoot stems, shoot leaves, stolon (runner) stems, stolon leaves and flowers from flowering (growing in black soil) and non-flowering (growing in red soil) plants. Essential oils were isolated from these parts and were compared for compositional variations.

In addition, essential oils isolated from different cultivars grown in Hyderabad were compared with an oil sample obtained from north India for differences in chemical composition.

Chemical composition of the oil samples was analysed with Perkin Elmer gas chromatograph (model 8500) fitted with flame ionisation detector (FID), GP-100 printer-plotter and an electronic integrator, using a bonded phase fused silica capillary column (BP-1; 25 m x 0.5 mm i.d., film thickness, 0.25 μm) coated with polydimethyl siloxane. Nitrogen at a flow rate of 40 ml min.$^{-1}$ (linear velocity : 34 cm sec.$^{-1}$) and 10 psi inlet pressure was the carrier gas employed. Temperature was programmed from 60 - 220°C at 5°C min.$^{-1}$ with a final hold time of 10 min. Injector and detector were maintained at 250°C and 300°C, respectively. The sample (0.1- 0.2 μl) was injected neat with 1:80 split ratio. Essential oil components were identified by comparing retention times of the peaks with those of reference compounds run under identical conditions, Kovat's retention indices with literature data and peak enrichment on co-injection of standard samples. Peak areas and retention times were measured by the electronic integrator. The relative amounts (peak area %) of individual constituents were computed from peak areas without FID response factor correction.

Results and discussion

Genotypes

Three genotypes namely, MAS-1, MAS-25 and MAS-77 (HY-77) were evaluated for biomass and essential oil yields. When planted in the first week of December, they gave 2 harvests (94 and 147 days after planting), 21.5-26.3 t ha^{-1} biomass yield, 135.6-162.8 kg ha^{-1} essential oil yield, Rs.9830 -10145 net profit ha^{-1} (with the oil price of Rs. 150 kg^{-1}) and responded to application of 120 kg N ha-1 (Rajeswara Rao & Singh 1988). In Tamil Nadu cv. Shivalik produced 20 t ha^{-1} biomass yield and 100 kg ha^{-1} oil yield from one harvest performed 120 days after planting when the plants were in flower (Rajeswara Rao *et al.* 1999c).

Propagating materials

Rhizome, runner (stolon) and shoot cuttings as propagating materials (Rajeswara Rao 1999a) recorded 24.3, 28.2, 26.4 t ha^{-1} biomass yield; 126.2, 161.2, 142.1 kg ha^{-1} essential oil yield; 63.8, 79.3, 74.8 kg ha^{-1} N uptake; 10.9, 13.8, 12.2 kg ha^{-1} P uptake and 71.4, 83.9, 79.7 kg ha^{-1} K uptake, respectively from 2 harvests. Thus, runner cuttings were superior to rhizome and shoot cuttings as propagating material (Kattimani 1998). Shoot cuttings with 8 leaves produced better rooting characters than those having more or less number of leaves (Kattimani *et al.* 1998).

Planting dates

Among the 5 planting dates tried, August, November and December planted crop (cv. Shivalik) produced significantly superior total biomass (63.5, 59.0, 48.2 t ha^{-1}, respectively) and total essential oil (271.5, 261.0, 235.9 kg ha^{-1}, respectively) yields compared to September and January planted cornmint. August and September planted crop gave 7 harvests, while other planting dates afforded 6 harvests (Rajeswara Rao 1999b). This is the first record of taking 6-7 harvests from this crop.

Row spacings

Four row spacings (30, 40, 50 and 60 cm) were tested with cv. MAS-1. The widest row spacing (60 cm) registered the highest biomass yield (26.7 t ha^{-1}), essential oil yield (155.2 kg ha^{-1}), N uptake (73.6 kg ha^{-1}), P uptake (12.0 kg ha^{-1}) and K uptake (78.6 kg ha^{-1}) from 2 harvests (Kattimani 1998).

Fertilizer application

Menthol mint responded to application of N (0, 75, 150, 225 kg ha^{-1}) and P_2O_5 (0, 40, 80 kg ha^{-1}) fertilizers. Application of 225 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} gave significantly higher biomass and essential oil yields and highest net return (Rs. 29284) from 2 harvests. 225 kg N ha^{-1} recorded 32.2 t ha^{-1} biomass yield, 156.3 kg ha-1 essential oil yield. 91.9 kg ha^{-1} N uptake, 15.2 kg ha^{-1} P uptake and 95.0 kg ha^{-1} K uptake. 40 kg P_2O_5 ha^{-1} registered 24.3 t ha^{-1} biomass yield, 123.8 kg ha^{-1} oil yield, 68.1 kg ha^{-1} N uptake, 12.1 kg ha^{-1} P uptake and 71.0 kg ha^{-1} K uptake (Kattimani 1998).

Intercropping

Intercropping of menthol mint cv. Shivalik in rose-scented geranium decreased biomass and essential oil yields of menthol mint by 53.4% and 59.1%, respectively (Rajeswara Rao 2000). However, tomato crop intercropped in widely spaced menthol mint (60 cm row spacing) gave bonus yield of 6.3 t ha^{-1} tomatoes which was equivalent to 26.6 kg of menthol mint oil (Rajeswara Rao 1999b).

Harvest schedules

Different harvest intervals were examined for the first (90, 100, 110 and 120 days after planting) and the second (40, 50 and 60 days after the first harvest) harvests. Harvests performed 100 days after planting (first harvest) and 60 days after the first harvest (second harvest) produced maximum phytomass (26.7 t ha^{-1}) and essential oil (143.1 kg ha^{-1}) yields and removed 61.8 kg N, 11.5 kg P and 71.5 kg K ha^{-1} (Kattimani 1998).

Oil quality

a) South India vs. North India : The chemical composition of oils isolated from 4 cultivars (MAS-1, HY-77, Gomti, Shivalik) grown in south India was compared with the oil of cv. Shivalik cultivated in north India. The concentrations of isomenthone, isomenthol+α-terpineol and menthyl acetate were higher in north Indian oil. The menthol content varied from 70.5-87.2% in south Indian oils in comparison to 75.5% in north Indian oil (Rajeswara Rao 1999b). The oil of cv. Shivalik grown in Tamil Nadu contained 69.5% menthol and 15.0% menthone (Rajeswara Rao *et al.* 1999c). All the oils were readily accepted in the market.

b) Different plant parts : Essential oils extracted from different plant parts revealed that flowers (53.2%) and runner stems (43.7%) contained minimum content of menthol, while shoot stems (78.2-82.3%) possessed maximum percentage of menthol. The menthone content varied from 4.6-30.2% in various plant parts. Stem oil, therefore, is important for imparting good quality to the oil (Rajeswara Rao *et al.* 1999a, 2000).

Experiments conducted so far clearly indicated the economic feasibility of cultivating menthol mint in south India. More studies are needed to evaluate the performance of the crop under different agroclimatic conditions and farming systems. Potential exists for its large-scale cultivation in south India.

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References

Kattimani K N 1998. Effect of planting material, spacing, nitrogen, phosphorus and harvest intervals on growth, biomass, nutrient uptake, oil yield and quality of Japanese mint (*Mentha arvensis* L.). Ph.D. thesis. Acharya N G Ranga Agricultural University, Hyderabad.

Kattimani K N, Reddy Y N & Rajeswar Rao B 1998. Effect of leaves on rooting of stem cuttings of Japanese mint. Karnataka J. Agric. Sci. 11 : 853 - 854.

Rajeswara Rao B R 1999a. Terminological jargon in mint literature. J. Med. Arom. Pl. Sci. 21 : 2 - 3.

Rajeswara Rao B R 1999b. Biomass and essential oil yields of cornmint (*Mentha arvensis* L.f. piperascens Malinvaud ex Holmes) planted in different months in semi-arid tropical climate. Indust. Crops Prod. 10 : 107 - 113.

Rajeswara Rao B R 2000. Effect of row spacings and intercropping with cornmint (*Mentha arvensis* L.f. *piperascens* Malinv. ex Holmes) on the biomass and essential oil yields of rose-scented geranium (*Pelargonium* species) J. Horti. Sci. Biotechnol. (communicated).

Rajeswara Rao B R, Bhattacharya A K, Mallavarapu

G R & Ramesh S 1999a. Volatile constituents of different parts of cornmint (*Mentha arvensis* L.) Flavour Fragr J. 14 : 262-264.

Rajeswara Rao B R, Bhattacharya A K, Singh K, Kaul P N & Mallavarapu G R 1999b. Comparative composition of cornmint oils produced in north and south India. J. Essent. Oil Res. 11 : 54 - 56.

Rajeswara Rao B R, Kaul P N, Bhattacharya A K & Naqvi A A 1999c. Cultivation of cornmint (*Mentha arvensis* L.f. *piperascens* Malinv. ex Holmes) in Tamil Nadu : Yield and quality of the essential oil. J. Essent. Oil Bearing Pl. 2 : 128-131.

Rajeswara Rao B R, Kaul P N, Mallavarapu G R & Ramesh S 2000. Comparative composition of whole herb, flowers, leaves and stem oils of cornmint (*Mentha arvensis* L.f. *piperascens* Malinvaud ex Holmes). J. Essent. Oil Res. (in press).

Rajeswara Rao B R, Prakasa Rao E V S & Singh S P 1983. Influence of NPK fertilization on the herbage yield, essential iol content and essential oil yield of bergamot mint (*Mentha citrata* Ehrh.). Indian Perfume. 27 : 77 - 79.

Rajeswara Rao B R & Singh K 1988. Production potential of improved genotypes of Japanese mint in Andhra Pradesh. PAFAI J. 10 (4) : 37-39.

Rajeswara Rao B R, Singh S P & Prakasa Rao EVS 1984. Effect of row spacing and nitrogen application on biomass yield, essential oil concentration and essential oil yield of bergamot mint (*Mentha citrata* Ehrh.). Indian Perfum. 28 : 150-152.

Agronomic investigation on lemongrass (*Cymbopogon flexuosus* (Steud.) Wats.) under semi-arid tropical conditions

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Abstract

Lemongrass (*Cymbopogon flexuosus* (Steud.) Wats.) is an important perennial aromatic grass cultivated in India. Lemongrass oil is a rich source of citral, which is used in perfumery and pharmaceutical industries. India is a major producer of lemongrass oil. Appropriate agronomic inputs such as fertilizers, plant population, irrigation have shown to increase the yield substantially. However, the interaction of certain factors appear to influence the oil production significantly. The response of N fertilizer was governed by water supply from 0.75 IW: CPE ratio to 0.25 IW : CPE ratio. A study made in lemongrass has shown that under intensive cultivation, narrow plant spacing (45 x 45 cm) and high N application (150 kg N/ha/yr) resulted in high essential oil yields. High oil yielding varieties of lemongrass have been evaluated, among them, Cauvery and Krishna gave more oil yield than OD 19, Pragati and CKP-25. Intercropping system improved the land use efficiency and natural resources. Content and quality of oil were not influenced by plant population, fertilizer and soil moisture regime.

Key words : essential oil, intercropping studies, irrigation, lemongrass, nitrogen, plant spacing, water use efficiency

Introduction

Lemongrass (*Cymbopogon flexuosus* (Steud.) Wats.) is a perennial, multi-harvest aromatic grass. The crop is cultivated to obtain citral-rich essential oil used in the perfumery, cosmetic and pharmaceutical industries. Traditionally lemongrass is grown in high rainfall area as a rainfed crop. But under semi-arid tropical conditions, lemongrass thrives well under irrigated conditions. Research showed that herb yield can be increased with nitrogen application (Prakasa Rao *et. al.* 1985). It appears from published data that no systematic studies have been carried out to assess the interaction effects of plant spacing, nitrogen and irrigation. Very meagre information is available about intercropping system and long-term studies on oil content, yield, quality and soil fertility in relation to nitrogen application. Hence the present studies were conducted to study the agronomical investigation on lemongrass under semi-arid tropical conditions.

Materials and methods

The field experiments were carried out at the Central Institute of Medicinal and Aromatic Plants, Field Station, Bangalore (13° 05'N, 77° 35'E, 930 m a.m.s.l.). The soil was a red sandy loam (alfisol) of medium fertility with pH of 6.5. The soil contains 0.4% organic carbon, 251 kg ha^{-1} available N, 15.8 kg ha^{-1} available P_2O_5 and 153 kg ha^{-1} exchangeable K_2O. The water holding capacity of the soil was 15.6% at –0.3 Mpa and 6.5% at –1.5 Mpa and bulk density 1.5 g cc^{-1}. The climate of the experimental site is characterised as semi-arid tropical with 890 mm mean annual rainfall. The mean minimum and maximum temperature ranges between 12°C-20°C and 26°C-36°C, respectively. The relative humidity is high which ranges between 73% and 91%.

Rooted slips of lemongrass were transplanted in the experimental plots of 12.96 m^2 on 4 August 1991. Full doses of P_2O_5 and K_2O at 40 kg ha^{-1} were applied as single superphosphate and muriate of potash at the time of planting in both years. Nitrogen was applied in six equal split doses at 60 days interval in the form of urea by placing at 5 cm below the soil in between the rows of lemongrass. Plants were harvested 20 cm above ground level. Weekly irrigation was given depending upon the climatic conditions. Weeds were removed by hand whenever necessary. Essential oil content was determined by steam distillation (Guenther 1948). Oil yield was calculated as a product of herb yield and oil content. The quality of essential oil (citral and geraniol) was determined by GLC on Perkin Elmer-8500 Gas Chromatograph fitted with a flame ionization detector (F.I.D.) and electronic integrator, using a 25 m x 0.25 mm BP-1 fused silica column. Column oven was heated from 120°C (3 min) to 230°C at 5°C min^{-1}. Injector and detector were kept at 250°C and 300°C, respectively.

Experiment 1. Effect of plant spacing and nitrogen on growth and yield of lemongrass

In the 1991-93 experiment, the treatment consisted of four plant spacings (60 x 60, 60 x 45, 60 x 30 and 45 x 45 cm) and four nitrogen levels (0, 50, 100 and 150 kg N ha^{-1} $year^{1}$) arranged in a split plot design with three replications. The plant spacing were in the main plots and nitrogen application rates were in sub plots. The crop was planted on 4 August 1991. Five harvests were obtained on May 1992, August 1992, January 1993, May 1993 and August 1993. At each harvest, fresh herbage yields of lemongrass were recorded.

Experiment 2. Effect of irrigation and nitrogen on herbage, oil yield and water use of lemongrass

This experiment was conducted during 1991-93 and 1993-95. The experimental treatments consisted of three levels of irrigation (0.25, 0.50 and 0.75 IW : CPE ratio) and three rates of N application (0, 100 and 200 kg ha^{-1}) with three replications. Irrigation levels were arranged in main plots and nitrogen levels in sub-plots in a split-plot design. Before imposing irrigation treatment, four common irrigations were given (at 25 mm water per irrigation) for the proper establishment of the crop.

Five harvests were taken during 2 years period (May 1994, August 1994, January 1995, May 1995 and August 1995).

Experiment 3. Intercropping studies in lemongrass

A field experiment was conducted during 1992-93. The treatments consisted of N levels (0, 50, 100 and 150 kg N $ha^{-1}year^{-1}$) and intercropping systems (lemongrass sole, lemongrass + blackgram, lemongrass + cowpea and lemongrass + soybean) along with sole crop of blackgram, cowpea and soybean. These treatments were arranged in a randomized block design with three applications. The intercrops were sown between the rows of lemongrass at a spacing of 10 cm between plants on 16 August 1992. Two harvests of lemongrass were taken during crop periods May 1993 and August 1993. The intercrops were harvested during November 1992. Land Equivalent Ratio (LER), Area x Time Equivalency Ratio (ATER) were calculated as suggested by Mead and Willey (1980) and Heibsch and Mc Collus (1987), respectively.

Experiment 4. Long-term studies on oil content, yield, quality and soil fertility of lemongrass in relation to nitrogen application

This experiment was conducted during 1992-97. The experimental treatments consisted of four nitrogen level (0, 50, 100 and 150 kg N $ha^{-1}year^{-1}$) with nine replications which were arranged in a randomised block design. This experiment was planted on 5 August 1992. Fourteen harvests of lemongrass were taken during the five year period. At each harvest, herb yields of lemongrass were recorded and essential oil content in the plant was determined.

Results and discussion

Experiment 1. Herbage and oil yields

Herbage and oil yield was markedly influenced by spacing (Table 1). Significant higher total herb yield of 81.8 t ha^{-1} was obtained with closer spacing of 45 cm x 45 cm compared to wider spacing of 60 cm x 60 cm (66.5 t ha^{-1}). There was an almost two fold increase of total herbage yield due to application of 150 kg N ha^{-1} (94.9 t ha^{-1}). Among the five harvests the second and fifth harvests substantially contributed towards total herbage yield. These results are parallel to the findings of Beech (1990) and Pal *et. al.*(1992).

The profound impact of nitrogen levels was also reflected in terms of oil yield. Oil yield increased gradually with harvesting at different intervals, irrespective of spacing and nitrogen levels. Even a wider spacing of 60 x 60 cm enhanced the oil yield at each cutting from 125 kg oil yield ha^{-1} at first harvest to 142.5 kg oil yield ha^{-1} at fifth harvest. Closer spacing of 45 cm x 45 cm resulted in higher oil at all harvests. Singh *et al.* (1983) reported that closer spacing of 30 cm x 30 cm was optimum for maximum herb and oil yield.

Experiment 2

Fresh herbage and essential oil yields increased significantly by irrigation although the effect was not significant for the change from 0.25 to 0.50 IW : CPE ratio at the first two harvests. As one would expect, the same results were obtained for oil yield. The

Table 1. Effect of plant spacing and nitrogen on herbage and oil yield of lemongrass

Treatment	Total herbage (t/ha)/2 yr	Total oil yield (kg/ha)/2 yr
Plant spacing (cm)		
60 x 60	66.46	530.83
60 x 45	71.47	558.33
60 x 30	72.68	570.42
45 x 45	81.80	645.17
SEm±	2.13	20.00
C. D. (P=0.05)	7.38	69.30
N level kg ha^{-1} $year^{-1}$		
0	48.39	395.60
50	66.67	529.90
100	82.43	640.80
150	94.91	738.40
SEm±	3.07	24.75
C.D. (P=0.05)	8.95	72.00

differences were significant and beneficial for the comparison of the 0.25 and 0.75 IW : CPE ratios for both herbage and oil yields. The low oil yield obtained at 0.25 IW :CPE ratio was attributed to moisture stress, which adversely affected crop growth. These results agree with that of Singh *et al.* (1996).

The application of 100 kg N ha^{-1} produced significantly higher fresh herbage and essential oil yields compared with that from 0 kg N ha^{-1} (control) as reported by Prakasa Rao *et al.* (1985) and Rajan *et al.* (1984). The application of N increased herbage and oil yield but there was no increased benefit from the highest application rate of 150 kg N ha^{-1} compared with that at 100 kg ha^{-1}.

Interaction effects of irrigation and N rates were significant for the production of herbage and essential oil yields. The response of lemongrass to increasing N application rates was greater at the highest than at the lower water regime.

Water use efficiency (WUE) by lemongrass was lowest in wet regimes and highest in dry regimes. The decrease in WUE at higher soil moisture regimes is due to a dilution effect, which is in agreement with the findings of Yadav & Prasad (1988) in sugar cane.

Table 2. Herbage, oil yield of lemongrass and legumes as affected by intercropping

Cropping system	Herb yield (t/ha)	Oil yield (kg/ha)	Legume seed yield (t/ha)
Lemongrass sole (L.G.)	31.19	212.0	
L.G. + Blackgram	30.24	213.5	0.38 (0.90)
L. G. + Cowpea	31.80	207.5	0.61 (1.36)
L. G. + Soybean	29.55	203.3	0.66 (0.82)
SEm±	1.93	11.93	-
C. D. (P=0.05)	N.S.	N.S.	-

Figures in paranthesis are for sole crops of the legume

Quality of essential oil was not influenced by moisture or by N treatment (data not presented).

Experiment 3

Studies were made to explore the possibility of intercropping food legumes with lemongrass. Result revealed that the food legumes like blackgram, cowpea or soybean could be intercropped in the initial stage of lemongrass to get extra yields over and above that of lemongrass, without affecting the yield of lemongrass (Table 2).

Lemongrass is a slow growing initially, leaving most of the land uncovered and hence low return results in the first year of planting. To avoid this loss and improve resource utilization a suitable intercrop may be grown.

Land use efficiency

The intercropping systems with lemongrass at 150 kg N ha^{-1} $year^{-1}$ resulted in LER, between 1.65 to 1.94 (Table 3) which indicate that 65-94% more land would

Table 3. Land Equivalent Ratios (LER) and Area x *Time Equivalency Ratios (ATER) in different intercropping systems with lemongrass at 150 kg N ha^{-1} $year^{-1}$*

Cropping Systems	LER	ATER
Lemongrass + Blackgram	1.70	1.33
Lemongrass + Cowpea	1.65	1.28
Lemongrass + Soybean	1.94	1.37

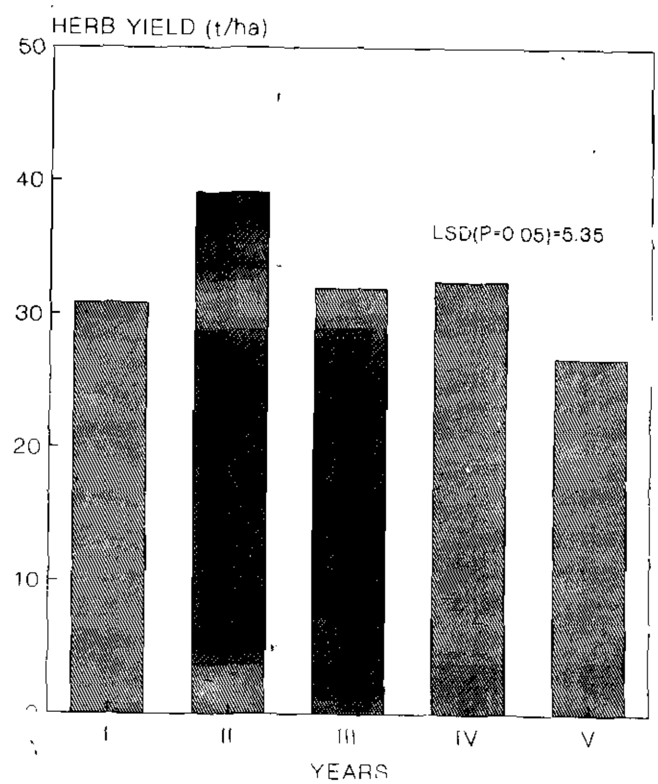
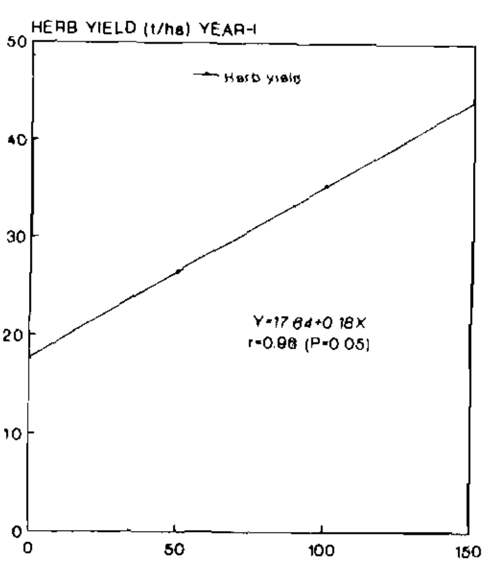


Fig. 1. Yield behaviour of lemongrass over a five year period.



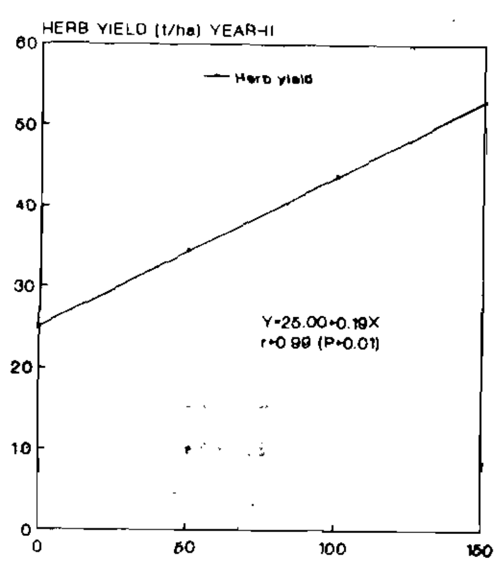
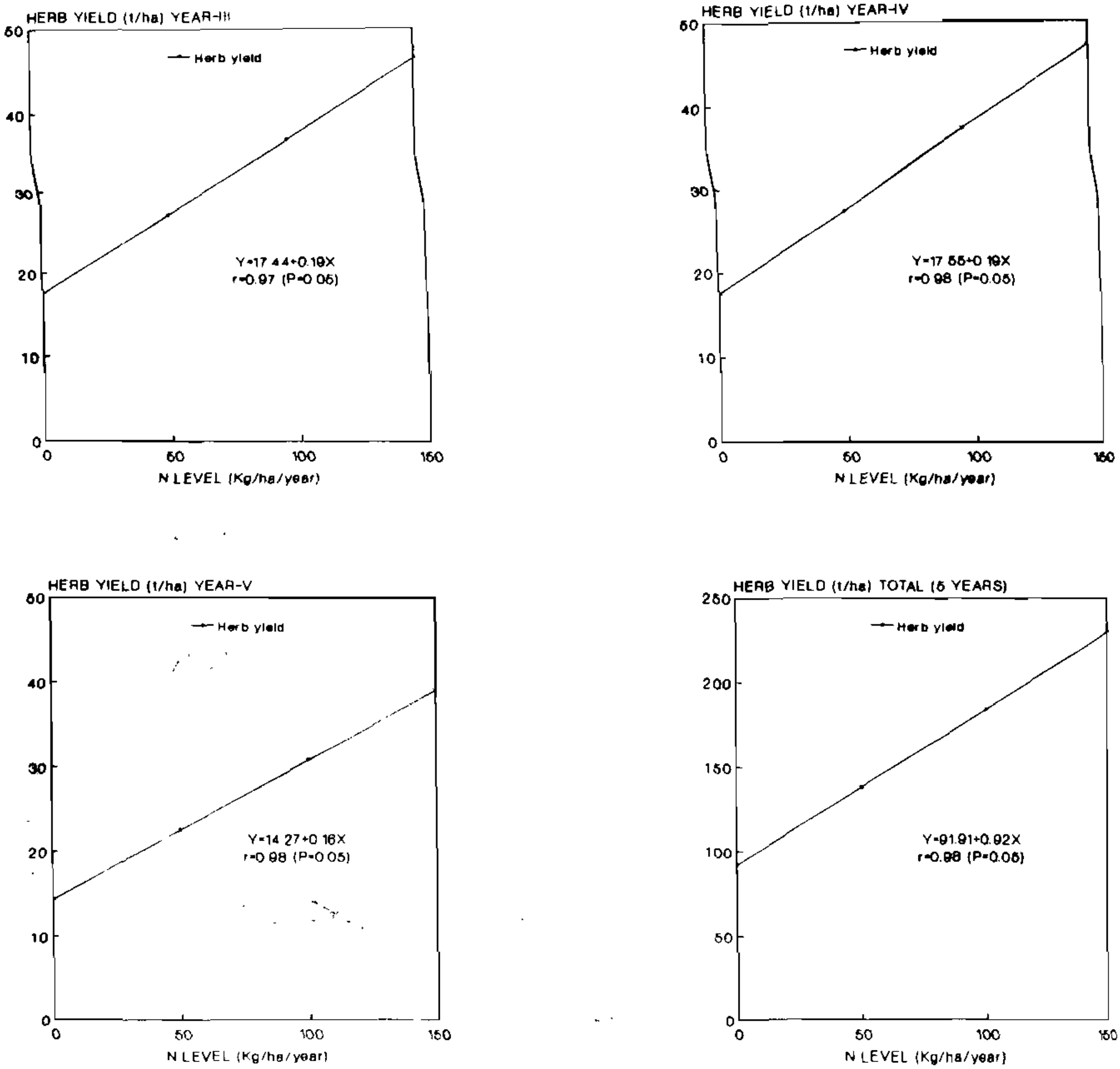


Fig. 2. Response pattern of lemongrass to nitrogen during different years of crop growth.

Fig. 2 (contd)


HERB YIELD (t/ha) YEAR-III
Herb yield
Y=17 44+0.19X
r=0.97 (P=0 05)
N LEVEL (Kg/ha/year)
HERB YIELD (t/ha) YEAR-IV
Herb yield
Y=17 55+0 19X
r=0 98 (P=0.05)
N LEVEL (Kg/ha/year)
HERB YIELD (t/ha) YEAR-V
Herb yield
Y=14 27+0 16X
r=0 98 (P=0 05)
N LEVEL (Kg/ha/year)
HERB YIELD (t/ha) TOTAL (5 YEARS)
Herb yield
Y=91.91+0.92X
r=0.98 (P=0.05)
N LEVEL (Kg/ha/year)

have to be planted to sole crops to achieve similar yield levels of lemongrass and the cropping systems tried in this study. Area x Time Equivalency Ratio (ATER) showed that there was an increase of 28-37% in land use efficiency in the intercropping systems.

Experiment 4

The herb yield of lemongrass differed significantly between years (Fig. 1). The yield in the second year was significantly higher than that of the first, third, fourth and fifth year. Similar results were reported in Java citronella (Prakasa Rao & Singh, 1991).

Application of nitrogen fertilizers increased the herb yield significantly in all the five years. The response function to N in various years are presented (Fig. 2). These functions were linear in all years and for total herb yield also.

The content and chemical composition of lemongrass oil were not affected by N application (data not presented). Soil analysis data shows that potassium was depleted and there was no effect on nitrogen and phosphorus except control.

Performance of lemongrass varieties at varying nitrogen level showed that application of 200 kg N ha^{-1} and variety Krishna gave significantly higher yield than other varieties (OD 19, Pragati, Cauvery & CKP-25).

References

Beech D F 1990. The effect of carrier and rate of nitrogen application on the growth and oil production of lemongrass (*Cymbopogon citratus*) in the Ord irrigation Area, Western Australia. Australian Journal of Experimental Agriculture 30 : 243-250.

Guenther E 1948. The production of essential oils: Method of distillation, enfleurage, maceration and extraction with volatile solvents. In : E. Guenther (ed.) The Essential Oil Vol. I pp 87-226. D. Van Nostrand, Princeton, New Jersey.

Hiebsch C K & Mc Collus R E 1987. Area x Time Equivalency Ratio. A method of evaluating the productivity of intercrops. Agron. J. 79 : 15-22.

Mead R & Willey R W 1980 The concept of Land Equivalency Ratio and advantages in yields from intercropping. Expt. Agric. 16 : 217-228.

Pal S, Chandra Suresh, Balyan S S, Singh A & Rao B L 1992. Nitrogen requirement of new lemongrass strain – CKP 25. Indian Perfumer 36 : 75-80.

Prakasa Rao E V S, Singh M & Ganesha Rao R S 1985 Effect of N, P and K fertilizers on yield and nutrient uptake in lemongrass. Int. J. Trop. Agric. 3(2) : 123-127.

Prakasa Rao E V S & Singh M 1991. Long-term studies on yield and quality of Java citronella (*Cymbopogon winterianus* Jowitt) in relation to nitrogen application. J. Essen. Oil Res. 3 : 419-424.

Rajan K C, Sadanandan N & Nair E V G 1984. Effect of graded levels of nitrogen on the yield and quality of lemongrass oil. Agric. Res. J. Kerala 22 : 37-42.

Singh R S, Pathak M G & Bordoiloi 1983. Citral of lemongrass under different plant population and pH. Pafai Journal 5 b : 33-36.

Singh M, Chandrasekhara G & Prakasa Rao E V S 1996.Oil and herb yields of Java citronella (*Cymbopogon winterianus* Jowitt) in relation to nitrogen and irrigation regimes. J. Essen. Oil Res. 8 : 531-534.

Yadav R L & Prasad S R 1988. Moisture use characteristics of sugarcane genotypes under different available soil moisture regimes in alluvial entisols. J. Agric. Sci. Cambridge 110 : 5-11.

Soil erosion under medicinal and aromatic plants in the Nilgiris

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Abstract

A study was initiated during the year 1998 to quantify the runoff and soil loss under the cultivation of medicinal and aromatic plants. The six species of medicinal and aromatic plants namely geranium, rosemary, cineraria, thyme, mentha and digitalis were planted on 15 per cent land slope. Digitalis recorded highest average green biomass yield followed by geranium and mentha. Preliminary results of the first two years of study, suggest that digitalis followed by mentha and geranium perfomed better in checking runoff and soil erosion.

Introduction

India is endowed with a rich wealth of medicinal plants. Thus, despite the rich heritage of knowledge on the use of plant drugs, little attention had been paid to grow them as field crops in the country till the latter part of the nineteenth century (ICAR 1987). The Indian herbal industries face inherent problems in procurement of raw material. A plausible solution to the problem could be the cultivation of medicinal and aromatic plants (Vijaya Lakshmi 1999). The commercial scale cultivation of these plants is however of recent origin (Ghosh 1998). The Nilgiri district is endowed with a wonderful climate conducive to the growth of a wide variety of medicinal plants ranging from temperate to subtropical. There are hundreds of valuable species of herbs growing in Nilgiris (Magesh & Vanya Orr 1999). Some of the farmers are cultivating these crops and also marketing facilities are catching up slowly in the area. As the Nilgiris is subjected to major land degradation process of soil erosion due to steep land slope, the extent of soil erosion under cultivation of medicinal and aromatic plants is of great importance. Information regarding runoff and soil loss from these plants are not available. From the sustainable agriculture point of view also we must have such a system where natural resources can be exploited without deteriorating them and with conserving them for future generations. Therefore present study was initiated to quantify the runoff and soil loss under the cultivation of medicinal and aromatic plants in high hills of Nilgiris.

Materials and methods

Six species of medicinal and aromatic plants viz: geranium (*Pelargonium graveolens*), rosemary (*Rosmarinus officinalis*), cineraria (*Ceneraria maritima*), thyme (*Thymus vulgaris*), mentha (*Mentha piperita*) and digitalis (*Digitalis purpurea*) were selected as treatments in the experiment. The experiment was laid out following R.B.D. on a natural slope of 15% having plot size of 15 m X 5 m each. Initial bench mark fertility status was analysed by taking composite soil samples from each plot at two depths (0-20 cm and 20-40 cm). Data showed medium level of overall fertility status due to acid nature of soil (Table I).

The planting was done during June 1998 at a uniform spacing of 40cm X 30 cm except in case of mentha where it was kept as 40cm X 20 cm. A basal dose of 10 t/ha FYM was applied before planting. Uniform dose of 40 kg/ha each of N, P and K was applied in furrows after 100 days of planting. Observations on canopy percent, plant height were recorded after 150 days of planting at different periods. In this regard, five representative sites and plants were selected in each case. Canopy percent was measured by canopy frame and plant height by scale from the ground surface to the top most point of the leading branch of the plant. Runoff and soil loss were measured by installing runoff tanks and multislot divisors at the out let point of each plot.

Results and discussion

Growth performance

Geranium and digitalis had maximum canopy percent followed by cineraria, rosemary, mentha and thyme

Table 1. Initial soil fertility status under different treatments at two depths (0-20cm & 20-40 cm).

Treatment	pH		EC(dSm⁻¹)		OC%		Available nutrients (kg/ha)					
							N		P		K	
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
Geranium	4.67	4.72	0.26	0.1	2.92	2.03	658.57	482.95	11.18	2.78	500.08	294.79
Rosemary	4.63	4.72	0.29	0.15	2.46	2.28	623.45	447.82	10.62	4.66	463.23	210.56
Cineraria	4.52	4.56	0.23	0.12	2.75	2.49	641.01	544.4	11.18	2.56	479.03	289.57
Thyme	4.55	4.44	0.25	0.15	2.5	2.66	676.10	649.78	11.96	2.65	431.65	242.14
Mentha	4.49	4.40	0.23	0.16	2.57	2.61	667.35	570.76	10.27	3.15	394.8	247.41
Digitalis	4.61	4.48	0.25	0.14	2.77	2.60	605.89	614.67	10.72	3.56	515.87	326.37

Table 2. Per cent canopy of medicinal and aromatic plants at different periods.

Treatment	Months after planting				
	5	6 ½	11 ½	14 ½	16 ½
Geranium	22	56	68	80 (2 MAH 1st)	86 (4 MAH 1st)T 2
Rosemary	6	29	43 (4 MAH 1st)	51 (6 ½ MAH 1st)	60 (8 ½ MAH 1st)
Cineraria	7	32	44	50 (2 MAH 1st)	63 (4 MAH 1st)
Thyme	9	28	24 (4 MAH 1st)	32 (6 ½ MAH 1st)	41 (8 ½ MAH 1st)
Mentha	36	56	38 (4 MAH 1st)	62 (6 ½ MAH 1st)	58 (1 MAH 2nd)
Digitalis	44	88	56 (4 MAH 1st)	60 (1½ MAH 2nd)	82 (3 ½ MAH 2nd)

MAH 1st denotes Months After First Harvest
MAH 2nd denotes Months After Second Harvest

(Table 2). Plant height was maximum in geranium and lowest in thyme and mentha (Table 3). Data on green biomass (Table 4) show that digitalis recorded highest yield (39.06 t/ha) followed by geranium (20.53 t/ha) and mentha (17.71 t/ha). Thyme and rosemary recorded the lowest green biomass yield of 0.49 t/ha and 0.96 t/ha, respectively.

Runoff and soil loss

Runoff and soil loss was more during north east monsoon as compared to South West monsoon. Digitalis, mentha and geranium gave lesser runoff and soil loss due to better canopy percent as compared to other species during both the monsoon seasons (Table 5). The total runoff and soil loss was maximum in cineraria

Table 3. Plant height (cm) of medicinal and aromatic plants at different periods.

Treatment	Months after planting				
	5	6 ½	11 ½	14 ½	16 ½
Geranium	36	59	73	79 (2 MAH 1st)	86 (4 MAH 1st)
Rosemary	15	21	36 (4 MAH 1st)	39 (6 ½ MAH 1st)	51 (8 ½ MAH 1st)
Cineraria	18	23	40	31 (2 MAH 1st)	45 (4 MAH 1st)
Thyme	15	20	13 (4 MAH 1st)	18 (6 ½ MAH 1st)	19 (8 ½ MAH 1st)
Mentha	34	47	29 (4 MAH 1st)	44 (6 ½ MAH 1st)	28 (1 MAH 2nd)
Digitalis	36	40	20 (4 MAH 1st)	27 (1½ MAH 2nd)	39 (3 ½ MAH 2nd)

MAH 1st denotes Months After First Harvest
MAH 2nd denotes Months After Second Harvest

followed by thyme and rosemary due to their poor canopy cover (Fig. 1). The lowest total soil loss was observed from digitalis (0.001 t/ha) followed by mentha (0.007 t/ha) and geranium (0.01 t/ha) suggesting that they performed better in checking runoff and soil loss.

The results of first two years of this study have shown better performance of digitalis followed by mentha and geranium in checking runoff and soil erosion on sloping lands. These species may hold promise in rehabiliting degraded/ waste lands and provide a value added land use system in watershed management programmes in the area.

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Table 4. Green biomass yield of medicinal and aromatic plants during 1999

Treatment	Yield (t/ha)
Geranium	20.533
Rosemary	0.960
Cineraria	7.333
Thyme	0.493
Mentha	17.706
Digitalis	39.066

Table 5. Runoff and soil loss under medicinal and aromatic plants

Treatment	South west monsoon			North east monsoon			Total		
	Runoff		Soil	Runoff		Soil	Runoff		Soil
	mm	%	loss (t/ha)	mm	%	loss (t/ha)	mm	%	loss (t/ha)
Geranium	2.42	0.81	0.000	5.16	1.00	0.10	8.97	0.91	0.010
Rosemary	2.18	0.73	0.005	42.01	8.18	0.859	45.68	4.67	0.916
Cineraria	6.32	2.11	0.091	77.79	15.16	2.257	86.75	8.88	2.390
Thyme	5.11	1.77	0.022	63.49	12.37	2.017	72.46	7.41	2.091
Mentha	0.60	0.20	0.000	3.86	0.75	0.007	4.97	0.50	0.007
Digitalis	1.16	0.38	0.000	3.25	0.21	0.001	4.69	0.48	0.001

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References

I C A R 1987. Medicinal and aromatic plants. In Hand Book of Agriculture, pp-1188.

Ghosh S P 1998. Research and development in horticulture–medicinal and aromatic plants. Indian Horticulture 42 : 25-27.

Magesh K & Vanya Orr 1999. Medicinal plants in Nilgiris – Present scenario and opportunities. Workshop on "The Strategies for Horticultural Development in Nilgiris"from 12-13 March 1999. Udhagamandalam, Tamil Nadu.

Vijay Lakshm K 1999. Cultivation of medicinal plants and contract farming. Plant Horti. Tech. 1 : 39-41.

Ecological decline of cardamom hills - an analysis

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Abstract

In Kerala, cardamom is mainly grown in the erstwhile Travancore area in the present Idukky district and it is known as the Cardamom Hill Reserve (CHR). This covers an area of 86,506 ha in the taluks of Devikulam, Udumbanchola and Peermedu. The cardamom rules (Travancore) were framed for the assignment of government lands for the cultivation of cardamom by the Maharaja of Travancore in 1935. Various provisions under different rules would bring out the extreme concern shown by the government for the maintenance of the ecosystem at the same time promoting cardamom cultivation. Despite many regulations and restrictions, coming up of plantations results in permanent loss of natural forests. Rapid expansion of area under cardamom results in loss of natural vegetation and pave the way for the process of encroachment. Total disregard even for a minimum of ecological safe guards in all the activities have together precipitated an extraordinarily severe environmental crisis in the cardamom hills. Over time, cardamom yield gets reduced and with rapid price fluctuation in the world market, the crop itself becomes unprofitable. Inspite of stringent laws, invariably the cardamom hills get converted to some other currently profitable crop, now mostly to coffee and pepper. These crops require more sunlight and this result in further removal of trees. The plantations are exposed to extreme fluctuations in the local climate resulting in successive crop failures. Variations in soil, water, organic matter content, flora, fauna etc. are analyzed. Future strategies are proposed taking into account the ecosystem approach to satisfy the ecological requirements of the component crops. Afforestation with cardamom friendly trees, provision of catchment forests to protect the watersheds, alternate farming and cropping systems, strategies for pest and disease management, crop improvement programmes, post harvest technologies etc. have been discussed. Every one - small farmer, big planters, and the corporate agribusiness must evolve the same sustainable ecorestorative land husbandry for sustaining cardamom cultivation at the same time conserving the Cardamom Hill Reserve.

Key words: afforestation, cardamom, *Elettaria cardamomum.*

Abbreviations:

CHR = Cardamom Hill Reserve

FAO = Food and Agricultural Organization

IPM = Integrated Pest Management

Introduction

In Kerala, cardamom is mainly grown in the erstwhile Travancore area in the present Idukky district and it is known as the Cardamom Hill Reserve (CHR) which was specially reserved and denotified and removed from the control of the forest department by the orders of the Travancore Government. The area had been earmarked for cardamom cultivation by the Travancore Government as early as in 1892 and the lease of the government land for cardamom cultivation has been regulated by rules which have the force of law under Article 162 of the constitution of India. By royal proclamation dated 15th *Medam* 997 (ME) 334 square miles (86,506 ha) in Devikulam, Udumbanchola and Peermedu taluk of the present Idukky district was declared as CHR for the

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promotion of cardamom cultivation.

After Independence, the government of Kerala adopted the policy of promoting cardamom cultivation in this area and full control over the registered and unregistered lands in the above area was transferred to the revenue department, limiting the control of the forest department to that of trees alone.

The cardamom rules

The cardamom rules (Travancore), framed for the assignment of government lands for the cultivation of cardamom was passed by the government of Highness, Maharaja of Travancore on 30-09-1935.

Rule, 28, 30 and 31 of the cardamom rules refers to the manner in which under growth and other trees in the area assigned in the cardamom rules are to be dealt with.

Rule 28 provides that holders of cardamom land may remove the under growth and fell such trees as it is necessary to clear, in order to admit sufficient sunlight for the cultivation of cardamom, but they shall not fell any other tree exceeding 4 feet in girth at a height of 3 feet from the ground before getting sanction from the Commissioner, Devikulam.

Rule 30 gives specific directions as to how the undergrowth in a new clearing can be burned without affecting the surrounding jungle.

Under Rule 31, holders are permitted to collect dead trees uprooted by storms as fuel, free of charge, but no tree shall be purposely uprooted for including it among dead trees and thereby using it for fuel.

Rule 29 states that holders of cardamom land can utilise trees kept for shade for growing pepper, vanilla and rubber vines. Other crops which will not interfere with the cultivation of cardamom can also be grown in the plantation with the sanction of the Commissioner, if in the opinion of the Commissioner, growing such crops will not interfere with the cultivation of cardamom.

The above provisions under different rules would bring out the extreme concern shown by the government for the maintenance of trees in the cardamom plantation.

History of cardamom cultivation

The CHR remained for long an inadequately known, sparsely inhabited, heavily forested difficult terrain. Few tribal communities, each with a small population occupied an insignificant portion of the forests.

Intensive agriculture came to the high ranges when the cash crop plantation practice was brought in by the European planters early in the 19th century. Until then cardamom was only a forest produce. The native tribes and Tamilians of the boarder areas collected the panicles of mature capsules, dried it on rocks and sold to traders, mainly for outside trade to Arabia. Almost through 19th century, the Travancore-Kochi governments held an unruled monopoly over the trade in cardamom. After the turn of the century, the monopoly was given up. Planters were allowed to sell their produce at will. Since land revenue and tax on agricultural produce constituted the major source of state revenue, the government policy was one of encouraging commercial cultivation of this highly remunerative crop. The land regulations drawn up between 1860-1925 were meant to attract people to the region and open up the high land. Tea, coffee and cardamom plantations began to grow in the area as the land was made available at liberal terms. Despite many regulations and restrictions, the coming up of plantations means a permanent loss of natural forests. Plantations were usually started by the British or by people from adjoining areas of Tamil Nadu. Rapid expansion of the area under cardamom resulted in a permanent loss of natural vegetation and paved the way for a process of encroachment upon forest land.

Increased accessibility, potentially favourable agro-climatic conditions for the profitable cash crops and the complex political and other socio-cultural conditions of the region directly encouraged and abetted the colonisation and settlement of these hills by the plains people.

Ecological destabilisation

Rampant deforestation in every part of the hills, extremely destructive agricultural practices with constantly changing crop combinations for maximum profit, in particular in the heavy rainfall steep higher ridges and the total disregard even for a minimum of ecological safeguards in all the developmental activities have together precipitated an extraordinarily severe environmental crisis in the CHR. Earlier agricultural manipulations were minimum with less effect on the ecosystem. Resource exploitation was very little. But practices like opening up of the canopy to enhance light penetration, felling of trees, clean cultivation, growing cardamom in steep slopes (without resorting to soil conservation measures), unjudicial application of agricultural chemicals etc. have totally tilted the environ mental equilibrium and overall ecology of the area which ultimately decides the viability of any cultivation. Changes in the soil microclimate and the nutrient cycling due to the removal of the understorey and thinning of the canopy result in the gradual or rapid depletion of soil fertility, flora and fauna. Over time, cardamom yield gets reduced and with rapid price fluctuation in the world market, the crop itself becomes unprofitable. In spite of stringent laws and the existence of an official machinery to over see the cardamom lands, invariably the cardamom land get converted to some other currently profitable crop, now mostly to coffee, arecanut and or pepper. These crops require more light and this results in further removal of trees.

Climate changes

Over the years, the forest cover diminished drastically exposing plantations to extreme fluctuations in the local climate. The area which once had less intense fairly distributed rainfall (drizzling rains) now gets heavy down pours in a limited period. In this situation, without a closed canopy shelter, the soil degrades within a couple of monsoons. No catchment forests are retained to protect the water sheds. Water sources are drying up. Local climate and soil changes are inducing acute water scarcity during summer. Demand on irrigation water has increased drastically. Unprecedented and unsustainable demands are being made on the rapidly disappearing water source. More and more energy demanding water management measures are being implemented in this energy scarce hill area. Cardamom is fetching less and less returns in the global manipulated markets. They would force abrupt crop changes and other internal structural adjustments further destabilising the environmental and social equilibrium. Successive crop failures coupled with the oscillating price fluctuation in the international market have created a tense situation among the cultivators and considerable area has been put to other crops like coffee, pepper etc.

Cardamom is a sensitive plant and any serious disturbance in the environment, especially the climatic factors will adversely affect the growth, development and production. Droughts are almost a recurrent phenomenon and the period between two successive droughts is decreasing. In the last decade the CHR witnessed miserable crop failures due to continuous periods of dry spell coupled with dessicating winds from Tamil Nadu plains and the resultant outbreak of pests.

Future vision

So far attention has been focussing on single component alone, the cardamom. Being part of a large dynamic system each and every component need to be given importance. Change in any one of the component alters the other and hence each component has to be studied in relation to others. Ecological requirements of cardamom need to be strictly adhered to taking into account the following factors.

Soil

If the soil is healthy, plant will also be healthy. According to FAO standards cultivation is not viable beyond 50% slope. But generally we find cardamom standing in steep slopes. Loss of canopy, clean cultivation etc. coupled with heavy down pour result in loss of top soil, organic matter etc. and brings down the water holding capacity. Eroded soil get deposited in the plains and flooding of the foot hill plains and far delta areas become inevitable. Some of the mobile/soluble nutrients are liable to erode along with soil particles. Nutrient loss has to be seriously considered especially in closed nutrient system which is the peculiar phenomenon in forest soils. Once the soil nutrient cycle is disturbed, soil degradation becomes fast, ultimately the entire ecosystem is collapsed. Soil conservation measures are more crucial in the coming years.

Organic matter

Loss of vegetation has resulted in depletion of organic matter content of the soil. Cardamom survived well on the soil rich in organic matter and the forest soils were rich in humus. Over time, due to various anthropogenic reasons, the soil has depleted its organic matter content and natural replenishment of organic matter does not take place. Addition of external organic matter is also negligible. Further, copious quantities of chemical fertilizers are applied every year. This has also resulted in loss of soil properties, fertility and a decrease in soil microfauna. Measures to enhance the organic matter content of the soil have to be taken up immediately.

Water

Water is to be stored in the soil itself and not in dams and hence the water holding capacity of the soil must be brought up. Strategies for rainfed farming are to be evolved. Energy intensive costly irrigation practices may be replaced by low cost energy efficient practices. Mulching is an important operation to be given due importance. If, after the North East Monsoon plantations are heavily mulched, moisture can be saved and with a life saving irrigation crop will easily withstand the summer. Water management becomes crucial. Undulating topography of cardamom lands also facilitates irrigation by gravitational flow.

Afforestation

Sufficient research findings are available that 50-60% shade is required for cardamom for successful cultivation. But there are only few estates which satisfy this requirement. There is urgent need to afforest the cardamom lands. The situation now is such that replacing the trees removed during the past years is the only way to increase the total biomass production.

A study conducted at Cardamom Research Station, Pampadumpara to assess the organic carbon content of the CHR dominated by different tree species is presented in Table 1.

In undisturbed ecosystems the organic carbon content of soils does not vary much. In the study comparatively higher organic carbon content was recorded in cardamom production systems than pepper. That is clearly attributed to the lack of native tree species and the low biomass production of the dominant tree - Erythrina. Besides, the warmer soil environment experienced in pepper production systems due to shadeless condition directly and indirectly influences the decomposition of soil organic matter. Yield decrease up to 175 kg ha^{-1} yr^{-1} has been reported in Rubber when the soil organic matter content decreased by 0.1 per cent (Samarappuli *et al.* 1999). So in any production system the organic carbon content is to be maintained to avoid land degradation.

The general trend in the CHR is to plant fast growing trees. Now the area has both native as well as introduced forest trees. Afforestation programmes with native cardamom friendly trees viz. Chandanavayambu (*Toona ciliata*), Korangatti (*Acrocarpus faxinifolius*), Anjili (*Artocarpus hirsutus*), Vellakil (*Dysoxylum malabaricum*), Venga (*Pterocarpus marsupium*) etc.

Table 1. Percentage of soil organic carbon content of CHR dominated by various tree species

Common name	Botanic name	Production system	Organic carbon content (%)
Korangatti	Acrocarpus fraxinifoius	Cardamom	1.78
Perumarom	Ailanthus triphysa	Cardamom	1.76
Plavu	Artocarpus heterophyllus	Cardamom	1.76
Chorakkali	Bischofia javanica	Cardamom	1.78
Vediplaavu	Cullenia exarillata	Cardamom	1.77
Mullumurikku	Erythrina indica	Pepper	1.61
Murukku	Erythrina lithosperma	Pepper	1.64
Porivatta	Mallotus tetracoccus	Cardamom	1.54
Kulamavu	Persia macrantha	Cardamom	1.61
Chandaravayambu	Toona ciliata	Cardamom	1.76
Pottama	Trema orientalis	Cardamom	1.67
Karana	Vemonea arborea	Cardamom	1.69
Underdisturbed mixed forest not under cultivation	Native Forest trees	Cardamom	2.10

has to be given priority. Native trees of medicinal value like wild nutmeg (*Myristica dactyloides*), Thelli (*Canarium strictum*), myrobalans, nuxvomica etc may also be planted to have an additional income.

In larger holdings a certain area of the forest may be kept apart untouched so that it can full fill the ecological functions and stabilise the macro climate of the area.

Alternate cropping and farming systems

Failure of monocropping is evident everywhere. For sustaining cardamom cultivation inter / mixed cropping may be tried with cardamom as the lead crop. In the yester years, the crop diversity was high, cardamom lands permitted the growth and production of many food crops especially tuber crops like tapioca, yams, dioscoreas etc. and millets like ragi. Now the system is that we have totally eliminated food crops and more and more cash crops are brought in which are high input demanding. Any agricultural system is bound to fail in the long run unless there is provision for food crops. So along with cardamom, food crops suitable to the ecosystem need to be evaluated and combinations worked out. Another possibility is fruit crops. Evergreen subtropical fruits like banana, gamboge, mangosteen, litchi, malayan apple, avocado, rambutan, citrus sp. etc. may be tried as shade trees.

Sreenivasan *et al.* (1999) have reported that inclusion of black pepper in the cropping system which is in practice in many parts of CHR gives a cost:benefit ratio of 1:4 and is economically viable.

Organic farming technologies which are low input demanding, energy efficient and with little disturbance on the ecosystem have to be evolved. Operations like tillage, weed management, manuring, shade regulation, mulching etc. have to be standardised.

Pest and disease management

Indiscriminate use of insecticide on calendar based schedule is normally practiced. This causes severe concern to ecological as well as environment stability coupled with pest resistance, resurgence and out break of non target secondary pests. This practice results in tremendous build up of residues on this export oriented produce which recently raised queries on our cardamom that was exported. Moreover wash off of the toxic chemicals are bioaccumulated in the water bodies at the down stream causing imbalances on the aqueous biotic system. So the single factor approach of only pesticide application has to be replaced by the universally accepted concept of IPM.

Strategies to be adopted

1. Monitoring of insect pests and need based judicial application of optimum doses of pesticides.

2. Use of botanicals and biorationals such as hormone agonists and antagonists.

3. Encourage biologicals like parasitoides and predators and microbial entomopathogens.

4. Adopt regulation methods strictly.

Breeding for suitable varieties

Lot of variability exists in the germplasm of cardamom. Varieties suitable to different situations as tolerance to drought, pests and diseases, varying degrees of shade and with good capsule characters need to be evolved rather than concentrating on few high yielding sensitive varieties.

Processing

Demand on fire wood goes on increasing. We cannot afford to cutting of trees any more. Alternate fuels have to be tested. Diversification is essential rather than depending only on fire wood. Kerosene based units are found promising. Solar energy is still to be tapped in this field.

References

Kunhikrishnan K V 1999. Cardamom, the agenda of profit and the impact on forest ecology - A historical overview. Paper presented in the seminar on cardamom for rainforest conservation at Rajeev Gandhi Center, Thekkady.

Nair S C 1993. The Highranges. INTACH. New Delhi.

Samarappuli I N, Enanayake A & Samarappuli L 1999. Effect of land degradation on rubber yields. J. Plantn. Crops 27(3) : 101-104

Srinivasan K, Siddagangaiah, Biswas A K & Krishnakumar U 1999. Mixed cropping systems in cardamom (*Elettaria cardamomum* Maton) - An analysis. J. Spices Aroma Crops 8(1) : 63-66.

Influence of boron and molybdenum on the yield of small cardamom grown under natural shade

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Abstract

The experiment was conducted at Regional Research Station, Mudigere, Karnataka during 1992-99. The experiment was laid out in randomized block design comprising seven treatments of different micronutrients involving boron and molybdenum. Borax was applied both as soil application and as well spray in the form of di-sodium tetra borate. Molybdenum was applied in the form of sodium molybdate. The variety chosen for the study was 'M1' and spaced at 1.8 x 1.8 m. Application of boron @ 20 kg/ha and molybdenum @ 0.25 kg/ha independently or in combination increased the capsule yield of cardamom by 20 per cent.

Introduction

It is a common experience of the growers that despite a good management, the yield levels steadily decrease in the cardamom plantations. One of the main reasons for not maintaining the sustained yield was attributed to micronutrient deficiency in the soils. The present study was concentrated on boron and molybdenum nutrients on yield pattern of the crop.

Materials and methods

The experiment was conducted at Regional Research Station, Mudigere, Karnataka, during 1992-99. A survey was taken up at our center during 1989-90 to assess the status of micronutrients in cardamom soils. Soils exhibited zinc deficiency in 5.12 per cent and boron deficiency in 19 per cent of the soil samples analysed.The soil of the site was red loam, having medium carbon (1.1 per cent), low P_2O_5 (7.1 kg/ha) and K_2O (312 kg/ha). The experiment was laid out in randomized block design comprising seven treatments of different micronutrients involving boron and molybdenum. Boron was applied both as soil application and as well spray in the form of borax (di-sodium tetra borate). Molybdenum was applied in the form of sodium molybdate. The variety chosen for the study was 'M1' and spaced at 1.8 x 1.8 m. There were six plants for each treatment. Other practices were followed as per the package.

Results and discussion

The effect of different micronutrients on green capsule yield is presented in table 1. Micronutrient application influenced the green capsule yield significantly during 1998 and 1999. During these years, application of borax @ 20 kg/ha or molybdenum @ 0.25 kg/ha when applied either independently or in combination resulted to obtain significant green capsule yield over control where NPK was only applied. Though the data for initial 3 years remain statistically non significant, but the above said treatments registered numerically higher yield over other treatments. The mean of the 5 years data found significant and the trend remained same, in that the above said treatments recorded 20 per cent higher yield over control. The exploitation of organic status in the soil during early years, might have resulted its deficiency and subsequent application caused better response in later stages. The studies on effect of micronutrients such as boron and molybdenum are very much limited in the field of spices.

The economic analysis for pooled data (Table 2) revealed that highest marginal returns were realised in the plots of borax and molybdenum application (Rs. 4980). This was followed by the application of molybdenum alone (Rs.3720) or borax alone (Rs.3540). However, the maximum BCR was found in molybdenum application (Rs. 6.07/rupee investment) followed by borax application (Rs.3.00/rupee investment) and together (Rs. 2.35/rupee investment).

Table 1. Effect of different micronutrients on green capsule yield

Treatment	Green capsule yield (kg/ha)					
	1995	1996	1997	1998	1999	Mean
NPK - Recd.dose	367	370	268	376	327	342
Borax -10 kg/ha (soil application)	385	450	287	390	366	378
Borax - 20 kg/ha (soil application)	425	443	260	476	401	401
Borax - 0.2% (foliar spray)	392	416	258	445	347	372
Molybdenum - 0.25kg/ ha (soil application)	365	463	295	474	424	404
xMolybdennum - 0.50 kg/ ha (soil application)	347	404	277	447	370	369
Borax - 10 kg/ha + Molybdenum-0.25kg/ha	455	498	264	465	443	425
S.Em.±	26.2	33.0	16.2	20.8	7.0	10.7
C.D. (0.05)	NS	NS	NS	64.1	21.1	29.7
C.V. (%)	13.4	10.6	11.9	16.6	3.6	12.5

Table 2. Effect of different micronutrients on economics

Treatment	Mean green capsule yield	Addnl. yield over rec. NPK	Correspo-nding dry yield	MR	MC	BCR
Recd. NPK	342	—	—	—	—	—
Borax -10 kg/ha (soil application)	378	36	7.2	2160	1700	1.27
Borax - 20 kg/ha (soil application)	401	59	11.8	3540	3200	1.10
Borax - 0.2% (foliar spray)	372	30	6.0	1800	600	3.00
Molybdenum - 0.25kg/ ha (soil application)	404	62	12.4	3720	612.50	6.07
Molybdenum-0.50 kg/ ha (soil application)	369	27	5.4	1620	1025	1.58
Borax - 10 kg/ha + Molybdenum-0.25kg/ha	425	83	16.6	4980	2115	2.35

MR = Marginal returns, MC = Marginal cost, BCR = Benefit cost ratio
Cardamom @ Rs.300/kg. Borax - Rs. 150/kg Sodiuum molybdate

Effect of fertilizer levels on the yield of small cardamom under natural shade

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Abstract

The experiment was conducted at Regional Research Station, Mudigere, Karnataka during 1992-99. The experiment was laid out in randomized block design comprising six treatments of different NPK levels. The variety chosen for the study was 'M1' and spaced at 1.8 x 0.9 m. In each treatment fertilizers were applied in two split doses first at May last week and second at September first week. The crop responded positively for the fertilizer application, highest application of 150:150:225 kg/ha NPK recorded highest green capsule yield (644 kg/ha). However, the application of 75:75:150 kg/ha NPK recorded 547 kg/ha green capsule yield with highest benefit cost ratio of 4.66.

Introduction

Amongst the several constraints responsible for the low productivity of cardamom, application of appropriate level of fertilizers is the main one. The cardamom growing areas receive heavy rainfall and also had undulated topography. Leaching, run off nutrients and depletion of nutrients due to continuous cultivation of the crop results poor growth and yield of crop. Growers consider 5-6 years as heavy economic bearing years and few of them practice high density for achieving the purpose. The present study was aimed at evaluating the optimum fertilizer level for high density plantations.

Materials and methods

The experiment was conducted at Regional Research Station, Mudigere, Karnataka during 1992-99. The soil of the site was red loam, having medium carbon (1.2 per cent), low P_2O_5 (8.2 kg/ha) and K_2O (280 kg/ha). The experiment was laid out in randomized block design comprising six treatments of different NPK levels. The variety chosen for the study was 'M1' and spaced at 1.8 x 0.9 m. There were six plants for each treatment. In each treatment, fertilizers were applied in two split doses first at May last week and second at September first week.

Results and discussion

The effect of different levels of fertilizers on green capsule yield is presented in table 1. During all the years of experimentation, the levels significantly influenced the green capsule yield. The maximum level of NPK application (150-150-225 kg/ha) recorded highest green capsule yield during all the years. The pooled data over 5 years of study was also significant and indicated that application of 38-38-75 kg/ha resulted around 100 kg higher green capsule yield (434 kg/ha) over control. Also, 75-75 150 NPK kg/ha resulted another 100 kg higher green capsule yield (547 kg/ha) over its previous dosage. But, further increase in fertilizer levels to either 100-100-175 or 125-125-200 NPK kg/ha fail to mark the consistent increase as they record only 50 kg more over their previous dosage. But, it was possible to enhance green capsule yield to a maximum level of 644 kg/ha by applying 150-150 -225 that marked almost 300 kg over control, 200 kg over 38-38-75 and 100 kg over 75-75-150 NPK kg/ha application. At Pampadumpara, for 'PV-1' clone, it was found that application of either 75:75:150 kg/ha NPK along with 1 kg neem cake/clump or 100:100:175 kg/ha NPK gave encouraged results (Anon. 1999).

The recommended fertilizer application of 75-75-150 NPK kg/ha for normal spacing (1.8 x 1.8 m) performed better here also by achieving 200 kg more over control and maximum BCR of 4.66 (Table 2). The comparison among this dose and further increased dose was not linear. By applying the higher doses, the cost involvement will be more as one can get only less benefit. However, the application of 150-150-225 NPK kg/ha recorded 5820 rupee more income over 75-75-150 NPK kg/ha and over this dosage it recorded BCR 3.01. The data indicate that for high density population (1.8 x 0.9 m) also application of 75-75-150 kg/ha is more beneficial.

Reference

Anonymous 1998-99. Annual Reports AICRP (Spices).

Table 1. Effect of different fertilizer levels on green capsule yield

Treatment	Green capsule yield (kg/ha)					
NPK (kg/ha)	1995	1996	1997	1998	1999	Mean
0 - 0 - 0	410	204	163	464	455	339
38 - 38 - 75	530	355	181	572	533	434
75 - 75 - 150	620	493	284	684	656	547
100 - 100 - 175	684	496	295	742	732	590
125 - 125 - 200	706	571	302	734	679	598
150 - 150 - 225	854	559	280	786	740	644
S.Em.±	31.8	62.8	13.6	31.3	20.9	16.2
C.D. (.05)	95.9	189.2	41.1	93.8	63.1	46.9
C.V. (%)	10.0	28.2	10.9	9.4	6.5	13.7

Table 2. Effect of different fertilizer levels on economics

Treatment NPK (kg/ha)	Mean Yield	Dry yield	Return (Rs.)	MR	MC	BCR
0 - 0 - 0	339	67.8	20340			
38 - 38 - 75	434	86.8	26040	5700	1400	4.07
75 - 75 - 150	547	109.4	32820	12480	2680	4.66
100 - 100 - 175	590	118.0	35400	15060	3380	4.46
125 - 125 - 200	598	119.6	35880	15540	4100	3.79
150 - 150 - 225	644	128.8	38640	18300	4800	3.81

N - Rs.8.30/kg, P - Rs.13.75/kg, K - Rs.5.13/kg, cardamom - Rs. 300/kg.

Some production aspects of paprika *(Capsicum annuum* L.) under plains

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Abstract

For studying appropriate spacing and fertilizer levels for paprika *(Capsicum annuum* L.) production, a field experiment was conducted during 1999 *kharif* on medium deep black soil at main research station, Dharwad (Karnataka). The treatments were three spacings viz., 60 x 60 cm, 60 x 45 cm and 60 x 30 cm and four levels of fertilizer viz., 0, and NPK at the rate of 75:37.5:37.5, 150:75:75 and 225:112.5:112.5 kg/ha. The results revealed that the closer spacings were beneficial for growth parameters and closer spacing with increased nutrients level helped in obtaining higher fruit number and yield.

Key words: nutrients, paprika, spacing, yield

Introduction

Paprika being an important spice which has gained place of pride in the international trade. The fruits are usually spherical to conical in shape which are big in size with thick flesh containing large amount of red colouring matter. The fruit has its unique feature as it is sweet to mild pungent in taste (Anon 1995). There is a great demand for paprika powder and oleoresin in Western countries. Paprika powder is used as a food flavourant, colourant and also used in medicinal and cosmetic preparations. But in India, preparation of ground product and oleoresin are being practised from hot chillies. The same demand can be met with paprika cultivation since there is high demand in Western world. Hence, it is desirable to extend the area under paprika cultivation in India with ultimate object of increasing exports of oleoresin and ground products. Paprika needs heavy manuring for putting up good growth and high yields (Anon 1995). However, the information regarding the production technology is meagre. Keeping this in view, a study was conducted in the Department of Horticulture, University of Agricultural Sciences, Dharwad to know the spacing and fertilizer requirement of the crop in Southern plains.

Materials and methods

Paprika variety Kt-P1-19, which was stabilized for Southern plains is used for the study. The seedlings were raised during the month of June and transplanted in July 1999 in *Kharif* season on medium deep black soil at main research station, Dharwad (Karnataka). Recommended package of practices were followed in nursery and during crop growth period. The duration of the crop was 120-130 days. The following treatments were imposed for the experimentation.

Spacing: Three levels of spacing viz.,

S1 = 60 x60 cm, S2 = 60 x 45 cm and S3 = 60 x 30 cm

Fertilizers: Four levels of fertilizers.

F0

F1 = 75 : 37.5 : 37.5 5 kg NPK/ha

F2 = 150 : 75 : 75 (RDF) NPK/ha

F3 = 225 : 112.5 : 112.5 NPK/ha

and combination of the treatments were followed.

Fisher's method of analysis of variance was applied for analysis and interpretation of the study. Levels of significance of 'F' test was P=5 per cent (Gomez & Gomez 1984).

Results and discussion

The plant height differed significantly in response to spacing whereas the application of fertilizer had no effect on plant height. However, the combined effect of spacing and fertilizer was significantly higher. Among the 12 treatments, S3F0 (60 x 30 cm and '0' fertilizer) has given the highest plant height (59.67 cm) followed by S3F3 (59.33 cm). The increased plant height can be attributed mainly to the closer spacing which could have increased apical dominance and competition between the plants for light (Table 1).

Table 1. Effect of spacing and fertilizer levels on growth and yield of paprika.

Treatment		No. of primary branches/plant	Plant Ht. (cm)	No. of fruits per plant	Yield (kg/plant)	Yield (t/ha)
T1 (S1F0)		2.33	47.67	44.33	6.67	6.18
T2 (S1F1)		2.67	51.67	39.33	8.75	8.10
T3 (S1F2)		2.33	52.00	41.67	6.83	6.33
T4 (S1F3)		2.33	46.67	47.00	5.18	4.80
T5 (S2F0)		2.34	45.33	41.67	6.78	6.28
T6 (S2F1)		2.33	46.33	44.00	5.21	4.83
T7 (S2F2)		2.30	48.33	47.67	8.10	7.50
T8 (S2F3)		2.66	46.33	44.33	8.47	7.04
T9 (S3F0)		2.33	59.67	49.67	10.54	9.77
T10 (S3F1)		2.66	53.67	47.00	13.09	12.12.
T11 (S3F2)		2.33	51.33	51.00	13.70	12.68
T12 (S3F3)		2.33	59.33	50.67	14.46	13.39
S.Em ±	A	0.16	0.75	0.57	0.66	0.62
	B	0.18	0.86	0.66	0.77	0.72
	AxB	0.32	1.49	1.14	1.34	1.24
CD at 5%	A	NS	2.19	1.68	1.96	1.82
	B	NS	NS	1.94	NS	NS
	AxB	NS	4.38	3.36	NS	NS

For the character number of primary branches per plant, the treatment combination S1F1 has recorded the highest numbers (2.67) which was followed by S2F3 (60 x 45 cm) & 50% > RDF and S3F1 (2.66). However, there were no significant differences observed between the treatments. Either the spacing or fertilizer or the combination of both did not have any significant effect on the number of primary branches. This may be due to genotypic inheritance of the variety.

Significant differences were observed for number of fruits per plant. Both the closer spacing and increase in the fertilizer have resulted in increased fruit number. Similarly, the interaction of spacing and fertilizer has also found to be significant. Among the different combinations S3F2 (60 x 30 cm & RDF) recorded the highest number of fruits (51.67), followed by the combination S3F2 (60 x 30 cm & 50% RDF) which has given 50.64 fruits per plant. This indicates the favourable effect of closer spacing and increased dose of fertilizer on the number of fruits. Higher number of fruits recorded was mainly due to the enhanced availability of nutrients as observed in bell peppers (Manchand & Singh 1998, Singh *et al.* 1998).

From the table it could be observed that the yield (kg/plot) differed significantly in response to the variation in spacing. Whereas, the fertilizers levels did not show any significant difference on the yield. Similarly, the combination of these two, spacing and fertilizer also did not differ significantly. The highest yield of 14.46 kg/plot was observed with the treatment combination of S3F3 (60 x 30 spacing and 50% more RDF) followed by the S3F2 (60 x 45 spacing and RDF) with the average yield of 13.70 kg/plot. The higher yield obtained in the present study can be attributed to the increased plant population per unit area and increased availability of nutrients. Sontakke *et al.* (1995) have also reported similar results in chillies. Similar, trend has also been observed with the yield (t/ha) where in the highest yield was obtained with the treatment S3F3 (13.39 t/ha) followed by S3F2 (12.68 t/ha)

References

Anonymous 1995. Tips for paprika cultivation. Spice India 8 : 16-18.

Gomez K A & Gomez A A 1984. Statistical procedures for Agricultural research 2nd edition. A Wiley-Inter Science publication, New York (U.S.A).

Manchanda A K & Singh B 1998. Effect of plant density and nitrogen on growth and fruit yield of bell pepper (*Capsicum annuum* L.). Indian Journal of Agronomy 33 : 445-447.

Singh V, Sharma D K & Bhagwan B V K 1998. Effect of levels of nitrogen and time of its application on growth and yield and net profit of chilli (*Capsicum annuum* L.). Progressive Horticulture 20 : 80-86.

Sontakke M B, Pardeshi P P, Mande A S & Shine N N 1995. Effect of graded levels of nitrogen and spacing on growth and yield of two cultivars of chillies (*Capsicum annuum* L.). Journal of Research, Andhra Pradesh Agricultural University 23 : 8-9.

Nitrogen nutrition and plant population management on dwarf chilli (*Capsicum annuum* L.)

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Abstract

An experiment was conducted at Vegetable Research Station, C .S. Azad University of Agril. & Technology Kalyanpur, Kanpur during *Kharif* seasons of 1995-96, 1996-97 and 1997-98 to find out the optimum plant density and nitrogen requirement of dwarf chilli variety KDCS- 810. Randomised Block Design was selected with three levels of N (90, 120, and 150 kg per ha) and five levels of spacing (30 x 45, 30 x 22.5, 30 x 30, 30 x 37.5 and 30 x 45 cm) with its basal dose of P_2O_5 and K_2O each @ 60 kg per ha. As regards the yield of chilli, nitrogen showed direct response more pronouncely at the lower levels of fertilization. The results revealed that during first and second year, significant increase in fruit yield of red ripe chilli (54.7 and 80.5 q per ha respectively) is obtained upto 120 KgN per ha. However, in the third year, it could not reach the level of significance. With respect to the spacing, three years data clearly manifested that closer spacing is alwasy beneficial and 30 x 22.5cm spacing produced the maximum red ripe chilli yield followed by 30 x 15 cm spacing. It is further concluded that the highest yield of chilli is found with 120 kg N per ha at 30 x 22.5 cm spacing.

Introduction

Chilli (*Capsicum annuum* L.) is one of the important cash crops of Uttar Pradesh. The non availability of important agricultural inputs, particularly fertilizers, irrigation and power in the country, chilli crop has assumed greater significance to the farmers because of its low cost of production on the hand and high net return per unit area on the other.

The present references throughout the country indicates the important role of nitrogen in crop production which is very much related with the crop geometry. The work on production side on the chilli crop in Uttar Pradesh is very scanty and this has resulted to plan out the present investigation.

Materials and methods

Field experiment was carried out at Vegetable Research Station, Kalyanpur of C.S.Azad University of Agriculture and Technology, Kanpur during *kharif* seasons of 1995-96, 1996-97 and 1997-98. The treatments were of three nitrogen levels (90, 120 and 150 kg per ha) and five spacings (30.00 x 15.00, 30.00 x 22.50, 30.00 x 30.00, 30.00 x 37.50 and 30.00 x 45.00) comprising total number of 15 treatments. These treatments were laidout in randomised block design with three replications. The variety KDCS-810 was planted on 25 August 1995, 28 August 1996 and 26 August 1997 with 60 kg per ha of phosphorus and potash each along with half of nitrogen as per treatment at planting, while remaining half dose of nitrogen was given after one month of transplanting.

The first picking of red ripe chilli was done on 11th January 1996, 16th December 1996 and 20th January 1997 during three years of investigation, respectively.

Results and discussion

Fruit yield of red ripe chilli has been presented in table 1. Nitrogen has direct response over this character more pronouncely by at the lower levels. Significant increase in fruit yield was obtained with increasing levels upto 120 kg N per ha in first and second year but in the third year it has not given the significant response. The highest fruit yield of red ripe chilli was obtained by the application of nitrogen at 120 kg per ha and lowest at the 90 kg per ha consistently in all the three years. The percentage increase in red ripe chilli yield at 120 kg N per ha were 11.9, 9.9 and 6.9 over the 90 kg N per ha; 6.9, 3.8 and 2.9 per cent over 150 kg N per ha in first, second and third years, respectively. On the mean basis at all the years, 120 kg N dose has produced 6.3 q per

Table 1. Effect of nitrogen levels and spacing on the fruit yield of chilli (q/ha)

Treatment (N-Levels kg ha^{-1})	1995-86	1996-97	1997-98	Mean
90	48.17	72.52	69.14	63.28
120	54.67	80.53	73.50	69.57
150	50.90	77.51	71.36	66.59
C.D.at 5%	6.43	6.50	N.S.	-
Spacing (cm)				
30.0 x 15.0	53.85	78.54	74.29	68.89
30.0 x 22.5	56.83	83.03	78.81	72.89
30.0 x 30.0	51.40	77.78	73.87	67.68
30.0 x 3.75	48.62	75.41	68.77	64.27
30.0 x 45.0	46.12	69.77	61.43	59.12
CD at 5%	8.31	N.S.	9.67	-
CV%	16.72	11.33	9.36	-

ha (9.04%) maximum fruit yield of red ripe chilli over 90 kg N dose.

As regards the effect of spacing over fruit yield of red ripe chilli, it is clear that only in first and third years of experimentation, there is a significant response. It is also clear from the data that the crop planting at 30 x 22.5cm spacing recorded highest fruit yield of chilli than the crop at other spacings. Among all the spacings, maximum fruit yield of red ripe chilli 5.2, 5.4 and 5.7 per cent was recorded with 30x22.5cm spacing, respectively in all the three seasons of study. Crowding within row caused severe competition for nutrient, solar energy, space for growth which resulted less branching, fruiting and less photosynthesis and finally reduced the fruit yield of red ripe chilli. Similar results were also reported by Kalra *et al* (1984) and Pundir & Porwal (1999).

Reference

Kalra G S, Thorat S T& Pawar, A B 1984. Response of improved groundnut varieties to different spacings under irrigated condition. Indian Journal of Agronomy 29 (1) : 40-42.

Pundir J P S & Porwal R 1999. Effect of spacing and fertilizers on growth, yield and physical fruit yield of chilli (*Capsicum annuum* L.) cultivars. Jouranl of Spices and Aromatic crops 8 (1) : 23-27.

Studies on fertigation with normal and water soluble fertilizers on fruit yield, quality and nutrient uptake of chilli

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Abstract

Field experiment was conducted at Horticultural Research Station, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bangalore during *rabi* seasons of 1997 and 1998 on red sandy loam soil to study the effect of fertigation in chilli and to compare the sources and levels of fertilizers. In general, fertigation was found to be significantly superior over the conventional methods of fertilizer application in the soil and subsequent irrigation either through furrow or drip system. Similarly water soluble fertilizers were found to be superior over normal fertilizers with respect to yield and yield traits. Fertigation with 80 per cent water soluble fertilizer resulted in significantly higher nitrogen removal, while with respect to P_2O_5 and K_2O, uptake fertigation with 80 and 100 per cent recommended fertilizers through water soluble fertilizer were statistically on par. There was no significant difference among the treatments for quality parameters.

Key words: fertigation, normal fertilizer, nutrient uptake, water soluble fertilizers.

Abbreviations

CPE = Cumulative pan evaporation.

FEE = Fertilizer expense efficiency

NF = Normal fertilizer

WSF= Water soluble fertilizer

Introduction

In agriculture every attempt is necessary to achieve higher nutrient efficiency in the light of reduced availability of resources for the manufacture of fertilizers coupled with limited water resources available for crop production. Hence, a better management system like drip irrigation with fertilizer application facility ensuring uniform nutrient distribution at the site of high concentration of active root improves the nutrient use efficiency and thus save the fertilizer cost, while raising the crop yields. Fertigation is defined as the application of solid and liquid fertilizer materials directly at the site of plant base through irrigation water (Magen 1995).

Chilli is one of the annual commercial spice crops of par excellence not only in India but also in the world. This crop requires adequate fertilizer and timely irrigation for achieving higher productivity. The major limitation for achieving high returns from the crop in Karnataka is the shortage of ground water. Adoption of modern and efficient methods of irrigation is one of the avenue to increase the output and at the same time to save precious water and fertilizer. Hence, there is ample scope for conducting research to findout management answers to the fertigation technology. This involves type of fertilizers to be used quantity and concentration by which it is applied to the crop. Therefore, the present investigation was undertaken to assess the feasibility of fertigation on yield and quality of chilli crop.

Materials and methods

Field experiment was conducted at the Horticultural Research Station, University of Agricultural sciences, Gandhi Krishi Vignana Kendra, Bangalore to study the effect of fertigation in chillies to compare the sources and levels of fertilizers during the *rabi* seasons of 1997 and 1998. The soil of the experimental site was red sandy loam with pH of 6.4 having low nitrogen, medium P and K_2O content. There were eight treatments laid out in RCBD design with three replications. Treatments consisted of T_1: Soil application of 100 per cent recommended dose (150:75:75 N, P_2O_5 and K_2O kg/ha^{-1}, respectively) through normal fertilizers with furrow irrigation once in 6 days at 0.6 CPE and T_2: Soil application of 100 per cent recommended dose of normal fertilizers with drip irrigation. While T_3, T_4 and T_5 involved drip fertigation of 60, 80 and 100 per cent of recommended dose through normal (local) fertilizers respectively. T_6, T_7 and T_8 consisted of drip fertigation of 60, 80 and 100 per cent of recommended dose through water soluble fertilizers. Plot size was 4 x 4 m. Drip system was installed soon after transplanting. Laterals were placed at 45 cm rows while the emitters were placed at 45 cm one each per plant. Drip irrigation system was run for one and half hour at every three days with an emitter discharge of 2 litres h^{-1}. Seedlings of 45 days old 'Byadagi Dabba' variety were transplanted. The crop took a total duration of 180 days for complete harvest. The normal fertilizers used in the experiment were urea, single super phosphate and muriate of potash as N, P and K source, respectively. Whereas, the 100 per cent water soluble (19:19:19 N, P_2O_5 & K_2O) fertilizers were supplied by Kemira Agro, Finland. Soil application of fertilizers was done as per the recommended practice, where 50 per cent of N, and full dose of P_2O_5 & K_2O were applied at the time of planting, remaining 50 per cent of N was applied 6 weeks after planting. In fertigation methods according to the treatments, required quantities of fertilizer (normal/WSF) were applied in 11 splits at 9 days interval upto 145 days of crop growth. In this method, required quantities of fertilizers for each treatment were first dissolved in a bucket of water and put in a fertilizer tank of 20 liter capacity. The experimental data was statistically analysed as per the procedure of Cochran & Cox (1965). Only pooled data is considered while discussing the results.

Results and discussion

Fruit yield and yield attributes

Fertigation of water soluble fertilizers (WSF) at 80 per cent recommended dose registered significantly higher dry fruit yield (1268.00 kg ha^{-1}) over rest of the treatments but was on par with fertigation of WSF at 100 per cent recommended dose (1237.82 kg ha^{-1}) (Table 1). Fertigation with 80 per cent WSF produced 2.40, 13.08, 17.23, 45.20 and 26.12 per cent higher yield over 100 per cent recommended dose with WSF or NF, 60 per cent recommended dose with WSF or NF and 80 per cent recommended dose with NF, respectively. The highest yield obtained in case of WSF might be due to 100 per cent solubility of fertilizer material in the water. Whereas, the lower yield in case of normal fertilizers may be due to the clogging of emitters in the system as they were not having 100 per cent solubility, which resulted in uneven distribution of fertilizers. Among soil application methods, drip irrigation resulted in 11.15 per cent higher yield over soil application of normal fertilizers with furrow irrigation. Fertigation with 80 per cent recommended dose with WSF resulted in 31.00 per cent higher yield over soil application of normal fertilizers with furrow irrigation. The results are in conformity with the findings of Hartz *et al.* (1993). All the fruit characters such as length (13.88 cm), girth (5.13 cm), surface area (46.51 cm^2), index (29.51 cm^2), volume (15.05 cm^3) and average weight (0.86 g) of fruit were significantly higher with fertigation of 80 per cent recommended dose with WSF. The results are in agreement with the findings of Muralidhar (1998). Even with same method and level of NF application, drip irrigation recorded significantly higher fruit quality characters over furrow method of irrigation. The beneficial effect of drip irrigation over furrow method of irrigation has been demonstrated by Ramesh (1986) & Kataria & Michael (1990).

Quality parameters

Quality parameters such as ascorbic acid, capsanthin and capsaicin content did not vary significantly either by irrigation methods or fertigation with normal and water soluble fertilizers (Table 2). Fertigation of 100 per cent recommended dose with WSF recorded maximum ascorbic acid content (134.74 mg 100 g^{-1}), while, capsanthin content was maximum with fertigation of 80 per cent recommended dose with WSF (0.49%) because of higher moisture and nutrient availability with fertigation treatments. Even with same method and level of NF application drip irrigation method recorded highest capsaicin content (0.48%) over furrow (0.45%) irrigation method. Higher capsaicin content under furrow irrigation may be related to lower availability of soil moisture under furrow irrigation as capsaicin content increases with decrease in the soil moisture. Similarly, Wierenga & Hendricks (1985) observed that the pungency of the green chilli peppers showed clear trend

Table 1. Fruit yield and yield attributes of chilli as influenced by fertigation, sources and levels of fertilizers.

	Treatment	Dry fruit yield (kg ha^{-1})	Fruit length (cm)	Fruit girth (cm)	Fruit surface area (cm^2)	Fruit index (cm^2)	Fruit volume (cm^3)	Average fruit weight (g)	Seed weight fruit^{-1} (g)
	Soil application								
T_1	100 per cent rec. dose with NF + furrow irrigation	874.90	11.95	3.92	30.66	19.40	8.35	0.75	0.22
T_2	100 per cent rec. dose with NF + drip irrigation	984.74	12.53	4.25	33.55	21.27	9.59	0.83	0.23
	Drip fertigation								
T_3	Fertigation of 60 per cent rec. dose with NF	694.91	11.28	3.57	25.38	16.12	6.09	0.75	0.20
T_4	Fertigation of 80 per cent rec. dose with NF	936.78	12.07	3.95	30.10	19.12	8.01	0.84	0.21
T_5	Fertigation of 100 per cent rec. dose with NF	1102.10	13.76	4.83	41.89	26.67	13.59	0.85	0.23
T_6	Fertigation of 60 per cent rec. dose with WSF	1049.48	13.53	4.75	40.47	25.67	12.86	0.84	0.21
T_7	Fertigation of 80 per cent rec. dose with WSF	1268.00	13.88	5.13	46.51	29.51	15.05	0.86	0.24
T_8	Fertigation of 100 per cent rec.dose with WSF	1237.82	13.85	5.09	44.43	28.19	15.17	0.85	0.24
	SEm ±	18.957	0.175	0.175	3.856	1.423	1.072	0.030	0.005
	CD at 5%	57.505	0.532	0.532	11.722	4.347	3.258	0.092	0.017

Table 2. Influence of fertigation methods, sources and levels of fertilizers on quality parameters, nutrient uptake and fertilizer expense efficiency of chilli.

Treatment	Quality parameter			Nutrient uptake ($kg\ ha^{-1}$)									Fertilizer expense efficiency ($kg\ kg^{-1}$)
				Nitrogen			Phosphorus			Potassium			
	Ascorbic acid ($mg\ 100g^{-1}$)	Capsanthin (%)	Capsaicin (%)	Haulm	Fruit	Total	Haulm	Fruit	Total	Haulm	Fruit	Total	
Soil application													
T_1: 100 per cent rec. does with NF + furrow irrigation	116.79	0.43	0.48	11.99	31.57	43.56	1.34	5.18	6.52	13.72	16.29	30.01	2.92
T_2: 100 per cent rec. dose with NF + drip irrigation	125.20	0.44	0.45	14.78	37.41	52.19	1.81	6.73	8.54	16.61	22.27	38.88	3.18
Drip Fertigation													
T_3: Fertigation of 60 per cent rec. dose with NF	118.84	0.43	0.43	11.69	27.13	38.82	1.26	4.06	5.32	13.03	14.93	27.96	3.86
T_4: Fertigation of 80 per cent rec. dose with NF	123.49	0.44	0.45	15.43	35.06	50.49	2.08	5.98	8.06	17.48	21.80	39.28	3.49
T_5: Fertigation of 100 per cent rec. dose with NF	131.38	0.47	0.46	17.16	45.64	62.80	2.28	7.83	10.11	19.33	28.28	47.61	3.67
T_6: Fertigation of 60 per cent rec. dose with WSF	124.09	0.47	0.44	15.25	41.39	56.64	1.85	6.72	8.57	16.69	22.47	39.16	5.83
T_7: Fertigation of 80 per cent rec. dose with WSF	134.13	0.49	0.46	18.52	55.15	73.67	2.83	9.00	11.83	21.14	32.13	53.27	5.28
T_8: Fertigation of 100 per cent rec.dose with WSF	134.74	0.48	0.46	17.87	48.20	66.07	2.44	8.73	11.17	20.56	30.18	50.74	4.13
SEm±	7.100	0.024	0.026	0.760	1.182	2.112	0.231	0.475	0.508	0.878	1.098	1.609	0.097
CD at 5%	NS	NS	NS	2.307	3.587	6.407	0.702	1.442	1.541	2.663	3.331	4.882	0.296

with the irrigation treatments, the drier the treatment, the more pungent was the pepper. Further in a study conducted at Bangalore in capsicum, higher levels of irrigation recorded significantly higher ascorbic acid and it was lower with lower levels of irrigation. While, capsaicin content was higher under dry or lower levels of irrigation and it was less with higher levels of irrigation (Bandi 1994).

Nutrient uptake

The increased yield with fertigation of 80 per cent recommended level with WSF might be related to the higher NPK uptake (Table 2). The regulated supply of water and nutrients directly to the root zone at different stages of crop growth resulted in increased density of functional roots which caused for greater uptake of total N (73.67 kg ha^{-1}), P_2O_5 (11.83 kg ha^{-1}) and K_2O (53.27 kg ha^{-1}). Thus, there was also simultaneous increase in fertilizer expense efficiency as depicted in Table 2. Although the same quantity of 60, 80 and 100 per cent recommended dose was applied either with NF or with WSF the relative benefit was considerably higher in WSF irrespective of the fertilizer levels with reference to FEE. Fertilizer expense efficiency increased with decrease in fertilizer levels from 100 per cent to 60 per cent recommended dose. FEE can often be increased and in some instances comparable or higher yields have been produced with savings of upto 60 per cent in fertilizer use (Kenworthy 1979, Miller *et al.* 1979).

In conclusion, application of fertilizers through fertigation was found to be significantly superior over the conventional methods of fertilizer application in the soil and subsequent irrigation either through furrow or drip system. Similarly water soluble fertilizers were found to be superior over normal fertilizers with reference to yield and use efficiencies of both water and fertilizers.

References

Bandi A G 1994. Effect of moisture stress on growth and yield of chilli under furrow and drip irrigation methods. Ph.D thesis submitted to University of Agricultural Sciences, Bangalore.

Cochran N G & Cox G 1965. Experimental designs, Asia publishing House, Bombay, 2nd Edition, p.168-169.

Hartz T K, Le Strange M & May D M 1993. Nitrogen requirements of drip irrigated peppers. Hort. Sci. 28(11) : 1097-1099.

Kataria D P & Michael A M 1990. Comparative study of drip and furrow irrigation methods. Proc XI Int. Cong on the use of plastics in agriculture. New Delhi.

Kenworthy A L 1979. Applying N in fruit trees through trickle irrigation systems. Acta Hort. 899 : 107-110.

Magen H 1995. Fertigation: An overview of some practical aspects. Fert.News. 40(2) : 97-100.

Miller C H, Mc Collum R E & Sootin Claimon 1979. Relationships between growth of bell pepper and nutrient accumulation during ontogeny in field environments. J.Amer. Soc. Hort.Sci. 104(6) : 852-857.

Muralidhar A P 1998. Effect of fertigation with normal and water soluble fertilizers compared to drip and furrow systems in capsicum-sunflower cropping sequence. Ph.D Thesis submitted to University of Agricultural Sciences, Bangalore.

Ramesh S 1986. A study on drip and furrow methods of irrigation in green chilli under different planting patterns and plant densities. M.Sc.(Agri) thesis, submitted to University of Agricultural Sciences, Bangalore.

Wierenga & Hendricks J M H 1985. Yield and quality of trickle irrigated chille peppers. Agric.Water Management 9 : 339-356.

Influence of nitrogen and phosphorus on growth, yield and nutrient content of fenugreek (*Trigonella foenum – graecum* L.)

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Abstract

A field experiment was conducted to study the influence of nitrogen and phosphorus on growth, yield and nutrient content of fenugreek (*Trigonella foenum – graecum*). Among the four nitrogen levels, (0, 30, 60, 90 kg/ha) the plants receiving 60 kg nitrogen were found to be significantly superior and recorded maximum plant height (45.55 cm), higher number of pods per plant (17.03), maximum dry weight (12.5 g) and higher seed yield (15.00 a/ha). While, among the four phosphorus levels (0,30,60,90 kg/ha) plants supplied with 90 kg phosphorus were found to record significantly higher plant height (46.53 cm), maximum number of pods per plant (15.06), dry weight (11.12) and better seed yield (12.49 q/ha). Similarly, interactions of N at 60 kg/ha and P at 90 kg/ha were found highly significant with respect to plant height (57.15 cm), dry weight (16.36 g) and recorded the enhanced seed yield 85q/ha, respectively). Hence, the fertilizer levels of 60:90:50 kg NPK were found optimum for better growth, yield and nutrient content in fenugreek.

Key words: fenugreek, growth, nitrogen, nutrient, phosphorus, yield

Introduction

Methi (Fenugreek) is one of the oldest cultivated spice crops. It is a robust annual herb, leaves are rich in minerals, vitamins (A&C) and protein. It is used not only as spice but also as medicine and condiment. In the United States it is used in the preparation of chutneys, spice blend, maple syrup, bean soup and fenugreek beef stew. It is also used in sweets served to ladies during the post-natal period. Recent studies indicate that, fenugreek seeds substantially contain the steroidal substance called 'diosgenin' which is used as a starting material in the synthesis of sex-hormones and oral contraceptives in family planning programmes. In India the crop is cultivated over forty thousand hectares and earning the foreign exchange of more than Rs. 2000 lakhs by exporting 15 metric tones of seeds. India being the major producer of spices can over take other countries in producing and exporting fenugreek.

The crop is usually cultivated both, during kharif and Rabi seasons. Since, there is an ever increasing demand, it is required to be cultivated on a large area. Hence, the production technology has to be standardized as the supply of plant nutrients at appropriate quantities is of utmost importance to enhance the productivity.

Materials and methods

The experiment was conducted at the Horticultural Research Station, University of Agricultural Sciences, GKVK, Bangalore. The experimental design was Factorial RCBD consisting of 16 treatment combinations. Nitrogen and phosphorus each were applied at four levels (0, 30, 60 and 90 kg/ha), while potash was constant at 50 kg/ha. The treatments were replicated four times with a net plot size of 1.2 x 1.2 m. The fertilizers were applied in the form of straight fertilizers. Nitrogen was applied as urea, phosphorous as single super phosphate and potassium as muriate of potash. The plots were applied with half the dose of nitrogen and full dose of phosphorus and potash as basal application at the time of sowing. According to the treatments, the remaining half dose of nitrogen was applied three weeks later. The plots were kept free of weeds by hand weeding and irrigation was given soon after sowing, twice a week for first four weeks and subsequently at weekly intervals to maintain optimum moisture. The observation on both morphological and yield characters were recorded and analysed as per Sundaraj (1972).

Results and discussion

The results of the present investigation on the effect of levels of nutrition and their implication on crop growth and crop growth and yield have been discussed hereunder and the data is presented in tables 1 and 2.

Table 1. Effect of nitrogen, phosphourus and their interactions on growth and yield parameters in fenugreek.

Treatments	Growth parameters					Yield parameters					
	Plant height (cm)	No. of branches /plant	No. of leaves /plant	Days to 50% flowering	Dry wt. /plant (q)	No. of pods/ plant	No. of s4eeds/ pod	Test (1000-seed) wt. (g)	Seeds/ plant (g)	Seed yield/ plot (g)	Seed yield/ ha. (g)
Nitroge levels											
0 kg N/ha (N_1)	38.73	3.86	62.15	36.00	7.78	9.05	11.81	10.61	1.21	145.218	5.38
30 kg N/ha (N_2)	38.63	5.13	76.98	35.13	9.60	12.36	14.05	11.86	1.98	241.84	8.96
60 kg N/ha (N_3)	45.55	6.32	89.30	36.38	12.93	17.03	15.52	12.52	3.38	405.07	15.01
90 kg N/ha (N_4)	45.36	5.54	87.98	41.75	9.41	12.44	14.78	11.56	2.15	257.76	9.55
F-test	**	*	**	**	**	**	**	**	**	**	**
SEm ±	1.205	0.399	2.234	0.305	0.386	0.755	0.289	0.149	0.165	18.994	0.704
CD at 5%	3.340	1.107	6.191	0.846	1.069	2.093	0.800	0.412	0.457	52.640	1.950
Phosphorus levels											
0 kg P_2O_5/ha (P_1)	39.40	4.83	72.34	38.19	9.33	11.44	13.43	11.19	1.85	222.03	8.23
30 kg P_2O_5/ha (P_2)	40.61	5.67	7.66	38.25	9.60	13.05	13.56	11.53	2.05	246.10	9.12
60 kg P_2O_5/ha (P_3)	41.72	4.95	78.84	36.94	9.76	11.52	13.81	12.03	2.04	244.44	9.06
90 kg P_2O_5/ha (P_4)	46.53	5.40	87.56	35.88	11.12	15.06	15.36	11.80	2.77	337.38	12.50
F-test	**	NS	**	**	**	**	**	**	**	**	**
SEm ±	1.205	0.399	2.234	0.305	0.386	0.755	0.289	0.149	0.165	18.99	0.704
CD at 5%	3.340		6.191	0.846	1.069	2.093	0.800	0.412	0.457	52.64	1.950
Interactions											
N_1P_1	34.03	2.70	45.28	37.00	6.67	6.35	10.68	9.73	0.680	81.61	3.03
P_2	37.46	5.45	67.57	36.50	5.59	14.45	11.63	10.68	1.87	224.55	8.32
P_3	39.56	3.25	61.71	35.75	6.33	4.71	10.3	11.50	0.69	76.32	2.83
P_4	44.86	4.06	74.03	34.75	8.54	10.68	14.63	10.55	1.66	198.65	7.36
N_2P_1	41.38	5.37	81.64	35.25	9.16	12.67	12.75	10.80	1.78	214.04	7.93
P_2	39.93	6.05	80.97	34.75	9.73	12.08	13.83	11.98	1.99	239.97	8.89
P_3	35.57	4.72	77.59	35.00	9.89	12.01	14.88	12.28	2.17	260.41	9.65
P_4	37.64	4.37	63.73	35.50	9.64	12.70	14.75	12.37	1.95	252.96	9.37
N_3P_1	41.63	4.81	78.02	37.75	12.03	15.45	15.55	12.28	2.95	354.05	13.11
P_2	40.01	5.76	77.70	40.00	10.99	13.75	14.54	12.30	2.41	295.05	10.93
P_3	43.40	6.69	83.78	35.00	12.30	15.78	15.18	12.28	2.95	345.53	13.13
P_4	57.15	8.00	117.70	32.00	16.36	23.13	16.77	13.22	5.14	616.64	22.85
N_4P_1	40.57	6.44	84.43	42.75	9.46	11.28	14.75	11.95	1.99	238.41	8.83
P_2	45.06	5.44	84.41	41.75	8.10	11.94	14.18	11.17	1.87	224.85	8.33
P_3	49.35	5.14	92.30	42.00	10.17	12.80	14.88	12.05	2.39	286.51	10.62
P_4	46.48	5.14	90.80	40.50	9.94	13.75	15.30	11.05	2.34	281.28	10.42
F-Test	**	*	**	**	**	**	**	**	**	**	**
SEm ±	2.40	0.799	4.468	0.611	0.722	1.511	0.578	0.297	0.330	37.987	1.40
Cd at 5%	6.679	2.213	12.382	1.692	2.139	4.186	1.601	0.824	0.914	105.297	3.90

* Significant ** Highly significatn NS = Non significant

Table 2. Effect of nitrogen, phosphorus and their interactions on nutrient (N and P) content of straw and seeds of fenugreek.

Treatments		Nutrient content (%)			
		Straw		Seeds	
		N	P	N	P
Nitrogen levels of kg/ha					
0 (N_1)		1.10	0.14	3.15	0.42
30 (N_2)		1.14	0.15	3.28	0.43
60 (N_3)		1.24	0.15	3.83	0.49
90 (N_4)		1.33	0.16	4.26	0.48
F-test		**	**	**	**
SEm ±		0.015	-	0.029	0.002
CD at 5%		0.001	0.081	0.081	0.006
Phosphorus levels of kg P_2O_5/ha					
0 (P_1)		1.19	0.14	3.54	0.43
30 (P_2)		1.17	0.15	3.57	0.45
60 (P_3)		1.19	0.15	3.38	0.46
90 (P_4)		1.26	0.15	3.84	0.47
F-test		**	*	**	**
SEm ±		0.015	-	0.029	0.002
CD at 5%		0.043	0.001	0.081	0.006
Interactions					
N_1	P_1	0.13	0.14	3.13	0.37
	P_2	1.02	0.14	3.15	0.42
	P_3	1.10	0.14	3.19	0.43
	P_4	1.15	0.14	3.14	0.45
N_2	P_1	1.12	0.14	3.20	0.42
	P_2	1.15	0.14	3.23	0.42
	P_3	1.16	0.15	3.23	0.42
	P_4	1.14	0.15	3.44	0.45
N_3	P_1	1.18	0.14	3.49	0.48
	P_2	1.21	0.14	3.77	0.50
	P_3	1.22	0.15	3.62	0.49
	P_4	1.37	0.16	4.44	0.40
N_4	P_1	1.31	0.15	4.27	0.46
	P_2	1.32	0.16	4.14	0.48
	P_3	1.32	0.16	4.26	0.49
	P_4	1.37	0.16	4.36	0.49
F-test		*	*	**	**
SEm ±		0.031	0.001	0.059	0.004
CD at 5%		0.086	0.002	0.163	0.011

* Significant ** Highly significant

The plant height and other vegetative characters were influenced significantly by the different levels of nitrogen, phosphorus and their interactions during the plant height (45.55 cm), number of branches (6.3), number of leaves (89.30) and dry weight (12.93 g) per plant, while the nitrogen at 30 kg per hectare was found to record minimum number of days to 50 per cent flowering (35.13). These results are in agreement with the earlier reports of Farooqi., *et al* (1991) in davana and Deteroja *et al* (1996) in fenugreek. Phosphorus application at 90 kg per hectare had a significant effect on some of the growth characters by recording the maximum plant height (46.53 cm), number of branches (5.4), more number of leaves (87.56), dry weight (11.12 g) and minimum number of days to 50 per cent flowering (35.88). Similar results were observed by Bhati (1996) and Kanwar and Saimbhi (1993) in fenugreek.

The interaction effects of nitrogen and phosphorus level at 60 kg and 90 kg per hectare, respectively, resulted in the maximum number of leaves (117.70), higher dry weight (16.36 g per plant) and minimum number of days to 50 per cent flowering (32.00). Results of Patel *et al* (1991) and Rathore and Manohar (1992) in fenugreek confirm the present findings.

The different levels of nitrogen, phosphorus and their interaction significantly differed with yield parameters also. The nitrogen application at 60 kg per hectare resulted in the maximum number of pods per plant (17.03), higher number of seeds per pod (15.22), highest test weight of seeds (12.52 g) and seed yield per hectare (15.01 q). Similarly, the application of phosphorus at 90 kg per hectare resulted in significantly higher production of pods per plant (15.06), number of seeds per pod (15.36), seed yield per plant (2.77 g), seed yield per plot (337.38 g) and seed yield per hectare (12.50 q) (Table 1). This may be due to the fact that phosphorus influences the reproductive growth and hence resulted in the production of more number of pods. Patel *et al.* (1991) and Bhati (1993) in fenugreek have also observed similar results.

The plants receiving 60 kg nitrogen and 90 kg phosphorus per hectare (interaction) recorded the maximum number of pods per plant (23.13), number of seeds per pod (16.77), test weight of seeds (13.22 g), seed yield per plant, per pod and per hectare (5.14 g, 16.64 g and 22.85 g, respectively).

The nitrogen and phosphorus contents (%) in both seed and straw tissues differed significantly with different levels of nitrogen, phosphorus and their interactions (Table 2). The maximum tissue nitrogen in seed (4.26%) and in straw (1.33%) was observed with the application of 90 kg nitrogen, while, the maximum phosphorus in seed (0.48%) and in straw (0.15%) was recorded at 60 kg nitrogen per hectare. Application of phosphorus at 90 kg per hectare recorded maximum tissue nitrogen (3.84% in seed and 1.26% in straw) and phosphorus (0.47% in seed and 0.15% in straw). The interaction effects of nitrogen and phosphorus at 60 kg nitrogen with 90 kg phosphorus level recorded the maximum tissue nitrogen (4.44% in seed and in straw 1.37%) and phosphorus (0.49% in seed and 0.16% in straw).

From the present investigation, it may be concluded that, the fenugreek should be applied with a fertilizer dose of 60:90:50 kg NPK per hectare to obtain the maximum growth and yield.

References

Bhati D S 1996 RMT-1 a high yielding fenugreek variety, Spice India 9(11) : 21-22.

Deteroja H J Sukhadia N M Khanepara V D Malavia D D & Kaneria B B 1996 Response of fenugreek to nitrogen, phosphorus and potassium, Indian J. Agron. 41(1) : 179-180.

Farooqi A A Devaiah K A Vasundhara M Raju B & Dashratha Rao N D 1991 Effect of nutrients on growth, yield and essential oil content of Davana, Indian Perfume 35(2) : 63-38.

Kanwar J S & Saimbhi M S 1993 Response of seed crop of "Kasuri" fenugreek to nitrogen, potassium and leaf cutting , Indian J. Agril. Sci., 6(5) : 299 - 300.

Patel B A Patel R H Ancil A V & Patel M 1991 Response of fenugreek to N, P and K, India J. Agron., 36(1) : 389-391.

Rathore P S & Manohar S S 1992 Effect of dates of sowing levels of N and P on ancillary characters and yield of fenugreek. Madras Agril. J. 79(1) : 45-47.

Sundararaj N, Nagaraju S, Venkatara M N & Jagadesh M K 1972 Design and Analysis of field experiments, Published by University of Agricultural Sciences, Bangalore.

Effect of sowing dates and planting methods on plant growth and seed yield of fennel (*Foeniculum vulgare* Mill.)

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Abstract

The experiment consisting of combinations of two planting methods and four dates of sowing was carried out at the research farm of CCS, Haryana Agricultural University, Hisar during 1996-97 and 1997-98 on seed crop of fennel cv. HF – 33.

Transplanted crop produced taller plants with more dry weight per plant, compared to direct sowing during both the years. Higher seed yield per plant was recorded with transplanted crop during both the years. Improvement in yield was about 38.7 per cent during 1996-97 and 33.5 per cent during 1997-98. Sowing / transplanting on 15[th] October produced tallest plant with more dry weight per plant. The biological yield and seed yield per plant were maximum in first sowing / transplanting date. Delay in direct sowing recorded more reduction in plant height, dry weight per plant and seed yield per plant compared to transplanted crop.

Key words : dry weight, fennel, growth, method of planting, planting date, seed yield

Introducton

Fennel (*Foeniculum vulgare* Mill.) commonly known as 'saunf' is one of the most important winter season seed spices grown in north India. The leaves and seeds are digestive, appetizing, stimulant and dried seeds have a fragrant odour. It is also largely used as a spice in cooking for flavouring various products such as soups, pickles etc. The fennel seeds contain 0.7 to 5.0 per cent pale yellow aromatic volatile oil which is used in perfumes, soaps and medicines. In spite of its various uses and demands within and outside the country, the fennel is not grown commercially in Haryana. This may be due to the lack of information on sowing time and planting methods of the crop for growing it successfully. Keeping in view the importance of this crop, an experiment was conducted to find out the optimum time of sowing and appropriate planting method for fennel under Haryana conditions.

Materials and methods

The experiment was carried out at the vegetable research farm of CCS Haryana Agricultural University, Hisar during the years 1996-97 and 1997-98. The treatments consisted of combinations of four sowing dates (5th, 15th and 25th October and 5th November during 1996-97 and 15th and 25th October, 5th and 15th November during 1997-98) and two planting methods (direct sowing and transplanting). The experiment was laid out in randomized block design with three replications. For raising seedlings, seeds were sown in nursery beds at 10 days interval starting from 1st September and the seedlings were ready for transplanting in 30-35 days after sowing. The sowing / transplanting was done as per treatments, at a spacing of 30 × 20 cm in plots measuring 3.0 × 2.4 m. In direct sown plots spacing was maintained by thinning the crop twice. All the cultural operations and plant protection measures were carried out as and when required. For recording data on seed yield per plant, crop was harvested in the first week of May during 1997 and last week of April during 1998. Data on plant height and dry weight per plant were recorded from three plants uprooted in each treatment (leaving border row and border plants) at 50, 75, 100, 125, 150 and 175 days and oven dried at 60°C to constant weight for recording data on dry weight. Plant height before bolting was recorded up to highest tip of leaf but after bolting it was recorded up to the highest umbel.

Results and discussion

Plant height (mean of all treatments) was 19.6, 36.3, 73.4, 104.7, 112.3 and 121.4 cm during 1996-97 and

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32.6, 64.6, 114.3, 121.7, 129.0 and 148.3 cm during 1997-98 at 50, 75, 100, 125, 150 and 175 days after sowing / transplanting (Table 1). It indicates that maximum increase in plant height took place between 75 to 125 days after sowing / transplanting. Date of sowing as well as planting method had significant effect on plant height. During 1996-97, sowing/transplanting on 15th October recorded highest plant height at 50, 75, 100 and 125 days after sowing / transplanting and was significantly superior to all the remaining three treatments. However, at 150 and 175 days after sowing / transplanting highest plant height was recorded in 5th October sowing / transplanting, but was on par with 15th October sowing / transplanting. Both the treatments recorded significantly higher plant height compared with 25th October and 5th November planting. During 1997-98, 15th October planted crop recorded highest plant height on all the occasions and was significantly superior to remaining three treatments at 75, 100, 125, 150 and 175 days after sowing / transplanting. On all the occasions plant height recorded in 15th November sowing / transplanting crop was significantly lower than that recorded on 5th November or 25th October sowing / transplanting. The results are in agreement with Randhawa *et al.* (1978) Plant height in transplanted crop was significantly higher than the direct

Table 1. Effect of sowing dates and planting methods on plant height (cm).

Treatment	Days after sowing / transplanting					
	50	75	100	125	150	175
			1996-97			
Sowing date						
5th October	19.2	32.2	68.0	103.5	121.7	131.0
15th October	24.0	42.7	77.5	116.5	120.7	127.7
25th October	20.0	38.0	74.5	100.2	110.7	117.5
5th November	15.0	32.2	73.5	98.7	96.2	109.5
C.D. at 5%	1.6	2.8	N.S.	5.0	8.3	6.2
Planting method						
Direct sown	13.1	22.2	52.9	93.7	99.6	109.6
Transplanted	26.0	50.4	93.9	115.7	125.1	133.2
C.D. at 5%	1.1	2.0	5.2	3.5	5.9	4.4
Mean	19.6	36.6	73.4	104.7	112.3	121.4
			1997-98			
Sowing date						
15th October	39.8	85.4	136.8	152.7	159.0	175.8
25th October	38.2	57.2	120.7	129.5	136.2	156.3
5th November	29.7	50.1	110.6	113.4	120.7	141.3
15th November	22.6	45.7	88.9	91.2	100.5	119.8
C.D. at 5%	4.2	3.6	5.8	6.3	10.7	9.6
Planting method						
Direct sown	21.4	33.8	91.9	102.5	115.8	138.2
Transplanted	43.7	85.4	136.6	140.9	142.3	158.4
C.D. at 5%	2.9	2.6	4.1	4.5	7.5	6.8
Mean	32.6	64.6	114.3	121.7	129.0	148.3

sown crop.

Interaction between sowing dates and planting methods was significant. During 1996-97, highest plant height at 50, 125, 150 and 175 days after sowing / transplanting was recorded in 15th October transplanted crop while at 75 and 100 days after sowing / transplanting, plant height was highest in 25th October transplanted crop. During 1997-98, highest plant height was recorded in 15th October transplanted crop which was significantly superior to all the remaining treatment combinations on all the occasions.

Dry weight per plant (mean of all treatments) was 0.9, 4.8, 10.9, 40.0, 52.3 and 99.6 g during 1996-97 and 2.1, 9.5, 25.4, 34.0, 47.0 and 63.8 g during 1997-98 at 50, 75, 100, 125, 150 and 175 days after sowing / transplanting (Table 2). It indicates that dry weight accumulation was very little during first 50 days and maximum dry weight accumulated between 150-175 days after sowing / transplanting. Date of sowing as well as planting method had significant effect on dry weight per plant. Sowing / transplanting on 15th October recorded highest dry weight on all sowing dates during both the years and was significantly superior to all the

Table 2. Effect of sowing dates and planting methods on dry weight per plant (g)

Treatment	Days after sowing / transplanting					
	50	75	100	125	150	175
			1996-97			
Sowing date						
5th October	0.8	3.3	11.6	43.5	48.1	105.2
15th October	1.5	6.0	13.7	51.0	71.3	147.6
25th October	0.8	5.4	11.2	26.8	56.7	100.4
5th November	0.6	4.4	7.1	38.5	35.1	45.2
C.D. at 5%	0.1	1.3	3.2	7.0	7.7	3.0
Planting method						
Direct sown	0.3	1.5	7.0	23.5	35.7	59.5
Transplanted	1.6	8.0	14.8	56.4	69.9	139.7
C.D. at 5%	0.1	0.9	2.3	4.9	5.4	2.1
Mean	0.9	4.8	10.9	40.0	52.3	99.6
			1997-98			
Sowing date						
15th October	4.2	15.1	39.0	56.1	71.6	101.8
25th October	1.8	10.0	25.4	35.4	62.5	84.4
5th November	1.3	7.8	22.3	26.6	30.7	36.9
15th November	1.1	5.1	14.9	13.0	23.2	28.3
C.D. at 5%	0.7	2.1	2.6	2.8	3.0	3.7
Planting method						
Direct sown	0.6	5.0	14.8	22.8	32.1	43.3
Transplanted	3.6	13.9	36.0	45.2	62.0	84.4
C.D. at 5%	0.5	1.5	1.8	2.0	2.1	2.6
Mean	2.1	9.5	25.4	34.0	47.0	63.8

remaining three treatments except at 75 and 100 days during 1996-97. During 1997-98, dry weight recorded in 15th November sown / transplanted crop was significantly lower than that recorded on 5th November sowed / transplanted crop on all the occasions except at 50 days after sowing / transplanting. Dry weight per plant in transplanted crop was always significantly higher than the direct sown crop.

Interaction between sowing dates and planting methods was significant. During 1996-97, highest dry weight at 50, 125, 150 and 175 days after sowing / transplanting was recorded in 15th October transplanted crop while at 75 and 100 days after sowing /transplanting the dry weight was highest in 25th October transplanted crop, closely followed by 15th October transplanted crop. During 1997-98, highest dry weight was recorded in 15th October transplanted crop which was significantly superior to all the remaining treatment combinations on all sowing dates.

Table 3. Effect of sowing dates and planting methods on seed yield per plant (g)

Treatment	Days after sowing / transplanting		
	Direct sown	Trans-planted	Mean
		1996-97	
Sowing date			
5th October	13.6	16.0	14.8
15th October	11.7	14.7	13.2
25th October	8.6	13.3	10.9
5th November	6.1	11.6	8.9
Mean	10.0	13.9	
		1997-98	
15th October	11.8	13.9	12.9
25th October	6.8	10.5	8.7
5th November	6.2	7.5	6.8
15th November	2.7	5.0	3.9
Mean	6.9	9.2	
C.D. at 5	Dates	Methods	Dates × methods
1996-97	0.8	0.6	1.1
1997-98	0.5	0.4	0.7

Since growth was better with earlier sowing / transplanting and it reduced with delay in sowing / transplanting, therefore, fennel seed yield reduced significantly with each delay in sowing / transplanting during both the years (Table 3). Total photosynthetic area was more in earlier sowing / transplanting dates compared with later sowing / transplanting date. This may have intercepted more light and thus resulted in higher yield. Similarly, since transplanted crop had better growth, it resulted in significantly higher seed yield compared with direct sown crop during both the years. Mehta *et al.* (1990) and Wagner (1993) also recorded higher yield from transplanted crop compared with direct sown crop.

Highest yield was recorded when transplanting was done on 5th October, closely followed by 15th October transplanted crop during 1996-97. During 1997-98, highest seed yield was obtained when crop was transplanted on 15th October which was significantly superior to all the remaining treatment combinations, whereas 15th November direct sown crop recorded very poor yield (2.7 g) because of poor plant canopy at the time of flower initiation and thus assimilates available for seeds to grow must have been low. Bhati & Agrawal (1987) & Patel & Patel (1987) also reported similar results. Thus, in fennel, transplanting is better than direct sowing for getting higher yield and the optimum sowing time is 15th October.

References

Bhati D S & Agrawal H R 1987. Effect of sowing dates of fennel (*Foeniculum vulgare* Mill.) varieties, National Symp. Spices Industries, New Delhi.

Mehta K G, Patel P G & Patel I D 1990. A new avenue of fennel cultivation in Gujarat. Indian Cocoa, Arecanut and Spices J. 13 (4) : 139-141.

Patel P G & Patel I D 1987. New agronomic practices for fennel crop. National Symp. Spices Industries, New Delhi.

Randhawa G S, Bains D S, Mahajan V P & Singh Kuldeep 1978. Effect of sowing date and levels of nitrogen on the yield of fennel. J. Res. Punjab Agric. Univ. Ludhiana 15 (3) : 229-235.

Wagner H 1993. Maximizing seed yield and important components of fennel (*Foeniculum vulgare* Mill.) I. Felt. Wissensehaft Tech. 95 (3) : 114-117. (Hort. Abstr. 65 : 7366).

Effect of row and plant spacing on growth and yield of fennel (*Foeniculum vulgare* Mill.) cv. PF-35

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Abstract

A field experiment was conducted on fennel cv. PF-35 during winter season of 1999-2000 to find out the optimum row and plant spacing for arid South-West Haryana under sandy soils. There were three rows (20, 30 and 40 cm) and three plant (15, 20 and 25 cm) spacings Thus, a total of 9 treatments were arranged in randomized block design with three replications. The maximum plant height (182.0 cm), number of primary branches per plant (6.55) and number of umbels per plant (30.5) were recorded at 40 x 25 cm spacing. However these growth parameters were recorded minimum at 20 x 15 cm spacing. Maximum fruit (24.16 q ha^{-1}) and biological yield (136.2 q ha^{-1}). were produced at 20 x 15-cm spacing. The fruit and biological yield were obtained minimum at 40 x 25 cm spacing. The harvest index was also found maximum (17.73) at 20 x 15 cm spacing.

Key words: fennel, harvest index, spacing, umbels, yield.

Introduction

Fennel commonly known as 'Saunf' is an important winter season seed spice. In India fennel is cultivated in arid and semi arid regions. In Haryana State its cultivation is restricted to South-West Haryana, that too in some pockets only. Its restricted cultivation is possibly due to the lack of information on the cultural requirements for growing it successfully. The present investigation was therefore, carried out with the objective to find out the optimum row and plant spacing of arid south-west Haryana.

Materials and methods

The study was undertaken at Regional Dryland Research Station, Bawal of Choudhary Charan Singh Haryana Agricultural University during 1999-2000. The soil of the experimental area was sandy having on an average organic carbon 0.20%, pH 8.1, available N, P and K 90.55, 6.20 and 315.46 kg per hectare, respectively. The experiment consisted of 3 row spacings viz. 20 cm, 30 cm and 40 cm and three plant spacings viz 15 cm, 20 cm and 25 cm. In this way a total of nine treatment combinations were made, which were laid out in a randomized block design with three replications. The plot size was kept 4.80 m x 3.00 m. Seed of variety PF-35 was sown on 26.10.1999 after giving a presowing irrigation. A total of 4 post sowing irrigations were given. A basal dose of 50 kg N and 50 kg P_2O_5 per hectare was applied at sowing time. The remaining 50 kg N per hectare was applied in two equal split doses, the one at initiation of umbel in the last week of December and the another at flowering stage during last week of February. Rest of the package and practices were followed as and when required. The crop was harvested on 18.4.2000.

Results and discussion

Effect of spacing on growth and flowering

In general, plants at wider spacing gave higher plant height, number of branches per plant and number of umbels per plantm (Table 1). The maximum plant height (182.2 cm), number of primary branches per plant (6.55) and number of umbels per plant (30.5) were recorded at 40 cm row and 25 cm plant spacing followed by 40 x 20 cm spacing. The minimum plant height, number of primary branches per plant and number of umbels per plant were observed with 20 x 15 cm spacing. Obviously plants at wider spacing received more sunlight for photosynthesis, more nutrients for proper growth and development and the more space to spread. These results are in concurrence with those of El – Gengaihi and Abdallah (1978) who while working on

Table 1. Effect of row and plant spacing on growth and yield of fennel.

Treatments	Plant height (cm)	Number of primary branches per plant	Number of umbels per plant	Days to 50% flowering	Biological yield (q ha^{-1})	Fruit yield (q ha^{-1})	Fruit yield (g $plant^{-1}$)	Harvest index
Spacing (Row x Plant in cm)								
20 x 15	140.8	4.06	20.4	115.4	136.2	24.16	8.05	17.73
20 x 20	147.4	4.65	23.7	115.8	134.1	23.57	10.47	17.57
20 x 25	156.3	5.10	26.2	116.0	128.8	19.32	10.73	15.00
30 x 15	154.1	5.15	26.0	116.1	132.2	19.50	9.75	14.75
30 x 20	165.3	5.72	26.9	116.7	124.2	18.66	12.44	15.02
30 x 25	172.4	6.20	27.6	117.0	120.3	16.75	13.95	13.92
40 x 15	164.5	5.75	26.8	116.9	123.6	17.08	11.38	13.81
40 x 20	174.1	6.25	28.2	117.1	117.1	16.33	14.51	13.94
40 x 25	182.0	6.55	30.5	116.8	105.4	15.50	17.22	14.70
CD at 5%	7.2	0.42	3.1	N.S.	8.1	0.60	2.42	1.3

fennel clearly stated that wider spacing produced the taller plant with more branches consequently more number of umbels per plant. No significant differences were observed among various treatments for days taken to 50 per cent flowering.

Effect of spacing on fruit and biological yield

Plants spaced at 20 cm row and 15 cm plant spacing produced maximum fruit (24.16 q/ha) and biological yield (136.2 q ha^{-1}) (Table 1). 20 x 20 cm spacing also produced fruit and biological yield similar to that of 20 x 15 cm spacing. The minimum fruit (15.50 q ha^{-1}) and biological yield (105.4 q ha^{-1}) was recorded under widest spacing at 40 x 25 cm. The increase in fruit and biological yield at closer spacing might be duc to increased plant population per unit area without any hindrance to plant growth and development. A progressive increase in seed yield of fennel at closer spacing was also supported by Sharma and Prasad (1990) and Mehta *et al.* (1990).

Effect of spacing on fruit yield per plant and harvest index

Data presented in Table 1 showed that fruit yield per plant was highest (17.22 g $plant^{-1}$) at 40 cm row and 25 cm plant spacing followed by 40 x 20 cm spacing. The minimum seed yield per plant (8.05 g) was recorded at 20 x 15 cm spacing. The better performance of individual plants at wider spacing was due to availability of more space to individual plant, which had a direct bearing on plant height and yield components. The higher fruit yield per plant at wider spacing has also been reported by E1 – Gengaihi and Abdallah (1978), while working on fennel. The relationship between harvest index and plant density in fennel may be useful in optimizing plant populations for maximum fruit yeild. The data revealed that harvest index was lower under wider spacing and was found higher under denser spacing. It was observed maximum (17.73) at 20 x 15 cm spacing. The harvest index of the crop at 20 x 20 cm spacing (17.57) was similar to those of 20 x 15 cm spacing The minimum harvest index (13.81) was obtained under 40 x 15 cm spacing, which was statistically similar to rest of the treatments except 20 x 15 cm and 20 x 20 cm spacing. Similar observations have also been reported by Oliva *et al.* (1988) in carrot seed crop.

From the results it is obvious that higher fruit and biological yield of fennel can be obtained at 20 x 20 cm and at 20 x 15 cm spacing under sandy soils of arid south-west Haryana.

References

E1 – Gengaihi S & Abdallah N 1978. The effect of dates of sowing and plant spacing on yield of seed and volatile oil of fennel. Pharmazie 33(9) : 605-606.

Mehta K G, Patel P G & Patel I D 1990. A new avenue of fennel cultivation in Gujarat. Indian Cocoa, Arecanut and Spices Journal !2(1) : 5-7.

Oliva R N, Tissaoui T & Brad ford K J 1988. Relationship of plant density and harvest index to seed yield and quality in carrot. J. Amer. Soc. Hort. Sci. 113(4) : 532-537.

Sharma R N & Prasad R 1990. Effect of seed rates and row spacing on fennel cultivars. Indian J. Agron. 35(4) : 455-456.

Influence of growth regulators and methods of application on rooting of thyme (*Thymus vulgaris* L.) cuttings

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Abstract

A comparative study on the methods (soaking, quick dip and powder form) of application and growth regulators Indole buteric acid (IBA), Napthelene acidic acid (NAA), Triademophon (TRF) and Paclobutrazol (PBZ) was conducted in thyme under medium cost polyhouse conditions. The results indicated that under soaking method, application of IBA at 150 ppm resulted in early root initiation (7.0 days), high percentage of rooting (94.30) and more number of roots (13.4) per cutting. Whereas in the quick dip method, IBA at 2000 ppm took the minimum time for root initiation (7.8 days) and had high per cent of rooting (88.40) and higher number of roots (11.60). However, when the growth regulators were used as powder formulation, application of IBA at 1000 ppm recorded early rooting (8.0 days) and a rooting percentage of 84.40 with 12.40 number of roots. Thus, the study indicated that for early and better rooting in thyme, it should be soaked in IBA at 150 ppm solution when compared to either quick dip or powder formulations.

Key words: growth regulators, rooting, thyme.

Introduction

Thyme (*Thymus vulgaris* L.) is an evergreen perennial herb belonging to family Lamiaceae and is commonly known as Garden Thyme. Thyme is used of herb in flavouring, seasoning and garnishing of food. While thyme oil is mainly used in perfumery industry, in soaps and detergent production. The dried leaves and floral tops have got germicidal properties and is effective against a variety of pathogenic bacteria (Hussain *et al.* 1988). Because of its multifarious utility the plant has received much attention in India. India has the potential to export thyme to countries like USA, Netherland and Japan. To develop the agro-techniques of this crop, propagation of genuine planting material needs to be standardized. Thyme can be propagated by seeds as well as cuttings. However, great variation exists in seed setting and germination. Also, thyme does not flower or set seeds under Bangalore conditions. Hence, standardizing the techniques for the mass production of elite planting material becomes a necessity. Therefore, studies were taken up to investigate the best growth regulator and the best method of application to obtain maximum rooting of thyme cuttings under medium cost polyhouse conditions.

Materials and methods

Basal cuttings (semihard wood) of 8-10 cm long with sufficient leaves from previous season's growth formed the material for this experiment. The cuttings were treated by (i) soaking them for 18 hrs at 50,100 and 150 ppm of IBA, 100, 200 and 300 ppm of NAA, 25, 50 and 75 ppm of TRF and 10, 20 and 30 ppm of PBZ; (ii) quick dip method for one minute at 1000, 2000 and 3000 ppm IBA, NAA and TRF and PBZ at 50,100 and 150 ppm and (iii) powder formulations at 500, 750 and 1000 ppm IBA, 1000, 1500 and 2000 ppm NAA and TRF; PBZ at 50,100 and 150 ppm along with either distilled water or plain talc which served as one of the treatments, while, cuttings without any treatment served as control. Each treatment consisted of 15 cuttings and it was replicated thrice. The experiment was laid out in Completely Randomized Design at the Herbal Garden of Horticultural Research Station, University of Agricultural Sciences, GKVK, Bangalore. The observations were recorded at 45 days of planting and the data was analysed using the procedure recommended by Sunderaraj *et al.* (1972).

Results and discussion

Growth regulators and their concentrations had a varying effect on root and shoot parameters. The observations recorded under different methods of application and growth regulators are presented in Tables 1, 2 and 3.

From the tables it can be seen the earliest root initiation was observed under soaking method with IBA at 150 ppm (7.0 days) which was on par with lower concentration of PBZ at 10 ppm (7.4 days). Whereas, the control (14.73 days) required the longest rooting period and was inferior to water soaking treatment . Similarly, under quick-dip method, IBA at 2000 ppm showed early root initiation (7.8 days) and was on par with NAA at 2000 ppm (8.00 days). Whereas, in powder formulation, the early root initiation was noticed under IBA at 1000 ppm (8.0 days) and was on par with NAA at 1500 ppm (8.4 days) (Table 1). The stimulation of rooting under soaking treatment with IBA may be attributed to leaching of rooting inhibitors which enhance the quality and quantity of roots and promote the activity of naturally occurring compounds which help in development of roots (Haissign 1965). Auxins are also known to stimulate the root development by inducing root initials which are different from the young secondary phloem, cambium and pith tissue (Gianfanga 1987). The better root formation may also be due to accumulation of metabolites at the site of application. It appears probably that success of IBA is due to its slow degradation by auxin destroying enzyme, which is quite strong and it is not readily translocated.

Table 1. Effect of growth regulators under soaking method on root and shoot parameters of *Thymus vulgaris* L. cuttings.

Treatment	Root parameters			Shoot parameters		
	Time taken for root initiation (days)	Cuttings rooted (%)	Roots/ cutting (No.)	Time taken for first sprout to appear (days)	Sprouts/ cutting (No.)	Length of longest sprout (cm)
IBA 50 ppm	10.73	85.00	13.40	14.00	16.00	15.86
IBA 100 ppm	8.26	88.30	14.00	13.60	16.33	16.23
IBA 150 ppm	7.00	94.30	16.00	12.40	17.53	18.23
NAA 100 ppm	12.06	76.30	11.60	13.86	12.26	13.60
NAA 200 ppm	11.13	83.10	12.00	13.60	12.53	16.40
NAA 300	9.60	85.00	13.40	12.60	13.40	16.60
TRF 25 ppm	8.93	81.40	7.20	13.80	10.86	11.93
TRF 50 ppm	8.86	85.00	11.20	13.00	12.46	12.60
TRF 75 ppm	8.06	88.20	12.20	11.86	13.13	13.83
PBZ 10 ppm	7.40	93.30	10.60	12.86	12.60	13.93
PBZ 20 ppm	7.80	92.00	8.80	13.46	11.06	13.63
PBZ 30 ppm	7.93	90.30	6.60	14.26	10.46	12.26
Distilled water	12.93	46.20	8.40	14.86	9.13	8.96
Control	14.73	41.13	6.00	16.26	7.93	7.80
SEm ±	0.23	1.39	0.57	0.24	0.20	0.27
CD at 5%	0.69	4.04	1.67	0.70	0.58	0.80
CV %	4.29	3.007	9.38	3.07	2.81	3.53

Under soaking method, the highest percentage of rooting (94.30) was observed under IBA 150 ppm treatment which was on par with PBZ at 10, 20 and 30 ppm (93.30, 92.20 and 90.30%, respectively). While the control recorded lowest rooting percentage (41.13). Similarly, in quick dip method, the best rooting (88.40%) was obtained in IBA at 2000 ppm, NAA at 2000 ppm and PBZ at 150 ppm (87.00 and 86.90%, respectively) which were on par with each other (Table 2). Whereas, in powder formulation, IBA at 1000 ppm and IBA at 750 ppm were found to be most effective in recording high rooting percentage (84.40 and 79.50, respectively) and were also on par with each other (Table 3), but significantly superior over all other treatments. The increase in rooting percentage may be attributed to root stimulating and promoting effects of IBA as it also helps in partitioning of photosynthates towards root development. An increase in rooting percentage with soaking treatment has been reported by Poi & Mazumdar (1989) in Bael cuttings.

Maximum number of (16.00) roots was observed under IBA at 150 ppm with soaking and was superior over all the other treatments including water soaking (8.4) and control (6.0). Similarly, under quick-dip method the highest number of roots (13.40) was recorded under IBA at 2000 ppm. Whereas, in powder formulation method, the maximum number or roots (12.40) was noticed in IBA at 1000 ppm treatment and was on par with NAA at 1500 ppm and PBZ at 100 ppm (12.00). The increase in number of roots under soaking treatment may probably be due to leaching of naturally occurring compounds within cuttings which inhibit root emergence (Vogt 1951). It may be also be due to poor translocation of IBA which is fixed in the base of cuttings, thus seems to be a superior root stimulator. Similar observations were also reported by

Table 2. Effect of growth regulators under quick dip method on root and shoot parameters of *Thymus vulgaris* L. cuttings.

Treatment	Root parameters			Shoot parameters		
	Time taken for root initiation (days)	Cuttings rooted (%)	Roots/ cutting (No.)	Time taken for first sprout to appear (days)	Sprouts/ cutting (No.)	Length of longest sprout
IBA 1000 ppm	8.33	81.10	11.00	14.66	13.93	12.53
IBA 2000 ppm	7.80	88.40	13.40	13.33	16.00	14.13
IBA 3000 ppm	8.40	81.40	11.20	14.20	15.60	13.60
NAA 1000 ppm	10.13	75.90	7.40	14.33	12.80	10.80
NAA 2000 ppm	8.00	87.00	11.60	13.86	15.26	12.80
NAA 3000 ppm	11.20	77.20	9.20	14.13	13.73	10.60
TRF 1000 ppm	8.20	75.80	9.60	14.73	10.93	9.80
TRF 2000 ppm	9.66	83.20	8.20	13.00	14.86	10.60
TRF 3000 ppm	10.80	81.20	8.20	14.06	14.06	8.00
PBZ 50 ppm	10.20	62.00	8.80	14.06	11.43	7.73
PBZ 100 ppm	10.33	74.33	10.00	14.06	12.26	8.93
PBZ 150 ppm	8.66	86.90	11.00	13.80	13.80	12.00
Distilled water	13.93	43.35	6.20	16.20	8.33	8.00
Control	14.73	41.13	6.00	16.00	7.93	7.80
SEm ±	0.23	1.49	0.98	0.25	0.26	0.26
CD at 5%	0.67	4.34	2.86	0.74	0.76	0.78
CV %	4.00	3.48	17.87	3.10	3.55	4.46

Khosla & Pushpangadan (1995) in clocimum.

Regarding the shoot parameters early sprouting (11.86 days) was observed under soaking in TRF (75 ppm) treatment. While control required the longest time for sprouting (16.26 days). Similarly, under quick-dip, sprouting was earliest (13.00 days) under TRF at 2000 ppm treatment which was on par with IBA at 2000 ppm (13.33 days). Whereas, in powder formulation, the least time (13.06 days) taken for the first sprout to appear was observed under TRF treatment with 1000 ppm but was on par with TRF 150 ppm (13.46 days) and PBZ at 50,100 and 150 ppm (13.40, 13.20 and 13.53 days, respectively). The early sprouting under soaking treatment with TRF was also observed by earlier workers like Niranjan Kumar (1993) in *Ruta graveolens*.

The highest number of sprouts (17.53) was observed under soaking with IBA at 150 ppm and was followed by IBA at 100 ppm (16.33) and IBA at 50 ppm (16.00). However, the treatment with NAA 300 ppm and TRF at 75 ppm were found to be on par (13.40 and 13.13, respectively). Similarly, under quick-dip method, IBA at 2000 ppm treatment resulted in more number of sprouts (16.00) and was on par with IBA 3000 ppm (15.60), NAA at 2000 ppm (15.26) and TRF at 2000 ppm (14.86). Under powder formulation method also, the higher concentration of IBA (1000 ppm) produced the maximum number of sprouts (15.73). The increase in number of sprouts under soaking treatment may be attributed to the growth regulators activating shoot growth leading to more number of sprouts.

Similarly, the longest sprout (18.23 cm) was also observed in soaking method with IBA 150 ppm treatment and in the case of quick-dip method, IBA at 2000 ppm resulted in longest sprout (14.13 cm). Whereas, in pow-

Table 3. Effect of growth regulators as powder formulation on root and shoot parameters of *Thymus vulgaris* L. cuttings.

Treatment	Root parameters			Shoot parameters		
	Time taken for root initiation (days)	Cuttings rooted (%)	Roots/ cutting (No.)	Time taken for first sprout to appear (days)	Sprouts/ cutting (No.)	Length of longest sprout
IBA 500 ppm	8.80	77.70	10.60	14.60	11.06	10.26
IBA 750 ppm	8.53	79.50	11.20	14.46	11.93	10.73
IBA 1000 ppm	8.00	84.40	12.40	13.33	15.73	13.80
NAA 1000 ppm	9.60	62.90	9.20	14.53	9.86	9.83
NAA 1500 ppm	8.40	77.70	12.00	14.00	13.93	12.90
NAA 2000 ppm	9.80	70.30	9.80	14.33	10.93	10.96
TRF 1000 ppm	9.73	62.90	9.00	13.56	9.80	10.50
TRF 1500 ppm	9.40	66.60	11.80	13.46	11.13	11.13
TRF 2000 ppm	10.20	58.60	11.40	13.66	10.33	10.90
PBZ 50 ppm	9.53	55.00	8.40	13.40	9.93	9.66
PBZ 100 ppm	9.20	64.80	12.00	13.20	12.20	11.43
PBZ 150 ppm	10.53	66.00	10.60	13.53	10.46	11.13
Plain talc	13.13	43.30	6.60	15.53	8.33	8.40
Control	14.73	41.43	6.00	16.23	7.93	7.80
SEm ±	0.30	1.93	0.57	0.17	0.16	0.26
CD at 5%	0.88	5.60	1.67	0.50	0.47	0.77
CV %	5.28	5.14	9.92	2.12	2.57	4.38

der formulation, the longest sprout (13.80 cm) was noticed in treatments with higher concentration of IBA (1000 ppm). The increase in length of sprout under soaking treatment was also observed by earlier workers such as Chauhan *et al.*(1992) in rosemary.

References

Chauhan V K, Jagmohan S & L J Srivastava 1992. Initiation of rooting in stem cuttings of Rosemary (*Rosemarinus officinalis)* through hormonal treatments. Indian J. Forestry. 15 (2) : 131-135.

Gianfagna T J 1987. In plant hormones and their role in plant growth and development. (Ed) Davies, P J Martinus Nijhoff Publishers Dordrechat, The Netherlands : 614-35.

Haissign B E 1965. Organ formation *in vintro* as applicable to forest tree propagation. Bot. Rev. 31 : 607-26.

Hussain A, Virmani O P, Ashok S, Anup K & L N Mishra 1998. Major Essential Oil Bearing Plants of India. Pub: Central Institute of Medicinal and Aromatic Plants, Lucknow, India : 215-216.

Khosla M K & Pushpangadan P 1995. A faster method of vegetative propagation in Colcimum (*Ocimum gratissimum* L.), Indian J. Forestry 18(1) : 56-60.

Niranjan Kumar S 1993. Influence of planting material and growth regulators on rooting in stem cuttings of *Ruta graveoleus* L. M.Sc (Hort) thesis submitted to U.A.S., Bangalore.

Poi A K & Mazumdar B C 1989. Auxin induced root regeneration in stem cuttings of Bael *(Limonia ocidixima)*. Indian Biologist 21(1) : 51-52.

Sunderaraj N, Nagaraju S, Venkataramu M S & Jaganath M K 1972. Design and analysis of field experiments. Univ. Agric. Sci., Bangalore.

Vogt I 1951. Planta 40 : 145-69.

Performance of kasuri methi (*Trigonella corniculata*) under Coimbatore conditions of Tamil Nadu

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Abstract

Based on the preliminary observation kasuri methi took 3.0 days for germination under Coimbatore conditions. The average plant height was 39.70 cm. The number of primary and secondary branches were 3.2 and 15.2, respectively. After 50 days of sowing 50 per cent flowering was observed. Among the yield characters, the pod length was 1.4 cm, the number of pods per plant was 31.6 and each pod produced 6.2 seeds on an average. The crop has taken 116 days duration in September-October season.

Key words: kasuri methi, *Trigonella corniculata*, yield

Introduction

In the genus of *Trigonella*, there are two economic importance species namely *T. foenum graecum*, the common methi and *T. corniculata*, the Kasuri methi. These two differ in their growth habit. Kasuri methi is slow growing and remains in rosette condition during most in vegetative growth period and it is well suited for greens. In Tamil Nadu the common methi (fenugreek) is cultivated largely for its seeds. However, it can be used as leafy spice when it pulled during early stages of crop growth to a lesser extent. Kasuri methi is cultivation is uncommon and this can be popularized as leafy in Tamil Nadu.

Materials and methods

Kasuri methi introduced from Bihar was tested at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. It was evaluated during Sept.- Oct. 1999. The experiment was laid out in Randamised Block Design and replicated four times. The plot size adopted was 1x1 m^2. and routine cultural operations were attended to. The yield and its parameters such as days taken for germination, height of plant, number of primary and secondary branches, days taken for 50 percent flowering, number of pods per plant, number of seed per pod, length of pod, duration of the crop and grain yield per plot were recorded.

Results and discussion

Based on the preliminary observation under Coimbatore condition kasuri methi has taken 3.0 days for germination. The average height of plant was 39.7 cm. The number of primary and secondary branches were 3.20 and 15.20 respectively. After 50 days of sowing 50 per cent flowering was observed. Among the yield characters, length of the pod 1.4 cm was recorded. The number of pods per plant was 31.60 and each pod produced 6.2 seeds on an average. The crop has taken 116 days duration in September- October season. This plant produced more branches with tender non-fibrous stems. The bulk foliage produced from kasuri methi was higher than the common methi (fenugreek). Based on the preliminary observations made this could be commercially and economically may be utilized in Tamil Nadu as one of the important leafy spice crop.

Influence of sowing time on yield and nutrient uptake in dill (*Anethum graveolens* L.) under rainfed conditions

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Abstract

A filed experiment was conducted during *kharif* 1992 and 1993 on clay soil under rainfed conditions to study the effect of sowing time on yield and nutrient uptake in dill (*Anethum graveolens* L.). The maximum seed yield and dry matter yield were recorded when crop was sown on 7th August. It was at par with yield when the crop was sown on 23rd July during both the years. However, further delay in sowing significantly decreased the seed yield as well as dry matter yield during both the years. Uptake of nitrogen, phosphorus and potassium was highest when the crop was sown on 7th August and decreased thereafter during both the years.

Key words: dill, nutrient uptake, rainfed, sowing time, yield.

Introduction

Dill (*Anethum graveolens* L.) is a very important crop, cultivated for its seed production and volatile oil. The oil is extracted both from herb and seeds. It contains 3 to 3.5% essential oil and is extensively used in gastro-intestinal disorders. The oil has a great demand in food, pharmaceutical, perfume, flavour, cosmetic and soap industries. However, the herb oil is preferred by the food industry because of its typical characters. Keeping in view the importance of the crop, the present study was undertaken to assess the effect of sowing time on yield and nutrient uptake of the crop.

Materials and methods

The field experiment was conducted with dill at Pratapgarh, Rajasthan during *kharif* 1992 and 1993 on clay loam soil. The treatments were laid out in randomised block design with five replications. The treatments comprised of 6 dates of sowing (8th July, 23rd July, 7th August, 22nd August, 6th September and 21st September). The soil of the expermental site was low in organic carbon (0.16%). alkaline reaction (pH 7.7), medium in available nitrogen (291.5 kg/ha), phosphorus (35 kg/ha) and potash (210 kg/ha). The crop was sown with 5 kg seeds/ha in rows, 30 cm apart. All the treatments received 30 kg N/ha, 20 kg P_2O_5/ha and 15 kg K_2O/ha. Full dose of N, P and K was applied at the time of sowing. The leaf N, P and K contents were determined by standard methods at harvesting stage of each treatment. The rainfall received during the season of *Kharif* 1992 and 1993 was 627 mm and 1023 mm, respectively.

Results and discussion

Seed and dry matter yield

Sowing time significantly affected the seed yield of dill during both the years. The crop sown on 7th Aug. gave significantly higher seed yield than that sown on all other sowing dates except on 23rd July which was on par during both the years (Table 1). The crop sown on 7th August produced 115 and 158 per cent higher seed yield during 1992 and 1993, respectively over the lowest yield of 4.0 and 3.5 q/ha obtained from the crop sown on 8th July during 1992 and 1993, respectively. The higher seed yield in case of 7th August sown crop may be due to the fact that the plants had longer period of growth with sufficient conserved moisture and favourable temparature for crop growth. Singh & Randhawa (1991) also reported the similar results.

The crop sown on 7th August rewarded highest dry matter yield, being 134.7, 5.4, 41.6, 74.8 and 98.4 per cent and 170.4, 7.8, 60.5, 97.4 and 125.9 per cent more than that sown on 8th July, 23rd July, 22nd August, 6th September and 21st September during 1992 and 1993, respectively.

Table 1. Yield and N, P and K uptake in dill as influenced by time of sowing

Date of sowing	Yield (q/ha)				Uptake (kg/ha)					
	Seed		Dry matter		N		P		K	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
8th July	4.0	3.5	21.3	20.3	39.0	37.0	47.6	54.0	85.6	82.4
23rd July	8.3	8.7	47.4	50.9	71.6	72.0	84.3	85.0	114.7	116.4
7th August	8.6	9.0	50.0	54.9	75.3	76.2	89.4	88.8	120.4	124.8
22nd August	6.7	6.4	35.3	34.2	47.6	46.4	66.4	64.7	106.4	103.9
6th September	5.5	5.2	28.6	27.8	43.0	42.0	52.4	50.2	96.5	93.2
21st September	4.6	4.4	26.2	24.3	64.8	62.4	57.2	55.4	90.6	88.4
CD at 5%	0.38	0.43	2.2	3.4	3.6	4.0	4.4	3.6	4.9	7.2

Nutrient uptake

The highest N uptake in plants was observed under the 7th August sowing, being 93.0, 5.1, 58, 1, 75.1 and 16.2 per cent and 105.9, 5.8, 64.2, 81.4 and 22.1 per cent higher than that recorded under 8th July, 23rd July, 22nd August, 6th September and 21st September during 1992 and 1993, respectively (Table 1).

The maximum P uptake was obtained under 7th August sowing, which was significantly higher than all the other treatments. The P uptake was 87.8, 6.0, 34.6, 70.6 and 56.2 per cent and 97.3, 4.4, 37.2, 76.8 and 60.2 per cent more than that of 8th July, 23rd July, 22nd August, 6th September and 21st September during 1992 and 1993, respectively.

The highest K uptake was obtained wit 7th August sowing, being 40.6, 4.9, 13.15, 24.7 and 32.8 per cent and 51.4, 7.2, 20.1, 33.9, 41.1 per cent more than those with 8th July, 23rd July, 22nd August, 6th September and 21st September during 1992 and 1993, respectively. Singh *et al.* (1993) also reported similar results in case of N, P and K uptake in dill .

In conclusion, the optimum sowing time for obtaining highest nutrient uptake and maximum dry matter and seed yield production in dill is 7th August .

References

Singh Avtar, R K Mahey & G S Randhawa 1993. Influence of sowing time and harvesting stage on herb yield and nutrient uptake in dill. Indian J. Agron. 3 : 622-625.

Singh Avtar & G S Randhawa 1991. Effect of cultural practices on periodic plant height and seed yield of dill. Indian J. Agron. 36 : 574-577.

Influence of sowing time on the performance of ajwain (*Trachyspermum ammi*) under rainfed conditions

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Abstract

A filed experiment was conducted to find out suitable date of sowing of ajwain crop at Agricultural research sub-station, Pratapgarh during *Kharif* 1992 and 1993 on clay loam soil under rainfed condition. The maximum seed yield was recorded in case of crop sown on 7th August but the yield was at par with the crop sown on 23rd July during both the years. Sowing after 7th August significantly decreased the seed yield during both the years.

Key words: ajwain, rainfed, sowing time, yield

Introduction

Ajwain (*Trachyspermum ammi* (L) Spraguae ex turrill) is a very important crop and grown in a large area of humid southern plain zone (zone IV b) of Rajasthan. It is commercially cultivated for its seed production and herb yield which has medicinal value. It is also used to improve the quality of namkin and biscuits. Seeds also yield essential oil which is used as an antiseptic, carminative, insecticide and for perfuming disinfectant soaps. The time of sowing is a non monitory input and simply adjusting the time of sowing of ajwain crop can increase the seed yield to a great extent. The information available on the time of sowing under rainfed condition of the area is meagre. Therefore, the present study was undertaken to work out suitable time of sowing of ajwain crop under rainfed medium textured soil situation of Rajasthan to get maximum seed yield.

Materials and methods

The present investigation was conducted with six dates of sowing of ajwain at Agricultural Research Sub-station, Pratapgarh during *kharif* 1992 and 1993 on clay loam soil. The crop was sown at fortnight interval i.e. 8th July, 23rd July, 7th August, 6th September and 21st September. The treatments were tried in Randomized Block Design with five replications. The soil of the experimental site was low in organic carbon (0.16%), alkaline in reaction (pH 7.7), medium in available nitrogen (291.5 kg/ha), phosphorus (35 kg/ha) and potash (210 kg/ha). The crop was sown with 4 kg seed/ha in rows 30 cm apart. The crop was fertilized with 30, 20 and 15 kg/ha nitrogen, phosphorus and potash, respectively as basal during both the years. The data on height, umbles per plant, seed weight per plant and seed yield were recorded at the time of harvesting. The total rainfall during the season was 627 mm and 1023 mm during 1992 and 1993 respectively.

Results and discussion

Results (Table 1) showed that plant performance in respect of plant height and yield attributes was better when crop was sown on 23rd July and 7th August during both the years. The plant attained significantly less height, less number of umbles/plant and less seed weight/plant as the sowing was delayed beyond 7th August. However, both 23rd July and 7th August sowing produced plants of equal height, umbles and seed weight/plant during both the years. The taller plants under 23rd July and 7th August sowing during both the years might be due to the longer favourable period possessed by them.

Sowing time significantly affected the seed yield of ajwain during both the years. The crop sown on 7th August gave significantly highest seed yield of 8.0 and 8.5 q/ha during 1992 and 1993, respectively resulted 81.8 and 165.6 per cent higher seed yield respectively over the lowest yield of 4.4 and 3.2 q/ha obtained from the crop sown on 8th July. The higher seed yield in case of 7th August sown crop may be due to the fact that the plants had longer period of growth with favourable temperature. The crop sown on 23rd July yielded 7.6 and 8.2 q/ha during 1992 and 1993 respectively which was found at par with that of 7th August sowing. Further delay in sowing from 7th August and 23rd July reduced the seed yield significantly.

Table 1. Plant height, umbles/plants, seed weight/plants and yield of ajwain as influenced by sowing dates.

Date of sowing	Plant height (cm)		Umbles/plant		Seed weight/plant		Seed yield (q/ha)	
	1992	1993	1992	1993	1992	1993	1992	1993
8th July	86.02	88.0	10.0	9.8	3.8	3.3	4.4	3.2
23rd July	98.4	103.6	15.4	16.6	6.2	6.4	7.6	8.2
7th August	97.0	102.8	16.0	17.2	6.6	7.0	8.0	8.5
22nd August	88.0	94.4	13.4	13.2	5.2	4.9	6.9	5.8
6th Sept.	84.0	89.0	11.5	11.0	4.8	4.2	5.3	4.6
21st Sept.	82.3	87.2	10.6	10.0	4.0	3.8	4.6	4.4
CD at 5%	4.6	5.3	0.8	1.2	0.5	0.6	0.5	0.3

Performance of black cumin (*Nigella sativa* L.) under Coimbatore conditions

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Abstract

An average plant height of 19.58 cm was recorded. The number of primary and secondary branches 4.40 and 10.00 respectively were observed. After 40 days of sowing 50 per cent flowering was observed. Among the yield components, the number of pods per plant was 10.80 and each pod produced 54.00 seeds on an average. The weight of 1000 seeds 1.75 g was observed. Based on this preliminary record there is a great potential for this black cumin in Tamil Nadu as a minor spice crop.

Key words: black cumin, *Nigella sativa,* yield.

Introduction

Black cumin *(Nigella sativa* L.*)* is an important minor seed spice crop commercially cultivated in Punjab, Himachal Pradesh, Bihar and Assam. Black cumin, other wise called as Karunjiragam, Kalonji or kala zeera, is used as condiment and for the treatment of cough, asthma and fever. The commercial product is the dried seed. The seeds of this plant emit an aroma resembling strawberries when crushed. In view of its importance as one of the minor spice crops, it is imperative to study the performance under Tamil Nadu conditions.

Materials and methods

The seed of the black cumin introduced from Bihar was tested at the Department of Spices and Plantation crops, Horticultural College and Research Institute, Coimbatore. It was evaluated during September - October 1999. The experiment was laid out in Randomized Block Design and replicated four times. The seeds were sown in plot size of 2 x 1 m. The routine cultural operations were attended to. The yield and the yield attributing characters such as days taken for germination, plant height, number of primary and secondary branches, days taken for 50 per cent flowering, number of pods per plant, number of seeds per pod, weight of 1000 seed and grain yield per plot were recorded.

Result and discussion

Black cumin took 14 days for germination. The average plant height was 19.58 cm. The number of primary and secondary branches were 4.40 and 10.00, respectively. After 40 days of sowing, 50 per cent flowering was observed. Among the yield characters, the number of fruits per plant was 10.80 and each pod produced 54.00 seeds on an average. The weight of 1000 seed 1.75 g was recorded. Based on this preliminary observation recorded under Coimbatore condition, this black cumin could be exploited as a potential spice crop as well as medicinal plant in Tamil Nadu if the cultural practices standardised under this condition.

Growth traits, dry matter accumulation, content and uptake of nutrients in mustard cultivars as influenced by row spacing and nitrogen levels in non-traditional eastern dry zone of Karnataka

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Abstract

Field experiment conducted at Agronomy Field Unit, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore during *kharif* seasons of 1998 and 1999 revealed that Chikkaballapur Local cultivar recorded significantly higher seed yield (836.44 kg ha^{-1}) than RH-30 cultivar (397.63 kg ha^{-1}). The seed yield was also higher at closer spacing (30 cm x 15 cm) and at higher nitrogen level (75 kg N ha^{-1}). The increased seed yield was accompanied by better growth traits and improved dry matter accumulation. RH-30 cultivar had significantly higher N, P, K contents (2.95, 0.82 and 0.61 per cent, respectively) than Chikkaballapur Local. However, NPK uptake was significantly greater in Chikkaballapur Local cultivar. Both content and uptake of nutrients were greater at closer spacing (30 cm x 15 cm) and at higher nitrogen level (75 kg N ha^{-1}).

Key words : nutrient content, nutrient uptake, spacing regime.

Introduction

Indian mustard is a new crop in non-traditional areas of Karnataka (zone fifth) which have been witnessing crop shifts in favour of this oil seed owing to growing demand for edible oil. Development of cultivars and hybrids with tailored ideotype suiting to diverse agro-ecologies and cropping systems is the need of the hour. Although mustard crop is considered as highly plastic, there are varietal differences for expression of plasticity and other agronomic traits viz. row spacing and nitrogen levels. One of the new vistas in the remunerative cultivation of oil seed *Brassicas* in the non-traditional areas is to select appropriate variety suited to particular situation which can yield more per unit of water and nutrients used. The performance of improved cultivars *vis-à-vis* local cultivars suited to these non-traditional areas and their differential trends in contents and uptake of nutrients due to varying nitrogen levels and row spacing has been assessed and analysed in the present investigation.

Materials and methods

The field experiment was conducted during *kharif* season of 1998 and 1999 at the Agronomy Field Unit, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore. The soil texture of the experimental site was red sandy clay loam (Alfisol). The soil was slightly acidic (pH 5.85) and the fertility status of the experimental site was medium to low with 219.70, 37.60 and 199.50 kg ha^{-1} of available N, P_2O_5 and K_2O, respectively.

The experiment consisted of twelve treatment combinations involving two cultivars, two spacing regimes and three nitrogen levels (Table 1). It was laid out in factorial RCBD with three replications. Nitrogen was supplied in the form of urea in two splits (basal and top dressing), while single dose of phosphorus and potassium were applied in the form of single super phosphate and muriate of potash, respectively. Observations on yield and yield components were recorded from net plot area. The plant analysis for percentage N was carried out by modified Kjeldhal's method, P by vanadomolybdo phosphoric yellow colour method and K by flame photometry (Jackson 1973). The uptake was calculated by multiplying the percentage nutrient content with the dry weight of respective parts. The data was statistically anlysed as per the procedure of Panse and Sukhatme (1967).

Results and discussion

Growth attributes

The data pertaining to effect of cultivars, row spacing and nitrogen levels on growth and yield of mustard is presented in Table 1. Significantly taller plants (162.01 cm) were observed with Chikkaballapur Local (V_2) cultivar than with RH-30 (128.67 cm). This might be due to increased cell division and cell elongation. The inherent branching potential by virtue of genetic make up in Chikkaballapur Local cultivar may be the reason for having significantly higher number of primary (12.22) and secondary branches (30.28). Significantly higher leaf area index (1.96) and subsequent higher leaf area duration (30.95) was associated with Chikkaballapur Local leading to greater actual assimilatory surface and higher seed yield (836.44 kg ha^{-1}) than RH-30 cultivar (397.63 kg ha^{-1}). Silique yield plant^{-1} was also higher than RH 30 cultivar.

Among the spacing regimes, closer spacing of 30 cm x 15 cm (S_1) recorded 8.43 per cent increase in yield over wider spacing of 45cm x 15cm (S_2). Although narrow spacing recorded significantly lesser number of primary (8.98) and secondary branches (21.81) and 1000 seed weight (2.62 g), leaf area duration was significantly higher (24.28). Increased yield with closer spacing can be ascribed to increased plant population effect.

The higher nitrogen level (N_3) of 75 kg ha^{-1} registered significantly higher leaf area duration compared to 25 and 50 kg ha^{-1}, which enabled the plant to intercept higher quantities of radiant energy with the larger assimilatory surface and accordingly contributed towards increased seed yield (685.33 kg ha^{-1}). The enhanced seed yield at N_3 level can also be attributed to better growth components viz., plant height, number of

Table 1. Growth traits, dry matter accumulation and seed yield of mustard as influenced by cultivars, row spacing and nitrogen levels

Treatment	Plant height (cm) at harvest	Number of branches at harvest		Leaf area duration B/W 45-60 DAS (Days)	Total dry matter accumulation (g plant^{-1})	1000 seed weight (g)	Siliquae yield plant^{-1} (g)	Seed yield (kg ha^{-1})
		Primary	Secondary					
Cultivar								
V_1 : RH-30	128.67	6.75	16.04	12.18	23.01	3.91	8.88	397.63
V_2 : Chikkaballapur Local	162.01	12.22	30.28	30.95	38.17	1.49	14.73	836.44
S.Em±	0.75	0.07	0.34	0.26	0.24	0.02	0.07	12.96
C.D. (at 5%)	2.20	0.21	1.03	0.78	0.71	0.08	0.22	38.02
Row spacing (cm)								
S_1 : 30 cm X 15 cm	145.46	8.98	21.81	24.28	27.39	2.62	10.94	669.52
S_2 : 45 cm X 15 cm	145.21	9.99	24.51	18.85	33.78	2.79	12.67	564.56
S.Em±	0.75	0.07	0.34	0.26	0.24	0.02	0.07	12.96
C.D. (at 5%)	NS	0.21	1.03	0.78	0.71	0.08	0.22	38.02
Nitrogen level (kg ha^{-1})								
N_1 : 25	140.2	8.95	22.57	17.71	29.21	2.54	11.62	556.46
N_2 : 50	142.27	8.98	22.93	22.55	29.98	2.68	11.67	609.32
N_3 : 75	153.42	10.52	23.98	24.44	32.57	2.89	12.12	685.33
S.Em±	0.91	0.09	0.41	0.32	0.29	0.03	0.09	15.88
C.D. (at 5%)	2.69	0.26	NS	0.95	0.87	0.10	0.27	46.57

NS : Non significant

primary and secondary branches, and yield components viz., 1000 seed weight and siliquae yield plant^{-1}. This is in accordance with the work of Sharma (1993) and Sarmah (1996).

Dry matter accumulation

In any given situation, production of dry matter is an absolutely essential pre-requisite. It not only signifies photosynthetic ability in a canopy but also other synthetic processes during developmental stages. Chikkaballpur Local cultivar (V_2) recorded 210 per cent increase in yield over RH-30 (V_1) cultivar. Such an increase in seed yield with V_2 can be attributed to 60.10% higher dry matter accumulation.

Although, 23 per cent higher dry matter accumulation (33.78 g) was observed with wider spacing (S_2) compared to closer spacing (S_1), seed yield (669.52 kg ha^{-1}) obtained with closer spacing was higher (15.6 per cent) than that obtained with S_2 (564.56 kg ha^{-1}). This can be attributed to higher plant population (2, 22, 222.22 plants ha^{-1}) under closer spacing than that (1,48,148.14 plants ha^{-1}) with wider spacing.

Application of nitrogen at 75 kg ha^{-1} (N_3) produced significantly higher dry matter (32.57 g) and hence the seed yield (685.33 kg ha^{-1}). The increase in yield at N_3 level is also due to better performance of yield components. Siliquae yield plant^{-1} and 1000 seed weight increased significantly with each successive level of N till 75 kg N ha^{-1}. Further, the number of primary and secondary branches were influenced significantly and had a significant positive correlation with yield (r=0.895 and r=0.875, respectively). Similar results were reported by Srinivas and Srinivas Raju (1997) and Sunit Tomas *et al.* (1996).

Nutrient content

The data presented in Table 2 reveals that RH-30 cultivar had significantly higher nitrogen, phosphorus and potassium contents (2.79, 0.74 and 0.58 per cent respectively) than Chikkaballapur Local as the former is an improved cultivar with bolder seeds and greater root ramifications. Similar results were reported on RH-30 cultivar by Roshan Lal *et al.* (1997).

Among spacing regimes, closer spacing (S_1) although recorded non-significant effect with respect to potassium content, there was significantly higher nitrogen

Table 2. Content (%) and uptake (kg ha^{-1}) of nitrogen, phosphorus and potassium in mustard seed as influenced by cultivars, spacing and nitrogen levels

Treatment	Nitrogen content	Phosphorus content	Potassium uptake	Nitrogen uptake	Phosphorus uptake	Potassium uptake
Cultivar						
V_1: RH-30	2.95	0.82	0.61	11.89	3.28	2.43
V_2 : Chikkaballapur Local	2.79	0.74	0.58	23.93	6.20	4.84
C.D. (at 5%)	0.02	0.01	0.01	1.07	0.27	0.21
Row spacing (cm)						
S_1 : 30 cm X 15 cm	2.94	0.78	0.89	19.69	5.16	3.93
S_2 : 45 cm X 15 cm	2.79	0.77	0.59	15.64	4.32	3.34
C.D. (at 5%)	0.02	0.01	NS	1.07	0.27	0.21
Nitrogen level (kg ha^{-1})						
N_1 : 25	2.75	0.74	0.57	15.38	4.05	3.16
N_2 : 50	2.86	0.78	0.59	17.22	4.69	3.59
N_3 : 75	2.99	0.81	0.61	20.39	5.48	4.14
C.D. (at 5%)	0.03	0.01	0.01	1.32	0.33	0.25

NS : Non significant

and phosphorus content (2.94 and 0.78 per cent, respectively) associated with S_1 compared to S_2 spacing. This may be due to deeper root ramifications and active rhizosphere-nutrient interaction as also reported by Sharma (1993).

Increasing level of nitrogen from 25 to 75 kg ha^{-1} increased significantly the leaf nitrogen, phosphorus, and potassium contents (Table 2). This may be due to the synergistic effects of nitrogen on phosphorus and potassium contents. Similar results were reported by Arthamvar *et al.* (1997) and Roshan Lal *et al.* (1997).

Nutrient uptake

The nitrogen, phosphorus and potassium uptake (23.93, 6.20 and 4.84 kg ha^{-1}, respectively) in Chikkaballapur Local was higher than that of RH 30. Among spacings, closer row spacing resulted in better N, P and K uptake (19.69, 5.16 and 3.93 kg ha^{-1}, respectively) than wider spacing (S_2). The results are in accordance with the findings of Anil Kumar *et al.* (1997).

Further the data presented in Table 2 clearly indicates that nitrogen, phosphorus and potassium uptake increased significantly with increase in nitrogen level from 25 kg (N_1) to 75 kg (N_3) ha^{-1}. This may be due to synergistic and positive interaction among N, P and K nutrients influencing their absorption and uptake from the root rhizosphere. There results are in conformity with those of Yadav *et al.* (1995) and Roshan Lal *et al.* (1997).

To conclude, for non-traditional eastern dry zone of Karnataka, Chikkaballapur Local cultivar is best suited on account of improved growth attributes, better dry matter accumulation , higher seed yield, better nutrient content and uptake under closer spacing and at higher nitrogen level.

References

Anil Kumar, Singh D P, Bikram Singh & Roshan Lal 1997. N P uptake of *Brassica* genotypes/cultivars as influenced by nitrogen levels. Haryana J. Agron. 13 (2) : 49-51.

Arthamvar DN, Shelke V B, Mundhe P R, Dhoble M V & Eksinge B S 1997. Effect of nitrogen and phosphorus levels on yield and nutrient uptake by mustard. J. Maharastra Agric. Univ. 21(3) : 378-386.

Jackson M L 1973. Soil Chemical Analysis. Prentice Hall of India Private Limited, New Delhi, pp 38-82.

Panse V G & Sukhatme P V 1967. Statistical Methods for Agricultural Workers, ICAR, New Delhi, pp. 51-55.

Roshan Lal, Surinder Singh, Yadav S K & Dharmabir Yadav 1997. NPK content and uptake in Brassicas as influenced by irrigation and nitrogen levels. Haryana J. Agron. 13 (2) : 26-32.

Sarmah P C 1996. Effect of sowing date and row spacing on rainfed mustard under late sown conditions. J. Oil Seeds Res. 13 (1) : 10-12.

Sharma M L 1993. Response of mustard varieties to spacings. Haryana J. Agron. 9 (1) : 47-49.

Srinivas A & Srinivas Raju M 1997. Response of Indian mustard (*Brassica juncea* L.) to nitrogen application in red sandy loam soils of Andhra Pradesh. PKV Res. J. 21(2) : 235-236.

Sunit Tomer, Sandeep Kumar, Savita Tomer & Subey Singh 1996. Response of Indian mustard (*Brassica juncea* L.) varieties to nitrogen, phosphorus and potassium fertilizers. Indian J. Agron. 41(4) : 624-626.

Yadav N S, Rajput R L, Tomar S S & Verma O P 1995. Effect of cropping system, irrigation schedule and nitrogen levels on nutrient uptake by mustard (*Brassicca juncea* L.). J. Oil Seeds Res. 12 (1) : 24-29.

Nitrogen requirement of rose scented geranium (*Pelargonium* species) bourbon type grown in *Eucalyptus citriodora* alleys

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Abstract

Field studies were conducted at the research farm of Central Institute of Medicinal and Aromatic Plants, Field Station, Hyderabad on sandy loam soils during 1997-99 to investigate the nitrogen requirement of rose scented geranium (bourbon type) grown in two years old *Eucalyptus citriodora* alleys. The treatments comprised of five levels of nitrogen application (0, 150, 300, 450 and 600 kg N/ha/year). Plant height, plant spread, green herb yield and oil yield significantly increased upto application of 450 kg/N/ha/year. Application of nitrogen beyond 450 kg/ha/year did not influence both the herb and oil yields. On the contrary, application of nitrogen decreased significantly leaf : stem ratio and oil concentration in green herb, particularly with application of nitrogen beyond 450 kg/ha/year. These negative effects of nitrogen were primarily due formation of dense canopy leading to yellowing and shedding of matured leaves situated at the lower and middle segment of the canopy. The estimated optimum dose of nitrogen declined to 0.11kg/ha/kg - N at 450 kg/ha/year from 0.18 kg/ha/kg-N at 150 kg/ha/year. The net income from *Eucalyptus citriodora* - geranium alley cropping system under optimum nitrogen supply was Rs. 90,500/- per hectare per year. The geranium oil quality measured in terms of not vary hydroxy citronellol, geraniol, linalool, 10 epi-γ- eudesmol, and (Z) and (E) rose oxides did appreciably due to application of varying levels of nitrogen. The results are discussed in terms of increasing area under cultivation of geranium and production of good quality geranium oil through its cultivation as alley crop in *Eucalyptus citriodora* plantations without affecting the yield of the later.

Introduction

The essential oil of rose scented geranium (*Pelargonium* spp.) is a high value product and finds wide application in perfumery and cosmetic industries world over. It has high demand in India and present requirements is mostly met through imports (120.64 t valuing Rs. 3.89 crores during 1996-97) (Monthly statistics of the Foreign Trade of India, March, 1997) because of low indigenous production (1-2 tonnes). The bourbon type is mostly cultivated in India because of its superior oil quality (1:1 geraniol and citronellol content). It responds well to application of fertilizer N (Prakasa Rao *et al.* 1985, Rajeswara Rao *et al.* 1990, Singh 1999). During last decade good efforts have been made to develop agronomic package of practices to popularize its cultivation in North and South Indian plains, but cultivation is not picking up because of frequent occurrence of wilt disease during rainy season (high soil moisture content coupled with high temperature) causing high plant mortality (15-70%) (CIMAP, Annual Report 1996-97) and more than 80% reduction in biomass and oil yields (Rajeswara Rao *et al.* 1999). Cutailment of excess solar radiation in alley cropping (raising of intercrop in the inter row spaces of tree species) has been shown to considerably improve biomass and essential oil yields of patchouli (Viswanathan *et al.* 1992). Likewise, the studies on production of geranium in fast growing and essential oil bearing *Eucalyptus citriodora,* showed high potential in terms of monetary advantages in semi-arid tropical climate of South India (Singh *et al.* 1998). There is, however, considerable scope of further improving productivity of geranium without affecting growth of *Eucalyptus citriodora* through optimisation of supply of nutrients particularly N. The present investigation was therefore carried out to find out the nitrogen requirement of geranium grown in *Eucalyptus citriodora* alleys.

Materials and methods

A field experiment was conducted during 1999-2000

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at the research farm of CIMAP Field Station, Hyderabad which is situated at 542 m above MSL, 17.20°N latitude and 78.30° E longitude. The annual rainfall in the area is 760 mm, 80-85% of which is received between June and September (South-West monsoon). The average mean maximum and minimum temperature range between 28-43°C. The soil of the experimental field was well drained, gravel sandy-loam in texture having organic carbon 0.3%, available N 65.6 kg/ha, available P 10.8 kg/ha and exchangeable K 150 kg/ha with pH 7.2. *Eucalyptus citriodora* was planted in the field in July, 1997 at a spacing of 3 x 2 m. They were allowed to grow upto a height of 2 m through periodical pruning (three harvests per annum). Altogether five *E. citriodora* alleys of 3 m wide and 15 m length were used for laying of the experiment. Each alley was subdivided into 4 small plots of 2.25 x 3.0 m size. There were 5 x 4, i.e 20 small plots. The treatments comprised of five levels of N applications (0, 150, 300, 450 and 600 kg/ha/year). The experiment was laid out in randomized block design with four replications. Rose scented geranium, bourbon type was planted in each small plot at a spacing of 45 x 30 cm using rooted cuttings in January, 1999. There were five rows of geranium in each plot. Phosphorus and potassium @ 60 kg P_2O_5 and 80 kg K_2O per hectare were

Table 1. Rose scented geranium height, spread and leaf-stem ratio at different harvests as influenced by nitrogen application.

Nitrogen rate (kg/ha)	Plant height (cm) Harvest			
	First	Second	Third	Pooled
0	42.2	50.1	52.2	48.2
150	57.4	60.6	63.1	60.4
300	64.0	68.7	70.5	67.7
450	68.4	73.0	73.8	71.7
600	67.4	73.2	73.5	71.4
LSD (P=0.05)	6.2	7.3	6.5	7.0
	Plant spread (cm)			
0	18.6	21.8	20.7	20.4
150	25.0	28.4	28.5	27.3
300	30.3	33.7	35.0	33.0
450	35.2	37.1	40.5	37.6
600	35.5	40.6	41.8	39.3
LSD (P=0.05)	2.8	3.5	3.6	3.6
	Leaf-stem ratio			
0	0.75	0.69	0.66	0.70
150	0.64	0.60	0.58	0.61
300	0.55	0.53	0.52	0.53
450	0.49	0.50	0.53	0.56
600	0.47	0.49	0.51	0.49
LSD (P=0.05)	0.06	0.05	0.05	0.06

applied as basal dose before planting of geranium. Nitrogen in the form of urea was applied as per treatments in six equal split doses (35 and 70 days after transplanting and 15 and 50 days after first and second harvests). Required cultural practices were followed to raise a good crop of geranium. The crop was irrigated at an interval of about 7 days during non-rainy period (October to May). Observations on plant height, plant spread and leaf-stem ratio were recorded before each harvest on five random plants of each plot. Geranium was harvested at a height about 30 cm above the ground surface three times in a year (May, September and December) and plot-wise green herb yield was recorded. The essential oil concentration in green herb was determined using Clevenger's apparatus. The oil yield was computed by multiplying herb yield with oil concentration. The essential oil samples were analysed using a Perkin Elmer gas chromatograph (Model 8500) fitted with FID and BP-1 (25m x 0.5 mm) capillary column coated with dimethysiloxane. Nitrogen at 40 ml/min. flow rate and 10 p.s.i. inlet pressure was used as the carrier gas. The temperature programing was 60°C - 220°C at 5° C per min. with a final hold time of 10 minutes. The oil samples were injected neat with a split ratio of 1:80. The injector and detector was maintained at 250°C and 300°C, respectively. The peaks

Table 2. Rose scented geranium herb yield, oil concentration, oil yield at different harvests as influenced by nitrogen application.

Nitrogen rate (kg/ha)	Green herb yield (t/ha)			
	Harvest			
	First	Second	Third	Total
0	2.92	4.63	4.45	12.00
150	4.63	11.50	11.80	27.93
300	7.94	16.43	16.21	40.58
450	9.25	20.50	19.35	49.10
600	10.20	20.21	19.06	49.47
LSD (P=0.05)	2.10	1.95	1.77	3.50
	Oil concentration (%)			
0	0.24	0.17	0.20	0.20
150	0.24	0.15	0.19	0.09
300	0.24	0.13	0.17	0.18
450	0.22	0.12	0.15	0.16
600	0.20	0.12	0.15	0.16
LSD (P=0.05)	0.03	0.02	0.03	0.03
	Oil yield (kg/ha)			
0	7.0	7.9	8.9	23.8
150	11.1	17.3	22.4	50.8
300	19.0	21.4	27.6	68.0
450	20.3	24.6	29.0	73.9
600	20.4	24.3	28.6	73.3
LSD (P=0.05)	1.2	1.8	2.1	5.0

were identified by comparing their retention times with those of standard compounds run under same conditions, Kavat's indices of the peaks with literature data and peak enrichment on co-injection of authentic chemicals. The data on each parameter were pooled and subjected to statistical analysis following analysis of variance.

Result and discussion

The weather conditions during the period of experimentation was normal and growth of geranium planted in *E. citriodora* alleys was excellent. As envisaged nitrogen application significantly increased plant height, plant spread and green herbage and oil yields but decreased leaf-stem ratio and oil concentration of geranium (Tables 1 & 2). Maximum green herbage and oil yields in first, second and third harvests were recorded when the crop was fertilised with 450 kg N/ha/year and application of N beyond 450 kg N/ha/year did not influence green herbage and oil yields. The total herbage and oil yields were 49.1 t/ha/year and 73.9 kg/ha/year, respectively at 450 kg N/ha/year. The increased herbage yield with N application was because of higher plant height and spread. Increase in herbage and oil yields with N application were earlier reported (Prakasa Rao *et al.* 1985, Rajeswara Rao *et al.* 19990, Singh 1999) but N requirement of geranium grown in *E. citriodora* alleys was found to be higher than sole crop of geranium. This was because of additional N requirement of main crop of *E. citriodora*. The leaf-stem ratio and oil concentration in green herbage declined with N application. These negative effects of nitrogen were possibly due to formation of dense canopy leading to yellowing and shedding of matured leaves situated at the lower and middle segment of the canopy as observed in *Mentha arvensis* (Kothari *et al.* 1996). The estimated optimum dose of nitrogen for geranium was 462 kg/ha. The nitrogen use efficiency measured in terms of oil yield output per kg applied nitrogen declined to 0.11 kg/ha/kg-N at 450 kg/ha/year from 0.18 kg/ha/kg - N at 150 kg/ha/year. The net income from *Eucalyptus citriodora* - geranium alley cropping system under optimum nitrogen supply was Rs. 90,500/- per hectare per year. The geranium oil quality measured in terms of hyroxycitonellol, geraniol, linalool, 10 -epi-γ-eudesmol, and (Z) and (E) rose oxides did not vary appreciably due to application of varying levels of nitrogen.

Thus, there appears to be good scope of increasing area under cultivation of geranium and production of good quality geranium oil through its cultivation in *Eucalyptus citriodora* and fertilizing it with 462 kg N/ha/year.

References

Annual report of Central Institute of Medicinal and Aromatic Plants, Lucknow, India, p 60 (1996-97).

Kothari S K, Singh V P & Singh U B 1996. The effect of row spacing and nitrogen fertilization on the growth and oil yield composition of Japanese mint. J. Med. Arom. Pl. Sci. 18 : 17-21.

Prakasa Rao E V S, Singh M, Narayana M R & Chandrasekhara G 1985. Effect of N, P and K nutrition on herb and oil yield of geranium. Indian Perfumer 29 : 147-150.

Rajeswara Rao B R, Bhattacharya A K, Singh H B & Mallavarapu G R 1999. The impact of wilt disease on oil yield and quality of two cultivars of rose scented geranium (*Pelargonium* species). J. Essent. Oil Res. 11 : 769-775.

Rajeswara Rao B R, Singh K, Bhattacharya A K & Naqvi A A 1990. Effect of prilled urea and modified urea materials on yield and quality of geranium (*Pelargonium graveolens* L. Her.) Fertilizer Research 23 : 81-85.

Singh K, Rajeswara Rao B R, Singh C P, Bhattacharya A K & Kaul P N 1998. Production potential of aromatic crops in the alleys of *Eucalyptus citriodora* in semi - arid tropical climate of south India. J. Med. Arom. Pl. Sci. 20 : 749-752.

Singh M 1999. Effect of soil moisture regime, nitrogen and modified urea materials on oil yield and quality of geranium (*Pelargonium graveolens*) grown on alfisols. J. Agril. Sci. Camb. 133 : 203-207.

Viswanathan, Radhakrishnan, Raghunath & Sosamma-Cherian 1992. Patchouli (*Pogostemon cablin*) as an intercrop in young coconut (*Cocos nucifera*). Indian J. Agric. Sci. 62 : 616-617.

Effect of maturity and season on rooting of curry leaf cuttings

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Abstract

The results has indicated that semi hard wood cutting from past season shoot planted during May and July recorded 30 and 20 per cent rooting while the semi hard wood cuttings from current season shoot recorded only 10 per cent in both season. The cutting from the past season shoot in May month was found to the best for rooting of cuttings in curry leaf.

Introduction

Curry leaf (*Muraya koenigi* Spreng.) of Rutaceae family is one of the unexploited spice of Indian origin. Curry leaf is commonly propagated by seeds and by root suckers. The trees left unpruned flowers once in a year during April to May. The fruits are collected during July to August and it has to be sown immediately within one or two days to avoid loss of viability. Seed propagation does not ensure genetic purity and in order to propagate true to type progenies of the elite varieties. Vegetative method of multiplication is the only way. For that study was carried out the effect of maturity of the shoot on the rooting ability in curry leaf cuttings.

Materials and methods

The investigations were under taken at experimental farms of the Department of Spices and Plantation crops, Horticultural College and Research Institute, Coimbatore. Semi hard cuttings from the past season shoot and current season shoot were taken and treated with 1500 ppm of IBA and planted in poly bags and kept inside the mist chamber. One month prior to separation of cuttings the whole plants was covered with poly bag for etiolation. Cuttings kept outside the mist, failed to root. The cutting took more than three months for visible root formation.

Results and discussion

The results have indicated that semi hard wood cuttings from the past season shoot planted during May and July recorded 30 and 20 per cent rooting, while the semi hard wood cuttings from current season shoot recorded only 10 per cent in both season. This is due to the presence of reserve material in the well developed past season shoot and current season shoot may not have sufficient food reserve to initiate rooting. The cuttings from the past season shoot in May month was found to be best for rooting of cuttings in curry leaf.

Session III

Economics & Marketing

The Indian black pepper: economics and marketing

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Black pepper (*Piper nigrum* L.) is one of the important spice commodities of commerce and trade in India since pre-historic period. The crop is the major source of income and employment for rural households in the predominantly pepper growing State of Kerala, which covers 230900 hectares. The crop is also the major source of foreign exchange earner for the country. Of the total production of around 65,000 tons in the country about 70% is exported annually. Pepper plays important and strategic role in Indian economy due to the following reasons:

Vast majority of rural population in Kerala gets income and employment (>40 million man days) through pepper industry.

Pepper (whole) account for 46.48% of the total spice exports of around Rs.1861.03 crores (1999-2000).

Spices as a whole contributed about 19.37% of the export earnings of all agricultural commodities valued at Rs. 7270.76 crores (1997-98).

Unit value of spices export (Rs.61546/ton) is 3.6 times more than that for horticultural exports (1997-98)

Pepper is produced

i. as a village crop in almost every compound

ii. as a mixed or intercrop trailed on various trees in the garden land

iii. as a pure crop on slopes and in valleys of low hills

iv. as a mixed crop on shade trees in tea and coffee plantations

Pepper growers believe in insuring themselves against violent fluctuations in farm income arising out of upswings and downswings in prices of pepper by growing not just pepper alone, but a basket of crops. Cultivation of pepper as a pure crop is becoming rare. It is more so in Kerala State, which accounts for 97.4 per cent of the total area of 238320 hectares under the crop in the country. When prices decline farmers tend to neglect their pepper vines. Bountiful rainfall and the nutrients provided to other crops in the same area keep the pepper vines alive until the next boom comes along. When prices goes up, use more of manure and follow better maintenance leading to high yield. Thus, production and productivity is linked to price movement. Each period of high prices followed by increased production, and low prices by decline in production. With more than 50% share in area under pepper in the world, its contribution to world production is about 30% of the total only.

Demand for black pepper and its products in the world market is increasing at the rate of 3.2% per annum in volume and 8% in value terms, but the world production of pepper remained oscillating between 1.7 and 1.9 lakh ton/annum (Ponnana 1999). With the emergence of 'Hot trend', 'nature food' 'ethnic food' ' yogic food' and emphasis on 'back to nature', uses of spices and spice based products, especially black pepper would be in a bullish market during coming years. The estimated domestic market for pepper during 1987 was around 39684 tonnes and it is growing at the rate of 1.3% due to increase in population and improvement in living standard (Anon 1988). Though reliable estimates are not available, at the above rate of increase, the domestic market must be consuming around 45600 tonnes by now. The share of Indian export in international trade is around 35% of the total. However, the average quantity exported from India accounts for more than 70% of the total production as per official estimates. So, the international market for pepper always had an effect on the domestic pepper industry. Therefore, there is a need to study the causes of disturbances in the international pepper market in relation to the four basic elements of marketing mix viz. product, price, promotion and place to plan the future strategy for pepper economy of India. This article is an effort in the direction.

Firstly, production of pepper and value added pepper products and their economic contribution is examined. Fluctuating pepper price in the international market and its impact on Indian pepper industry is also analyzed. Thirdly, efforts taken to improve the acceptability of

Indian pepper in the international market in the light of changing food habits and the need for modifying the contents of the export basket is verified. And lastly, the place i.e. the present direction of Indian exports and the future for Indian pepper in the international market were analysed.

The product

Pepper is a native of the Western Ghats in India. At one stage, India was the only producer and exporter of pepper in the world before other countries taking up pepper cultivation on commercial scale. Eventually, the country has lost its supremacy to other countries for apparent reasons.

Area of production

In the predominantly pepper growing state of Kerala, small (<0.5 acre) and medium (0.5 to 2.00 acres) farm holdings constitute more than 80% of the total number of pepper growers. However, pepper seems to be a crop of large farmers owing to the fact that the maximum of area under pepper crop (91.38%) comes under this category of farms. (Radhakrishnan 1993). For small farmers, on-farm income accounts for 52% of the total income and pepper contributes more than 50% of the total income through agriculture. The situation is almost similar for medium farmers as well (George *et. al*. 1986). Studies have also indicated that small farmers are more specialized and dependent on pepper farming than the large. A recent survey also indicated that smallholding accommodate more number of vines per unit area. Karnataka State is the second largest producer of pepper in India with an unofficial estimated production of around 30000 tonnes or more during 1998-99. Pepper vines are allowed to climb on the shade trees in the coffee plantations in the districts of Coorg, Chickamagalur, while it is cultivated both as a pure and mixed crop along with arecanut in the plains of Uttar and Dakshin Kannada districts.

Estimates of production

There is an argument that the present official estimates of area and production of pepper in the country is not realistic considering the amount of export, estimated internal consumption of more than 40000 tons and the stocks held by the traders every year. It is believed that the actual production of pepper in the country is much more than the estimated figures. The trade estimates of production have generally been higher by 10000 to 15000 tons than the corresponding official estimates (Table 1). However, from marketing point of view, what is relevant is the availability of exportable surplus at competitive price.

There is an increasing trend in the production and area extension during the past decade (1998-99). While area

Table 1. Production of black pepper in India (1989/90 – 1998/99)

Year	Area (Ha)	Production (MT) Official estimate	Production (MT) Trade estimate	Share in world production (%)
1989-90	171490	55190	65000	30
1990-91	173430	47950	55000	23
1991-92	184200	52010	60000	28
1992-93	189390	50760	60000	33
1993-94	190990	51320	50000	40
1994-95	193270	60740	55000	34
1995-96	198030	61580	60000	34
1996-97	180260	55590	60000	41
1997-98	181550	57270	65000	31
1998-99	238320	65990	80000	35

Source: Directorate of Economics and Statistics, New Delhi and Spices Board, Cochin.

extension has grown at the rate of 0.85%, production has grown at the rate of 2.38% during the period from 1987-88 to 1997-98. This implies that recent extension to the area is more productive or farmers given better care to their existing plantation to increase yield. Area under pepper has crossed the 2 lakh mark during the crop year 1998-99 with a record production of 65990 tons.

Productivity gap

Pepper productivity in India is one of the lowest in the world (315 kg/ha). The average productivity of pepper/vine is highest around 1kg in Karnataka and lowest around 0.6kg in Kerala. The estimated average yield/vine in the tea estates is 3.3 kg (Jose & Madan, 1998). India has enough potential to increase productivity in the country as shown in figure 1.

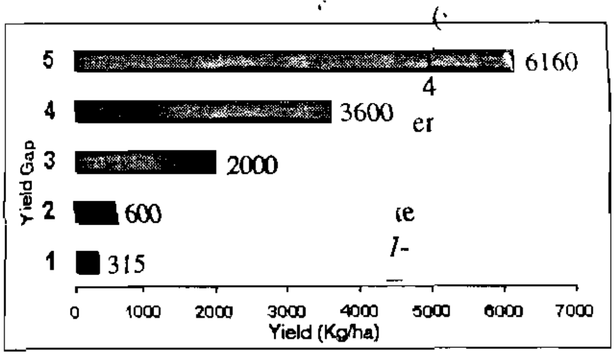

Fig 1. Yield gaps in black pepper production in India

Note:

1. National average (560 stands/ha)
2. Farmer's field with average maintenance (560 stands/ha)
3. Progressive farmer – optimum maintenance (1100 stands/ha)
4. Elite farmer – High Production Technology (HPT) (1100 stands/ha)
5. Research Station – High Production Technology (HPT) (5000 stands/ha)

Production cost

The estimated average cost of production per kilogram of black pepper excluding rental value of land at All India level was Rs.22.75 per kg. Among the states, the unit cost per kg of produce is highest in Kerala (Rs.23.04) and the lowest in Tamil Nadu (Rs.11.08) (Radhakrishnan, 1993). Cost of production (Rs./Kg) in Kerala has increased to Rs.35.59 in the year 1998-99 (Table 3). The estimated full supply price at 20% rate of interest which will encourage farmers to take more care to pe per vines than to other competing crops) is around Rs. 3/ per kg. and the minimum expected price of farm was between Rs.50-60/kg (Peter *et. al.*

Table 2. The estimated cost of production of black pepper (1997-98)

Cost component	Amount Rs./ha
Investment during establishment	65480
Compound interest on investment @ 15%	24623
Total investment (Sl. No. 1+2)	90118
Annuity value @ 15% for 15 yrs	14240
Annual maintenance cost	28466
Total cost of production	42706
Average annual production (kgs)	1064
Cost of production (Rs/kg)	35.59
Benefit cost ratio	4.5

Table 3. I' m-wise export of pepper products from India (199' 98)

Item	Quantity (MT)	Value (Rs.'000)
Black pepper (whole)	31511.1	4456667.4
Light pepper	461.6	36756.6
Pepper pinheads	961.5	45541.2
Pepper powder	574.8	74828.3
White pepper	191.6	44679.9
Dehyd. green pepper	410.9	111938.8
Fr. dr. green pepper	27.8	20867.5
Pepper in brine	664.2	37433.7
Frozen green pepper	153.8	6447.6
Pepper long	762.0	38970.8
Pepper oil	70.4	1411773.6
Pepper oleoresin	555.4	547050.6
Total	35719.3	4874131.6

1999). Thus, looking to the estimated cost and expected price by the farmers the prevailed farm gate price (Rs.130/kg) during the decade was high enough to work as an incentive to increase production and productivity. Pepper is a labour intensive crop providing employment opportunity to the rural mass. On an average the crop needs at least 178 man-days per annum per hectare (Vinning, 1990). This number will go up, when the intended end product is either white pepper or green pepper. Around 60% of the paid out cost of producing 1 kg of pepper is attributed towards labour cost. Price of labour has increased by about 400% in the predominantly pepper growing state of Kerala (during 1980-

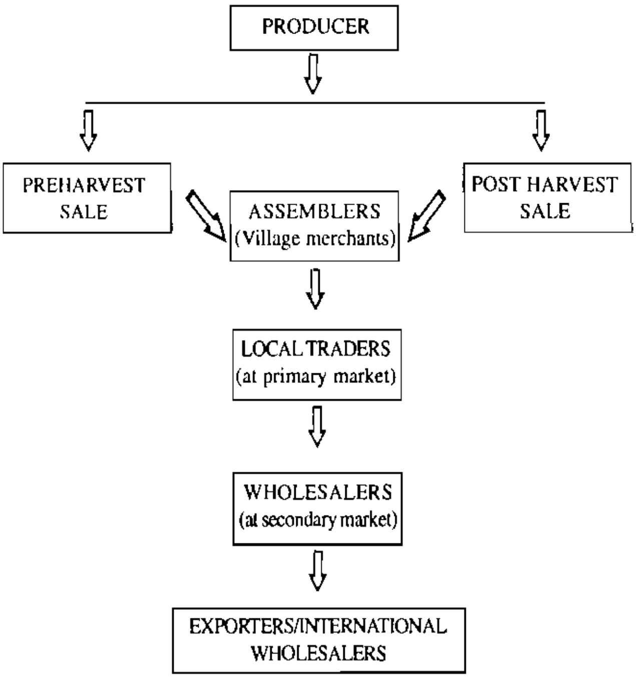

Fig 2. Marketing channel for black pepper

1995), while the increase is only 47% in Malaysia during the same period. Increase in labour wage during the past five years is 100%. This is the matter of concern not only for Indian pepper economy but also for the entire agriculture economy in the State.

The Product Distribution System (marketing system)

The existing product distribution system for black pepper can be described as a decentralized marketing system with alternate channels (Fig. 2).

Table 4. Distribution of marketing margin of black pepper

Institution	Percentage from the f.o.b. price		
	Export market	Domestic market	Overall
Farmers share	86.34	89.09	87.72
Marketing cost	7.23	6.24	6.74
Marketing marging	5.94	4.68	5.31
Price spread	13.17	10.92	11.06
Exporter's/Internal wholesaler's price	100	100	100

There are three types of middlemen between the farmers and exporters or domestic retailers. The first link in the marketing channel from the farm gate is assemblers in the village or popularly known as village merchant. The area of operation for the village merchant ends mostly in the local (primary) market. In the local market, the produce assembled by the local trader (second intermediary). The third intermediary in the marketing channel is the wholesaler. The wholesale trader purchases pepper in the assembly markets and moves it to the terminal markets where it is sold to internal wholesale merchants and for exporters. The exporters who act between the terminal domestic market and the overseas markets are the fourth member of the trade channels.

Wholesale traders do sorting and grading of pepper before selling the produce in the terminal market. The exporters do a storage function as well as sorting and grading. Almost more than 60% of the produce moves through the most common channel of:

Producer > Village assembler > Local trader > Wholesaler > Exporter.

The present marketing system for pepper is considered to be more efficient by providing increased share of consumer price (87.7%) to the farmer with comparatively low marketing cost (6.74%). The overall price spread (11.06) is much low when compared to other export oriented agricultural crops (Table 5).

The product combination

Vine harvested green pepper is converted/processed into different products to cater to the consumer de-

Table 5. Geographical regio-wise export of black pepper in terms of value (1991-92 to 1997-98)

Year	America	Europe	Africa	Russia	Asia & Pacific	Others	Total
1991-92	191681.4 (25.79)	132704.8 (17.86)	7849.9 (1.06)	341787.5 (45.99)	23202.2 (3.12)	45944.7 (6.18)	743170.5 (100)
1992-93	445329.1 (56.42)	158052.89 (20.02)	11530.1 (1.46)	70302.9 (8.90)	16935.1 (2.15)	87208.7 (11.04)	789358.7 (100)
1993-94	933784 (49.38)	408462.2 (21.60)	52526.3 (2.78)	210575.9 (11.13)	69347.4 (3.67)	216271.5 (11.43)	1890967 (100)
1994-95	1102272 (46.58)	558740 (23.61)	81074.3 (3.69)	430214 (18.17)	69936.8 (2.96)	124209.1 (5.25)	2366419 (100)
1995-96	658091.4 (33.5)	629264.5 (32.03)	119916.9 (6.42)	279835 (14.24)	45509.5 (2.32)	236884.6 (12:06)	1964709 (100)
1996-97	2384553 (57.83)	950224.9 (23.05)	40068.9 (1.02)	298653.2 (7.24)	154988.6 (3.76)	294695.8 (7.15)	4123184 (100)
1997-98	2436689 (49.99)	1212269 (24.87)	59133.3 (1.37)	452374 (9.28)	278698.7 (5.72)	434968.3 (8.92)	4874132 (100)
Average	1164629 (48.67)	578531.18 (24.17)	53157.1 (22.2)	297677.5 (12.44)	94088.33 (3.93)	205740.4 (8.60)	2393134.3 (100)

Figures in parentheses indicate percentage to total.
Source: Spices Board, Govt. of India, Cochin.

mand. There are more than pepper products being produced and marketed world over: Black pepper, white pepper, pepper powder, dehydrated pepper/canned green pepper, pepper oils and pepper oleoresins etc. Black pepper (whole) is by far the largest single spice commodity, which finds a place in all domestic and industrial use. Among the value added pepper products, India has near monopoly in production and marketing of pepper Oil and oleoresin. The oil and oleoresin industry in India with the present installed capacity of around 444 MT and 4203 MT respectively is one of the well developed in the world. Production of white pepper is also picking up slowly because of the government's promotional efforts. Table 3 presents the list of pepper products and their export during 1997-98. Since there is not much domestic market for most of these value added products, quantity exported can be taken as quantity produced.

Total export of pepper and pepper products from 1988-89 to 1997/98 increased significantly by 10.93% per annum in terms of quantity and 28.74% in terms of value. Regarding other products in the export basket, white pepper export increased by 7.8% per annum during the same period of time and there was a steady increase in export volume of pepper oil and oleoresins (9.25% and 9.24% respectively). Further, there is also a marked change in export value of other value added products. These figures lead to a conclusion, that the composition of export basket is changing slowly. In 1991-92, black pepper (whole) contributed around 93.92% to the total export value of pepper and pepper products and in 1997-98 the composition changed to 91.4% accommodating more of value added products in the export basket. But, the pace of change is encouraging looking to the availability of raw material and advanced technological base in the country.

Price

Price is the amount of money that consumers must pay in exchange for the product. The production decisions of the farmers are influenced by the price they receive at the farm level rather than the International market price for Indian pepper. The high fluctuation of price at the farm gate will lower the motivation of farmers to cultivate pepper intensively.

Educated and well informed pepper growers keep track of the price movement and bargain for better price for their produce. The efficient marketing system, which transmits the market information from one stage to other immediately and the increasing share of export in total production and the consequent share of Indian pepper in the international market lead to an impact of international pepper prices on domestic price and consequently on the pepper economy in the country. A near parallel movement of both domestic and international prices (fig. 3.) during the period from 1989/90 to 1999-2000 strengthens the above fact.

Traditionally pepper has been regarded as 'black gold', which can be kept apart for providing liquid cash when

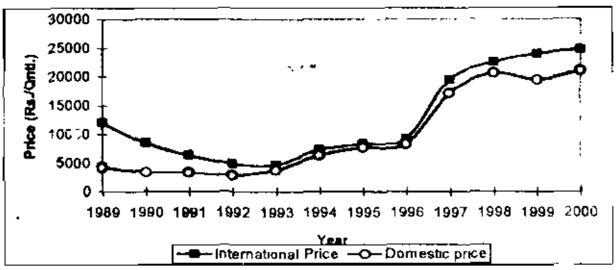

Fig. 2. International and Indian (domestic) prices for black pepper

most needed. When prices are high, the farmer converts his black gold into cash, on the other hand, when prices are low he would prefer to hold the sale of whole lot. Thus massive quantitites of pepper can be preserved by the farmers for long periods of time. The quantity available for exports would continue to be small until prices improve. In some strange manner, a collective supply manamgement decision is taken by the pepper growers of India, which results in securing maximum returns from pepper over the long term as compared to all other producing countries. It is significant to note that India always tends to be the leading exporter of pepper during years in which prices are high. When prices are low, India becomes the smallest of the four major exporters. For example during 1999-2000 though the crop is very poor ($3/4^{th}$ of the previous year) due to climatical factors, in order harvest the benefits of prevailing high price, the country has exported around 42,1000 tonnes worth 864.98 crores as against 34,864 tonnes valued Rs. 638.11 in the previous year.

Regarding value added products, there was not much domestic demand for these products and the entire production was exported. So, there was no marked influence of international price of these products on domestic prices. The price integration analysis carried out between New York and Cochin also proves the fact that there is an impact of international price on Indian market. When the impact is negative it severely affect the pepper economy. Therefore, it is important to eliminate the high fluctuation of export prices. Though the futures market is an effort in the direction, another reasonable way is by making a cartel price. India, that has around 30% share in the total world pepper supply should make a cartel price of pepper together with other major exporting countries such as Malaysia, Indonesia and Brazil. By making a cartel, unhealthy competition among major exporting countries will be eliminated and farmers in the countries will get high stable prices.

Place - Direction of exports

The destination countries of export depend on the type of pepper and pepper products. Most of India's export of pepper and pepper products are to USA. European countries are the other important trade blocks to import major share of Indian pepper. In the past decade, on an average around 50% of Indian pepper is exported to USA. India tops the list of pepper exporters to USA replacing Indonesia the traditional exporter of pepper to USA. In other value added pepper products also America is in the top of the list of major importers. During the eighties USSR and other Eastern European countries were importing Indian pepper in large quantity. USSR accounted for a steady 15-20 thousand tonnes of Indian pepper exports during the 80s. In 1991-92 trade to the USSR declined to 8500 tonnes. During 1997-98, the present day Russia has imported 3129.9 tons only. Among the East European countries Poland has imported around 942 tons during the same period. Thus, to-day India's export to erstwhile Russia and Eastern European block got reduced. The concentration of pepper export estimated using the Hirschman index was between 55.74 to 61.58 indicating the high concentration of exports to few regions and its future prospects also depend on the demand in countries these regions. Geographical block-wise export of pepper from India is given in table 5.

Analysing the opportunity

To sum up, while planning the above marketing mix it is necessary to use the managerial tool of 'SWOT Analysis' to list the strengths, weakness, opportunity and threats for the pepper industry in nut shell. The SWOT analysis carried out using the available data on Indian pepper industry including the above discussed reveals the following facts:

Swot analysis

Strengths

1. Superior Intrinsic Quality
2. Large production base
3. Good base in value added products industries
4. High demand in domestic market

Weakness

1. Low productivity
2. Insufficient supply of good planting materials
3. Diseases and pests
4. Unscientific processing methods
5. Weak promotional activities
6. High dependence on weather
7. Lack of brand name
8. Cultivated as a inter/mixed crop

Opportunity

1. Increased global demand
2. Change in lifestyle and food habits
3. Value added products
4. Unconventional usages

Threats

1. Increased production in competing countries
2. Violent fluctuation in prices
3. Increasing cost of production

In all, the country is better placed in the global economy for pepper against manageable threats. Proper mixing of the four Ps (Product, Price, Place and Promotion) looking to the present day situation and administering the same promptly by responding to the changes will help the country to maintain its leadership role in world pepper economy.

Conclusion

Kerala state is the major producer of pepper in India. Among the other pepper producing states, Karnataka contributes a sizeable quantity to the total production. Pepper has a high contribution ot rural employment and farmers' income in these regions of production. Although pepper price fluctuated sharply, pepper farming still exists and extending to new areas because of better returns over investment. This condition could strengthen the Indian pepper industry in the global competition. Pepper marketing in the regions of production also efficient involving less marketing cost and offering higher share in consumer price to producer.

Export of pepper increased significantly for the last ten years. However, there is a need to increase the share of value added products in the export volume. India has comparative advantage over the competing countries in value added products like oils and oleoresin with its well-developed industrial establishments. Since quality has become the key world in the world trade of spices, efforts to produce clean pepper should start from the farm itself instead of cleaning and exporting the produced material. Looking to the increased cost of production, and non-availability of enough labour at times of need, there is a need to develop and introduce labour saving devices for on-farm processing of spices. Since farm price plays greater role in production decisions and the farm price to a greater extend influenced by export price, there is a need to stabilize the export price (international price) by practicing a cartel price among major exporting countries including Vietnam. Grooming the huge domestic market will also protect and insulate the Indian pepper economy from violent changes in international pepper economy.

References

Anon 1990. Production and Export of Pepper. In: Status Paper on Spices, Spices Board, Government of India, Cochin.

George P S, Nair K N & K Pushpangadan 1989. The pepper economy of India. Centre for Development Studies Occasional paper. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.

Jose Abraham & M S Madan 1999. Preharvest yield estimation of black pepper at Arrepetta estate of Harrisons Malayalam Ltd., Meppady, Wayanad. Cosultancy report by Indian Institute of Spices Research, Calicut.

Madan M S, Peter K V, Jose Abraham & K Sivaraman 2000. Raising productivity of black pepper in Indian context. Spice India, Feruary-April 2000.

Ponnana K C 1999. Pepper economy review for 1997 and outlook for 1998/99. International Pepper Community, Jakarta.

Radhakrishnan C 1993. Economics of pepper production in India. Department of Economics, University of Kerala, Trivandrum.

Vinning, Grant 1990. Marketing Perspectives on a Potential Pacific Spice Industry. ACIAR Technical Reports No.15, 60 p.

Futures trade in pepper - an economic analysis

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The focus of economic liberalisation is slowly but surely shifting to agriculture. It is widely acknowledged that the essential components of reforms in agriculture are targeting subsidies in favour of durable and productive investment and phasing out of domestic trade and market restrictions. As the economic reforms programme in agriculture gathers momentum in the direction of market economy, the futures market will become increasingly relevant. The vast fluctuations in the prices, to which a large number of agricultural products are prone, is a demotivating factor to efforts towards higher levels of production and productivity.

Pepper is one of the most ancient and traditional crops of Kerala, whose origin is traced to the natural evergreen forests of the western ghats. Black pepper, considered to be the king of spices, has an important role in the Kerala economy and for a number of centuries, it has been the centre of attraction for many foreign traders and adventurers who came to India in the pursuit of pepper trade. Although the traditional pepper growing area comprises Kerala, Tamil Nadu and Karnataka, the state of Kerala accounts for over 90 percent of the area and production in India. Production of pepper in India is in the region of 60,000 metric tonnes annually from an area of 1.80 lakh hectares. Majority of pepper growers are small holders. Pepper is considered as a vital cash crop even though it is grown as a mixed crop not in a plantation scale like tea, rubber or coffee.

Future trading

The history of futures trading in this country goes back to well over a 100 years. It does not involve buying or selling commodities as in a ready market but it involves merely entering into agreements or contracts to buy and sell commodities at a future date. Forward contracts are of different types. There are non-transferable specific delivery (N.T.S.D) contracts, transferable specific delivery (T.S.D) contracts and transferable non-specific delivery contracts (or futures or hedge contracts as they are popularly known) while NTSD contracts make marketing of commodities possible over time and space, T.S.D contracts provide a better medium of marketing when there is no direct link between the producer and actual user.

Futures trading also known as hedge trading, it is a sophisticated risk management vehicle which assists trader/stockist, exporters, farmer and endusers in their market operation of buying and selling commodities by protecting them from adverse, price fluctuations (Khols 1997). Historically future trading developed because of a need felt by various trading interests in commodities to insure themselves against adverse price fluctuations in commodities acquired or held by them. To put it simply, future trading does not involve buying or selling commodities but merely entering into agreements or contracts to buy and sell commodities at a later date. There is no delivery payment or change of ownership until buyer and seller decide to do so during the delivery period specified in the agreement. Delivery is not mandatory.

Need for futures trading in pepper

The importance of black pepper in our economy needs hardly be emphasised. As far as Kerala is concerned pepper is a perennial fountain of prosperity and plentitude. Being an item of global production with increasing international demand, black pepper is a very sensitive commodity and therefore needs to be handled very cautiously. The desirability of ensuring fair return to the produces, the necessity of protection for the exporters and dealer against heavy price fluctuations and need to assure the concern of continuous availability are the major factors which subject black pepper to severe pulls and pressures. It is here that the future market play an important role and attempts to bring about a healthy compromise.

Pepper is having a long tradition of futures trading in India since 1957. According to international pepper community estimate, India tops the list of producing countries with 65,000 M.T. for 1997. India has emerged as a net exporter of pepper has been continuing as the leader in the spice family in the export basket till 1994-95. For viability of futures contracts the underlying commodity should have certain degree of homogeneity, storability and its trade should be of substantial volume. In the case of pepper these conditions are satisfied admirably.

International pepper futures market

The Union government has made the decision to implement the Kabra committee's recommendation of 1994 on allowing India to enter the international futures market in pepper. In one of its recommendations, the committee had stated that commodity markets in India could not function in an isolated manner in the context of the policy of globalisation of the economy. It had therefore, suggested that some of the commodity exchanges, particularly those dealing in pepper and castor seed, be upgraded to the level of international futures markets.

World pepper production in the 1995-96 was around 1.80 M.T and world trade, around 1.60 M.T. A notification is also being issued under the forward contract regulation Act to regulate the international contract only in Kerala and to prohibit it in the rest of the country. IPSTA is gearing up for the international future trading by developing the necessary infrastructure. The independent clearing house set up in Kochi for the purpose registered as a company on September 10, 1996. The guidelines for the international contract are being drawn up by the ministry of civil supplies with the help of the international pepper community, a body functioning under UNCTAD. The combined effort proposes to set down certain specifications regarding the contract size as well as the characteristics of the basic and the tenderable variety of pepper.

In terms of transactions, the international contract of pepper will be more expensive than other commodities since the dealers will give to pay a clearing house fee of about 0.02 per cent. The international contract will be designated in Indian measures for value and quantity, that is in rupees and quintals. In international future trading, a minimum delivery order of 15 tonnes will have to be made, and there will be a designated warehouse in all the delivery entries which will be looked after by SGS of Switzerland.

The push towards international pepper exchange has been stimulated by three factors. The first is the increasing volatility of pepper prices, the second is the felt need for expanded range of opportunities to hedge position, the third is the amazing development of international telecommunication and the spread of computer technology. These are the immediate factors that have encouraged he move towards the establishment of global pepper futures market. Internationalising is the process whereby pepper markets around the world became integrated into a single global market that transcend the geographical distances and time zones to operate on 24 hrs basis.

There are no studies reported the modelling of future market certain studies documented the evidences of the process integration of agricultural commodities. Cummings (1967) studied the inter price relationship among the markets in India for wheat. Nasurudeen and Subramanian (1995) employed Koyck's model to study the price integration of oils and oil seeds in Bombay market. The short run and long run price adjustments were estimated. Ravallion (1986) analysed the price series at different markets for one and the same commodity. In this paper Ravallion's model is used to measure the short and long run price adjustments.

Model

The estimation was done following Ravallion's general approach.

$$P_{ft} = \alpha + \delta i P_{ft-1} + \beta Pst + \gamma P_{st-1} + U_t$$

P_{ft} Future market's current month price of pepper. P_{ft-1} Future market's last month price of pepper, P_{st} Current month spot price of pepper, P_{st-1} Last month spot price of pepper. $\alpha, \delta, \beta, \gamma$ are parameters, to be estimated, U_t error term.

Results and discussion

The β gives the short run adjustments corresponding change in spot price. The long run adjustment is measured ie., $\beta K = \beta\ 1(1-\delta i)$

Short run adjustment = -.2417

Long run adjustment = -.2854

When there is an increase of Rs 1.00 in the last month future price, current month future price increase by 15 paise. When current spot price increases by Rs. 1.00, future price decreases by 25 paise. Future price increases by Rs. 1.00 when last month spot price increases by 28 paise.

δ = 0.1533 β = -.2417 γ = 1.0881

Average monthly prices for 10 years in the futures and domestic prices are taken. Ravallion model was fitted to analyse the price adjustments. Analysis gave a R^2

Table 1. Coefficients of estimated model

Variable	α	δ	t Value	β	t Value	γ	t Value
Y	22.28590	0.1533*	2.044	-0.2417**	3.148	1.0881*	21.325

** Significant at 1 per cent level * Significant at 5 per cent level

value of 0.98 which showed that the variables included i.e., last month future price, current spot price and last month spot price were highly relevant. All the variables are highly significant. To assess autocorrelation Durbin Watson 'h' test was employed and the value is within permissible limit which indicated that there was no autocorrelation problem.

References

Cummings Jr R W 1967. Pricing efficiency in the Indian wheat market. Impex pp 186-190.

Khols R L & N Uhi 1980. Marketing of Agricultural Products. Macmillan Publishing CO., Inc.

Nasurudeen P & S R Subramanian 1995. Price integration of oil and oil seeds. Indian J. Agrl. Eco. 50 (4): 624-633.

Ravallion Martin 1986. Testing market integration. American journal of Agrl. Economics 68(2): 102.

Market for spices - a world scenario

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Abstract

According to an ITC (International trace Centre, United Nations Conference on Trade and Development / World Trade Organization) report, the world import of spices went up from 8.48 lakh tonnes (valued at US $1.581 billion) in 1994 to 8.52 lakh tonnes (valued at US $1.837 billion) in 1995 before it declined to 8.13 lakh tonnes (valued at US $1.922 billion) in 1996 due to increase in price of spices, particularly black pepper. At present the European Union is the largest importer of spices in the world with annual imports of about 2.0 lakh tonnes, followed by USA with 1.7 lakh tonnes and West Asia 1.1 lakh tonnes. In West Asia, the UAE accounts for 64 per cent and Saudi Arabia for 18 per cent of the imports. The world consumption of pepper, chillki, ginger and mustard is rising because of popularity of ethnic cuisines and spicy foods. The demand for oleoresins and spice oils, however, has now stabilised after showing a healthy growth in the 1970s and 1980s. The market for encapsulated spices has started growing more rapidly in these countries.

Introduction

According to some US researchers, herbs and spices not only flavour and tenderise meat but also kill contaminating bacteria. By examining 4,164 traditional meat recipes from 31 countries, they found that onion, black and white pepper, garlic, lemon juice, hot peppers and ginger are among the most popular spices used in the world and most of them are powerful antibiotics. Onion, garlic, allspice and oregano kill all the bacteria they were tested against, including salmonella and staphyloccus while other spices such as hot peppers destroyed at least 75 per cent of their bacterial targets (The Hindu, February 5, 1998).

Production

India, at present, is the largest producer, consumer and exporter of spices in the world. India produces more than 50 varieties of spices and exports spices to some 120

countries in the world. The production of various spices in India went up from 19.00 lakh tonnes in 1991-92 to 27.80 lakh tonnes in 1996-97. The area under various spices rose from 20.05 lakh hectares to 25.40 lakh hectares and the yield from 0.95 tonnes to 1.09 tonnes per hectare.

The union government has plans to raise the production of spices in the country to 33.60 lakh tonnes and the exports to 2.58 lakh tonnes by the end of the Ninth Plan period by adopting an integrated approach in the development of black pepper, ginger, turmeric, chillies, cloves, cinnamon, saffron, vannila, herbal spices and seed spices.

According to the Directorate of Arecanut and Spices Development, the production of spices in the country has gone up from 21 lakh tonnes valued at Rs.5,200 crores in 1992 to 25 lakh tonnes valued at Rs.7,000 crores in 1995-96, 27 lakh tonnes in 1996-97 and 30 lakh tonnes in 1997-98. In 1998-99, it is likely to be 33 lakh tonnes and by the end of Ninth Plan 44 lakh tonnes.

Quality aspects to boost exports

In an attempt to promote quality consciousness and boost exports, the Spices Board has introduced a scheme of distributing a quality certificate, 'Spice House Certificate', to export houses who have genuine interest in improving and maintaining the quality of their products and sustain exports. Till the end of 1997-98, 107 applications were received by the Board and 44 exporters were issued this certificate.

These certificates are awarded to only those exporters who have installed in-house facilities for cleaning, grading, processing, packaging and warehousing of spices and have established a foolproof system for quality assurance at all stages of handling from purchase of raw material to selling of finished products with high degree of sanitation in their plants and worker cleanliness and personal hygiene observance. The scheme is meant for exporters who export spices in bulk whether whole or processed, ground, mixed, curry blends and also spice oils and oleoresins.

Organic spices – demand in international market

There is a very good demand for some organically grown spices like pepper, chillies, cardamom, ginger, turmeric and some seed spices in the international market. Such spices also command a premium in price. However, these spices require certification from some recognised international agencies which is a costly affair. The Spices Board is subsidising this by meeting upto 50 per cent of this cost to enable groups of growers to take up their production. In 1997-98, the Spices Board helped one society, Peermade Development Society, in obtaining such certification for pepper and cardamom. The Board spent Rs.14.22 lakhs in 1997-98 on this scheme.

Exports

India exports more than 52 varieties of spices. In the recent years, the exports of many spices have gone up substantially. India's exports of pepper and celery are substantial at 60-66 per cent and 90 per cent of their output. The world trade in spices is estimated at over 8 lakh tonnes and is valued at $2.00 billion.

In 1996-97, India's spice exports were 2,25,295 tonnes valued at Rs.1,230.72 crore ($333 million). The Spices Board had set a target to export 2,25,000 tonnes of spices (valued at Rs.1,200 crores) in 1997-98. In 1997-98 India's exports of spices went up value-wise to Rs.1,408.31 crore ($363.62 million) and quantity-wise to 2,28,821 tonnes.

In 1997-98, the export of cardamon (small and large), turmeric, coriander, cumin, fennel, curry powder and other seeds went up both in quantity and value while that of chilli, celery and fenugreek declined both in quantity and value. The export of pepper, ginger, garlic and other spices fell in quantity but went up value-wise. The export of mint oil went up in quantity but fell in value while that of spice oils and oleoresins was same as in the previous year quantity-wise but fell in value. The quantity-wise exports of black pepper fell by 25 per cent, chilli 15 per cent, ginger 5 per cent, celery 12 per cent, fenugreek 38 per cent, garlic 18 per cent and other spices by 9 per cent.

For 1998-99, the Spices Board had set a target to export 2,48,050 tonnes of spices valued at Rs.1,718 crores ($404.36 million). In 1998-99 India's exports of spices and spice products registered an 8 per cent decline in quantity to 210.255 tonnes from 2,28,821 tonnes but a 17 per cent increase in value at Rs.1,650.03 crores ($393.90 million) from Rs.1,408.3 crores ($378.72 million) in 1997-98. Pepper continued to lead in export earnings in 1998-99 also with a share of 38 per cent in total exports followed by spice oils and oleoresins and chillies.

In 1998-99, the exports of cardamom (small), chilli, turmeric, celery, fenugreek, spice oils and oleoresins, and other spices rose both in terms of quantities and value, while the exports of pepper and curry powder were higher in value terms and lower in quantity terms as compared to in 1997-98. The exports of cardamom (large), ginger, coriander, cumin, fennel, garlic and other seed spices fell both in terms of quantities and value (Tables 1 and 2).

Exports to European Union

The Commonwealth Secretariat in London has prepared a guideline report meant for the exporters of spices to the European Union. This report gives the structure of the EU spices market which includes the market size, its processing and institutional sector and the market share of individual countries. The report gives guidelines on how to do business in Europe, including the export procedures, tariffs and quotas.

Sweden, which occupies the eastern part of the Scandinavian Peninsula, is the fourth largest country in Europe. The main spices imported to Sweden are pepper, cardamom, turmeric, ginger, chilly, vanilla, cinnamon, cassia, cloves, nutmeg, mace, star anise, fennel, coriander, cumin, caraway, thyme, bay leaves, saffron and curry/curry mixtures.

Market

Over the past several years, the Swedish market for spices has remained relatively and growing slowly. Prices of spices vary considerably from year to year as per the amount importer keep on the stock causing price fluctuation on the apparent consumption figures. Swedish market for spices can be divided into three segments: (1) Consumer market, (2) Institutional market i.e., Restaurants, catering, hospital, etc. and (3) Industrial market. Size of the industrial market is more difficult to estimate than the other two, because im-

Table 1. India's exports of spices (Quantity (MT), Value (Rs. Crores)

Spice	1995-96		1996-97		1997-98		1998-99	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Cardamom (small)	527	12.97	226	8.70	297	10.63	355	22.49
Cardamom (large)	1,677	12.24	1,628	12.10	1,704	12.60	**1,050	**8.63
Celery	2,678	6.25	3,780	8.02	3,311	7.74	3,600	8.90
Chillies	56,165	195.46	50,051	201.45	42.489	138.47	56,750	210.13
Coriander	11,541	22.43	12,574	31.37	21,188	59.26	**17,300	**37.81
Cumin	3,871	17.39	6,375	34.38	15,744	79.28	**10,850	**59.00
Fennel	2,594	7.52	4,850	17.89	12,027	35.35	**5,000	**14.11
Fenugreek	15,138	18.67	8,891	12.05	5,529	9.17	8,200	15.21
Garlic	3,936	4.91	4.889	7.98	3,986	8.15	**3,350	**4.48
Ginger	18,483	38.92	29,737	59.24	28,312	71.90	**9,000	**27.44
Pepper	26,244	196.30	47,893	412.32	35,719	487.41	35,100	634.67
Tamarind	16,317	20.72	11,472	17.74	9,735	19.20	N.A.	N.A.
Turmeric	27,050	46.20	23,019	58.45	27,204	80.15	27,750	103.87
Curry Powder	4,246	17.55	4,639	20.57	4,891	22.95	**3,700	**20.84
Mint oil	1,352	4,750	2,371	134.50	3,016	95.94	3,400	95.68
Tree Spices	4,317	3.11	3,829	3.92	1,018	2.52	N.A.	N.A.
Herbal Spices	138	0.48	159	0.38	66	0.25	N.A.	N.A.
Spice Oils	366	15.28	383	13.95	220	30.85	N.A.	N.A.
Spice Oleoresins	1,545	99.74	1,975	145.07	2,131	192.36	*2,625	*293.10
Other seed spices	2,494	5.19	3,059	8.43	3,738	8.86	**1,750	**5.85
Other misc. spices	2,719	15.59	3,495	22,25	6,497	35.23	**15,500	56.00
Total	2,03,398	804.43	2,25,295	1,230.72	2,28,821	1,408.30	2,10,255	1,650.03

* includes spice oils also ** exports during Apr '98 – Jan '99

Table 2. India's exports of spices in April-December in 1997-98 and 1998-99 (Quantity MT.; Value Rs. Crores)

Description	1998-99		1997-98	
	Quantity	Value	Quantity	Value
Pepper	22,500	420.08	26.554	324.75
Cardamom (S)	170	9.70	178	6.44
Cardamom (L)	850	6.38	893	6.48
Chilli	21,250	86.95	34,547	112,70
Ginger	8,600	31.75	14,948	45.87
Turmeric	18,000	71.70	21,300	58.97
Coriander	16,500	34.81	16.643	47.27
Cumin	9,650	57.60	10,762	54.93
Celery	2,550	6.05	2,598	60.44
Fdennel	4,600	13.26	10,637	31.16
Fenugreek	5,900	10.88	4,218	6.98
Other seed (a)	1,600	4.55	2,925	6.58
Garlic	3,250	3.80	3,447	7.13
Other spices (b)	15,000	53.50	13,147	44.45
Curry powder	3,450	17.45	4,053	17.59
Mint oil	2,150	60.00	2,140	45.44
Spice oils and oleoresins	1,725	197.48	1,632	146.23
Total	1,37,495	1,085.91	1,70,652	999.02

(a) includes aniseed, bishops weed (ajwain seed), dill seed, etc., (b) includes tamarind, asafoetedia, cinnamon, cassia, kokam, saffron, etc. (Source: Spices Board)

porters/wholesalers normally do not sell the whole spices to their customers. Instead, they mix it with other ingredients, such as sugar, salt and other additives according to various recipes. It is estimated that the sales of such mixtures for food and bakery usage could be worth over SEK 1000 million.

Imports and exports

There are very few big importers of spices in Sweden. Since small importers are importing consumer packed branded spices while the big importers, import in bulk and pack and sell themselves as whole and ground. These big importers market their products to the neighbouring, Thailand, Denmark and Norway.

Quality demand/Import regulations

Generally speaking, Swedish market demands high quality spices. This does not mean that cheaper variety are not entertained. If the cheaper variety would be as good or better for a particular market when compared to the expensive this is imported. The end user's quality demand is taken care of by the importer. Spices are often imported as per International Standardization Organisation (ISO) standards. As a member of the E.U., Sweden follows the same rules and regulation and applies the same customs tariffs.

Report from Swedish International Development Cooperative Agency (SIDA) states that spices exporters have every opportunity to enter the Swedish market directly or through big traders in germany and the Netherlands. Quality assurance and consistent deliveries will certainly help to snatch the market. SIDA has recently signed an agreement with Association of the Swedish Chamber of Commerce and Industry for co-operation on trade promotion services. The objective is to increase and update business contacts between Sweden and exporters in Africa, Asia and Latin America.

Market for spices in the United States

In 1997, the US imported 2,90,200 tonnes of spices valued at $550 million against 3,04,300 tonnes valued at $499.6 million in 1996, India exported 42,344 tonnes of spices valued at Rs.424.69 crores to the US in 1997-98 against 46,872 tonnes valued Rs.417.75 crores in 1996-97.

The imports of various spices by USA in 1997 were 45,319 tonnes black pepper, 5,760 tonnes white pepper, 72 tonnes ground pepper, 19,122 tonnes chilli, 13,448 tonnes fresh and dried whole ginger, 6,560 tonnes cuminseeds, 5,800 tonnes garlic, 3,418 tonnes fennel seed, 3,100 tonnes coriander seeds, 2,198 tonnes vanilla beans, 2,043 tonnes turmeric, 1,160 tonnes spice oils and oleoresins, 900 tonnes curry powder, 475 tonnes ground dry ginger, and 300 tonnes small cardamom.

The major exporters of black pepper to the US were India (23,403 tonnes), Indonesia (13,500 tonnes) and Brazil (4,500 tonnes); chilli – India (9,365 tonnes), Mexico (4,400 tonnes), China (1,700 tonnes) and Chile (1,300 tonnes); ginger – Costa Rica (3,605 tonnes), Brazil (2,828 tonnes), India (1,792 tonnes) and China (300 tonnes); garlic – China; turmeric – India (1,900 tonnes) and Thailand (10 tonnes); cumin – India (2,024 tonnes), Turkey (2,000 tonnes), Pakistan and Syria; fennelseed – India (1,900 tonnes) and Egypt (1,500 tonnes); coriander – Canada (2,600 tonnes), India (250 tonnes) and Bulgaria (150 tonnes); cardamom – Gautemala (290 tonnes) and India (240 tonnes) and Thailand (180 tonnes); vanilla beans – Madagascar (1,450 tonnes) and Indonesia (620 tonnes); and Spice oils and oleoresins – India (800 tonnes) (Table 3).

The world consumption of pepper, chilli, ginger and mustard is rising because of popularity of ethnic, cuisines and spicy foods. The market for encapsulated spices has started growing more rapidly in these countries.

Table 3. World imports of spices (Quantity - million tonnes,x Value - US$ million)

Country	1994 Quantity	1995 Value	1996 Quantity	Value	Quantity	Value
European Union	0.206	483.91	0.219	595.89	0.215	591.24
USA	0.146	331.1	0.137	343.34	0.160	378.07
Japan	0.088	137.25	0.114	180.89	0.112	238.52
Singapore	0.086	103.64	0.082	120.33	0.086	139.09
Saudi Arabia	0.022	36.83	0.033	68.88	0.033	63.49
Malasia	0.039	33.73	0.032	36.15	-	49.80
Canada	0.017	46.25	0.017	50.11	0.018	48.76
Hong Kong	0.045	57.06	0.036	47.83	0.032	46.57
Republic of Korea	0.010	16.83	0.015	32.51	0.014	39.54
Mexico	0.015	36.75	0.009	27.61	-	33.59
Total	0.848	1580.96	0.852	1837.26	0.813	1921.53

References

Heriankunju 1998. Recent trends in United States Spice Market. Spice India, Spices Board, Cochin.

Iorns D 1998. Market trends of Spices in European Union. The Horticulturist 3(3).

Pruthi J S1986. Spices and Condiments. National Book Trust of India, New Delhi.

Sree Kumar. 1999. World Trade in Spices – Import and Re-exports of Pepper. Spice India, Spices Board, Cochin.

Session IV

Crop Protection

Uptake and persistence of potassium phosphonate and its protection against *Phytophthora capsici* in black pepper

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Abstract

Potassium phosphonate is recommended for the control of foot rot disease of black pepper (*Piper nigrum* L.). The uptake and persistence of this compound in black pepper was studied using a new formulation, Akomin-40 (Rallis India Ltd.). Initial studies with 500, 1000 and 2000 ppm of potassium phosphonate, both as aerial spray and soil drench, indicated that maximum reduction of foliar infection (upto 86.4 %) was noticed 4 days after treatment whereas root rot suppression (upto 70 %) was noticed 8 days after treatment. Further studies with higher concentrations ranging from 3 ml/l to 10 ml/l (1200 ppm to 4000 ppm) indicated that prolonged protection beyond 30 days could be obtained with 2400 ppm to 4000 pm concentration. There was no phytotoxicity on black pepper even at 4000 ppm.

Key words: black pepper, *Phytophthor capsici,* persistence, potassium phosphonate, root rot suppression

Introduction

The foot rot pathogen, *Phytophthora capsici* is a major limitation in the production of black pepper. The principal methods of controlling *P.capsici* include cultural practices and the use of fungicides. Oomycetes are not sensitive to most of the broad spectrum fungicides. For this reason, growers tend to rely on a limited number of fungicides.The present strategy to combat foot rot pathogen includes application of Bordeaux mixture, copper oxychloride and potassium phosphonate (Sarma & Anandaraj 1997). Potassium phosphonate has been shown to provide excellent control of a number of soil borne plant diseases caused by *Phytophthora* species (Cohen & Coffey 1986, Guest & Grant 1991, Ali *et al.* 1996, Opoku *et al.* 1998 and Rajan 2000). Disease management of foot rot of black pepper has been reviewed recently (Sarma & Anandaraj 1997) and emphasised the efficacy of potassium phosphonate both as foliar spray and soil drench in checking foot rot infection. Potassium phosphonate is ambimobile and because of its exceptional mobility through phloem, it can be applied either as a foliar spray or as a soil application. The effectiveness of potassium phosphonate against plant diseases depends on the sensitivity of pathogen to phosphonate (Guest *et al.* 1995). Eventhough much information on the sensitivity to potassium phosphonate of several *Phytophthora* species is available, only very little is known for *P.capsici.* Because of the complex mode of action of potassium phosphonate, results obtained with one host-pathogen combination can not readily be extrapolated from analogue combinations. In the present investigation, laboratory and pot culture experiments were used to determine the effectiveness, persistence and effect of higher concentrations of potassium phosphonate to control *P.capsici*, causing foot/root rot of black pepper.

Materials and methods

In vitro *antifungal activity*

Akomin –40 (Rallis India Ltd) containing 40 % phosphorus acid was used for the study.

Mycelial growth inhibition: Potassium phosph onate was added to autoclaved carrot agar medium to form concentrations of 200, 300, 500 and 1000 ppm. Discs of inoculum, 5 mm in diameter were taken from the edges of actively growing cultures (5 isolates) grown on carrot agar and placed centrally on to the fungicide amended agar in petri plates. The treated and untreated plates (3 plates/treatment) were kept in dark for 96 hrs at 24°C, and the colony diameter was measured.

Sporangial production: 5 mm discs were cut from the edges of actively growing cultures and placed in a sterile petridish. Fungicidal solutions at different concentrations: 1, 5, 10, 15, 20 and 50 ppm, were poured into the plates and kept under fluorescent light for 48-72 hrs. Number of sporangia/microspic field was recorded.

Zoospore germination: 50 µl each of zoospore suspension and 50 µl fungicidal solutions were added and placed on cavity slides to form final concentrations of 100, 150, 200 and 300 ppm. The germinated and ungerminated zoospores were counted under the microscope. Linear regression analysis was performed to determine EC 50 and EC 90 values.

In vivo *fungal activity*

Three to four months old rooted cuttings of black pepper var.Panniyur-1 raised in vermiculite were used for the study. For all experimental work, single zoospore isolate of *P.capsici* (99-101) isolated from the roots of black pepper was used. Three concentrations of potassium phosphonate, 500,1000 and 2000 ppm were prepared with distilled water and applied as foliar spray to one set of plants and as soil drench to the other set. Plants sprayed and drenched with distilled water served as control. Plants were uprooted on 2^{nd}, 4^{th}, 8^{th} and 16^{th} day after treatment. Plants were washed thoroughly and leaves were detached and inoculated with 5mm mycelial discs of 3 day old culture grown on carrot agar medium. The roots were dipped in zoospore suspension (1×10^6 zoospore/ml) for 24 hrs., washed thoroughly and kept in moist chamber for symptom development. The lesion size was measured in case of leaf inoculation and root rot was indexed using the score chart given below for root infection.

Root rot index

0 - healthy (no root rot)

1 - upto 25% root rot

2 - upto 50% root rot

3 - upto 75% root rot

4 - above 75% root rot

Based on the result of the first experiment, another experiment was conducted. Treatments were carried out in triplicates (5 plants/replication). Potassium phosphonate in concentrations of 1200, 1600, 2000, 2400, 2800, 3200, 3600 and 4000 ppm were used to find out the inhibitory effect on the fungus as well as phytotoxicity, if any. The plants were uprooted on 10^{th}, 20^{th} and 30^{th} day after treatment without causing any injury to the root system. Plants were washed thoroughly and dipped in zoospore suspension for 24 hrs and replanted in fresh medium for the symptom development.

Results and discussion

In vitro *antifungal activity of potassium phosphonate*

Growth inhibition was noticed at all the tested concentrations of the fungicide. The EC 50 & EC 90 values obtained with linear regression analysis are given in Table 1. The maximum growth inhibition was obtained with 1000 ppm (66.6% to 87.7 %). EC 50 and EC 90 values for different isolates varied from 365 to 480 ppm and 725 to 956 ppm respectively. Sporangial production was inhibited by comparatively at lower concentrations (EC 50 values ranging from 6.7 to 17.8 ppm and EC 90 values ranging from 14.3 to 39.5 ppm). Higher concentration, 50 ppm completely suppressed sporangial production and mycelial swellings were noticed. Compared to sporangial production, the concentration required for arresting zoospore germination was little high and it ranged from 119.2 to 237.4 ppm (EC 50) and 211.5 to 421.4 ppm (EC 90). Rajan (2000) reported that the EC 50 values for growth inhibition, sporangial production and zoospore germination as 100 ppm, 7 ppm and 60 ppm respectively.

In vivo *antifungal activity*

Both foliar and soil applications were effective in checking *Phytophthora* infection on leaf and root. The efficacy of potassium phosphonate to control *P.capsici* causing foot rot in black pepper was reported earlier (Ali *et al.* 1996, Rajan & Sarma 1997 and Rajan 2000). The results obtained with leaf inoculation is given in Table 2. Foliar application has more inhibitory effect on foliar infection than soil application. The maximum inhibition was expressed at 2000 ppm as spray and it was statistically significant to all the treatments. This was followed by 2000 ppm drenching and 1000 ppm spraying. The least effect was with 500 ppm drenching. In case of foliar application ,the maximum inhibition was noticed on 4th day and the effect declined with time. In case of soil application, the peak inhibition was noticed on 8th day and then declined. Higher concentration of 2000 ppm was found to be effective even after 16 days

Table 1. *In vitro* antifungal activity of potassium phosphonate on growth, sporangial production and zoospore germination.

Isolate No.	Mycelial growth		Sporangial production		Zoospore germination	
	EC 50	EC 90	EC 50	EC 90	EC 50	EC 90
1	480	917	17.8	39.5	174.7	319.5
2	425	845	15.4	34.2	180.6	330.2
3	415	828	6.7	14.3	133.1	241.5
4	478	956	9.4	25.4	237.4	421.4
5	365	725	7.9	16.3	119.2	211.5

Table 2. Effect of potassium phosphonate on foliar infection.

Concentration (ppm)	Lesion size (mm) Days after treatment			
	2	4	8	16
Foliar application				
500	11.33 d	10.00 c	12.20 c	20.20 c
1000	3.70f	2.80e	4.06f	6.33e
2000	1.73 g	1.10 f	3.06 g	4.60 f
Soil application				
500	17.80 b	12.90 b	16.70 b	22.57 b
1000	14.40 c	9.50 c	8.03 d	12.80 d
2000	9.63 e	7.30 d	6.00 e	6.18 e
Control	24.30 a	20.60 a	22.90 a	23.27 a
LSD(p=0.05)	1.557	0.769	0.8158	0.6961

Figures followed by same letters within a column are not significant in DMRT.

The inhibitory effect of potassium phosphonate on root rot, caused by *P.capsici* is given in Table 3. As in the case of foliar infection, 500 ppm failed to check root rot also. Both in case of foliar and soil application the maximum reduction of foot rot was noticed on 8th day. With 1000 ppm, the activity declined considerably after 8 days. The higher dose, 2000 ppm both as foliar and soil application was statistically significant in checking the infection and could check the pathogen even after 16 days. With all the three concentrations, soil application was more effective than foliar application in suppressing the symptom. Similar results were reported on *Pinus radiata* (Ali *et al.* 1999) and clover (Greenhagh *et al.* 1994).

The effect of higher concentrations of potassium phosphonate on disease suppression and persistence in black pepper plants is given in Table 4. When the plants were inoculated on 10th day, the concentrations

Table 3. Effect of potassium phosphonate on root rot suppression.

Concentration (ppm)	Root rot index Days after treatment			
	2	4	8	16
Foliar application				
500	4.0 a	4.0 a	4.0 a	3.96 a
1000	2.6 bc	3.6 a	2.0 c	3.8 a
2000	1.0 d	2.7 b	1.8 c	1.4 c
Soil application				
500	2.4 bc	3.5 a	3.5 b	3.8 a
1000	2.2 c	1.9 c	1.8 c	3.0 b
2000	0.8 d	1.6 c	0.8 d	1.2 c
Control	3.6 ab	4.0 a	4.0 a	3.96 a
LSD(p=0.05)	1.18	0.732	0.450	0.245

Figures followed by same letters within a column are not significant in DMRT.

Table 4. Effect of higher concentrations of potassium phosphonate on *Phytophthora* induced root rot.

Concentration (ppm)	Percentage survival of inoculated plants. Days after application		
	10	20	30
1200	53.3(46.9) c	39.3(38.8)d	32.9(35.0) c
1600	53.3(46.9)c	46.7(43.1) d	40.1(39.2) c
2000	67.0(54.9) c	54.0(47.3) cd	46.7(43.1) bc
2400	90.7(72.3) b	79.9(63.4) bc	73.7(59.1) ab
2800	100(90.0) a	97.6(81.1) ab	86.0(68.6) a
3200	100(90.0) a	97.6(81.1) ab	79.9(63.4) a
3600	100(90.0) a	100(90) a	90.7(72.3) a
4000	100(90.0) a	100(90) a	90.7(72.3) a
Control	19.9(26.5) d	26.2(30.8) d	19.9(26.5) c
LSD(p=0.05)	11.10	17.25	18.36

Figures followed by same letters within a column are not significant in DMRT.
Values in parenthesis are transformed values.

2800 to 4000 ppm were superior to all other treatments and there was no mortality. The concentration, 2400 ppm was significantly superior to 1200 to 2000 ppm. All the treatments were statistically superior to control.

When plants were inoculated 20 days after the treatment, the maximum protection was offered by 3600 ppm and 4000 ppm. Eventhough, there was mortality at 2800 ppm and 3200 ppm, they are on par with 3600 and 4000 ppm. The concentrations, 1200 ppm and 1600 ppm could not check the infection significantly.

After 30 days, the treatments 2800 to 4000 ppm, were superior to others. The survival percentage ranged from 79.9 to 90.7 and they are on par with the concentration 2400 ppm. Lower concentrations failed to check the infection significantly.

Phytotoxicity was not recorded with any of these concentrations. There are reports of phytotoxicity in other crops, Eucalyptus, 6g ai/l (6000 ppm), *P.cinnamomi*, (Aberton *et al.* 1999) and Pinus, 5 g ai /l (5000 ppm) (Ali & Guest 1998). Persistence of phosphonate in plant tissues contribute to its effectiveness as a fungicide. Tissue concentrations of phosphonate decline with time, necessitating sequential application of the fungicide to sustain critical concentrations and disease control (Allen *et al.* 1980, Bompeix 1989). Ouimette & Coffey (1989) reported that *P.capsici* is not very sensitive to Potassium phosphonate when they carried out experiment with 9 species of *Phytophthora*. The EC 50 values of *P.capsici* ranged from 0.17 to 0.23 meq/ml (340 ppm to 460 ppm) while those of *P.cinnamomi* was 0.02 to 0.08 m eq /ml (40 to 160 ppm). In the present context this might be the reason for minimum root suppression at lower concentrations. The concentration of potassium phosphonate in the tissues may not be sufficient to check the pathogen. Since there is no phytotoxicity, concentrations 6 to 7 ml (2400 to 2800 ppm) can be used which may ensure the persistence of compound for longer period. Eventhough the increased concentration causes hike in cost of treatment, it will be ensured with better protection.

References

Aberton M J, Wilson B A & Cahill D M 1999. The use of potassium phosphonate to control *P.cinnamomi* in native vegetation at Anglesea, Victoria. Australian Plant Pathology 28 : 225-234

Ali M M, Balasundaran M & Yesodharan K 1996. Fungicidal management of quick wilt disease of pepper in forest plantation. KFRI Research report 111, 12pp.

Ali Z & Guest D I 1998. Potassium phosphonate controls root rot of *Xanthorrhoea australis* and *X. minor* caused by *P.cinnamomi*. Australian Plant Pathology 27: 40-44.

Ali Z, Smith I, Guest D & Ali Z 1999. Effect of potassium phosphonate on root rot of *Pisus* radiata caused by *P.cinnamomi*. Australian Plant Pathology 280 : 120-125.

Allen R N, Pegg K G, Forsberg L I & Firth D J 1980. Fungicidal control in pineapple and avocado diseases caused by *P.cinnamomi*. Austral. J. Erpt. Agr. Anim. Husb. 20 : 119-124.

Bompeix G 1989. Fungicides and host-parasite interactions: the case of phosphonates. C R Acad. Agri. France 75 : 183-189.

Cohen Y & Coffey M D 1986. Systematic fungicides and the control of Oomycetes. Annu. Rev. Phytopathol. 24 : 311-338.

Greenhalgh F C, Boer R F de, Merriman P R, Hepworth G, Keane P J & De Boer R F 1994. Control of *Phytophthora* root rot of irrigated subterranean clover with potassium phosphonate in Victoria, Australia. Plant Pathology 43 : 1009-1019.

Guest D I & Grant B R 1991. The complex action of phosphonates. Austral. Biol. Rev. 66 : 159-187.

Guest D I, Pegg K G & Whiley A W 1995. Control of *Phytophthora* Diseases of Tree Crops using trunk injected phosphonates. Horticultural Reviews 17 : 299-330.

Opoku I Y, Akrofi A Y, Apiah A A & Luterbacher M C 1998. Trunk injection of potassium phosphonate for the control of black pot disease of cocoa. Tropical Science 38 : 179-185.

Ouimette D G & Coffey M D 1989. Comparative antifungal activity of four phosphonate compounds against isolates of nine *Phytophthora* species. Phytopathology 79 : 761-767.

Rajan P P 2000. Approaches towards the integrated disease management of *Phytophthora* infection of black pepper (*Piper nigrum* L.) Ph.D Thesis, University of Calicut, Calicut.

Rajan P P & Sarma Y R 1997. Compatibility of potassium phosphonate with different species of *Trichoderma* and *Gliocladium virens*. In: Edison S, Ramana K V, Sasikumar B, Babu K N & Eapen S J (Eds.) Biotechnology of spices, medicinal and aromatic plants, pp 150-155. Indian Society for Spices, Calicut, Kerala, India.

Sarma Y R & Anandaraj M 1997. *Phytophthora* foot rot of black pepper In: Agnihotri V P, Sarbhoy A K & Singh D V (Eds.) Management of Threatening Plant Diseases of National Importance, pp 228-236. Malhotra Publishing House, New Delhi.

Effect of organic soil amendments and chemical fertilizers on foot rot pathogen (*Phytophthora capsici*) of black pepper (*Piper nigrum* L.)

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Abstract

Black pepper (*Piper nigrum* L.), the 'King of Spices' is one of the important spice crops fetching an annual export earning of Rs.4165.22 million to the country. *Phytophthora* foot rot and slow decline continued to be the major production constraints in all the pepper growing countries. The annual crop loss due to *Phytophthora* foot rot on global scale is estimated to be around $ 4.5-7.5 million. Integrated approach on disease management has become an imperative to tackle this serious disease problem. As an eco-friendly approach of disease management, four commonly available organic soil amendments viz; coffee pulp, poultry manure, neem cake and farmyard manure were tested against *P.capsici*. For comparison, recommended doses of NPK were used. From this experiment, the root rot incidence varied with different treatments, the minimum root rot was noticed where coffee pulp was applied (10.0%) followed by neem cake (18.2%) and maximum root rot was noticed where chemical fertilizer was applied (94.5%).

Key words: amendments, black pepper, chemical fertilizer, *Phytophthora capsici,*

Introduction

Application of soil amendments at the base of pepper vine is a common practice among farmers, which support the growth and proliferation of micro organisms, water holding capacity of soil, suppress the pathogen population and enhance the root regeneration. Nutrition on host and its effect on the disease development have not been studied in blaek pepper - *Phytophthora* pathosystem. A pot culture experiment was conducted to study the influence of organic soil amendments on disease incidence. Locally available amendments viz; coffee pulp, poultry manure, neem cake and farm yard manure were used for the study. All amendments were analysed for their NPK and their quantities were adjusted to the recommended doses of NPK (140:55:270) by adding required chemical fertilizers. For comparison, recommended doses of NPK also were included as another treatment. The experiment was conducted during June - December period.

Inhibitory effect of soil amendments on *P.cinnamomi* was studied by several workers (Hoitink *et al.* 1977, Rosas Romero *et al.* 1986, Sivasithamparam 1981, Nesbitt *et al.* 1979). Spencer & Benson (1982) studied the effect of pine bark, hard wood bark compost and peat amendment on lupine root rot by different *Phytophthora* species.

Materials and methods

Host

Rooted cuttings of cultivar Subhakara (KS 27) were raised in polythene bags (6 x 10"), filled with 1kg nursery mixture, consisting forest soil, sand and farmyard manure (3:1:1). Two months old nursery cuttings were raised in polythene tubes, grown in soil mixture consisted of forest soil and sand at the ratio of 3:1. Cuttings were transplanted in earthen pots (12"), without disturbing root system, filled with forest soil and sand in the ratio of 3:1 @ 10 kg/pot. Plants were irrigated on alternate days with tap water. Plants with 5-6 leaves were selected for uniformity and different treatments were imposed. For each treatment, ten pots were maintained.

Organic soil amendments and chemical fertilizers

Locally available organic soil amendments viz. coffee pulp, poultry manure, neem cake and farm yard manure were collected and analyzed for the presence of NPK content. Depending upon the NPK content of each amendment, they were weighed to get the recommended dose of NPK (140 :55:270). To attain the recommended dose of NPK, amendments were supplemented with chemical fertilizers. As per the treatments, each amendment was added to the base of selected pepper cuttings after removing the upper layer of rhizosphere soil, without disturbing the root systems. For comparison, recommended dose of NPK also was used as another treatment.

Pathogen

Virulent isolate of *P.capsici*, isolated from infected roots of black pepper was used. Purified isolate of *P.capsici* was sub- cultured on Carrot Agar medium and incubated at 28+1°C for 48 hrs. For mass multiplication of *P.capsici* inocula, sieved sand (3mm) - 500g was filled in polypropylene bags (12 x 8) and moisturized with 150 ml carrot broth (200g carrot/litre of distilled water). The sand - carrot broth mixture was autoclaved for one hour at 121°C and 15 lb pressure. After cooling, each bag was inoculated with five culture discs (0.5 cm) of virulent *P.capsici*, collected from margins of actively growing 48hrs old culture and incubated at 28+1°C for 20 days.

Treatment wise microbial population viz. fungal, bacterial and actinomycetes colonies were monitored. Fifteen days after application of different amendments to the pepper plants, cfu of microbes were monitored at the dilution of 10^{-3} for fungi, 10^{-6} for bacteria and 10^{-5} for actinomycetes. Population of microbes were also monitored at the time of uprooting plants.

Fifteen days after imposing different treatments, all plants except absolute control were uniformly inoculated with 20 days old 2% (200g) inoculum of *P.capsici*, raised in sand carrot broth. Inoculum was applied at the base of pepper cuttings after removing the upper layer of soil, without disturbing the root system and later covered. Plants were irrigated daily to ensure high soil moisture. DPI of *Phytophthora* and pH of treated soil were also monitored every month. Six months after inoculation, plants were uprooted. Disease incidence, roots rot (%), fresh and dry weights of root and shoot were recorded.

Results and discussion

Before application of soil amendments, all the four organic soil amendments and forest soil were analysed for their nutritional status. From the analysis results, neem cake has got maximum nitrogen content followed by poultry manure and coffee pulp. Least quantity of N was detected in farmyard manure. Maximum P was noted in poultry manure followed by neem cake and least was noted in coffee pulp. Maximum K was noted (4%) in coffee pulp followed by poultry manure and neem cake and least was noted in farm yard manure(Table 1).

Table 1. NPK levels of different organic soil amendments and forest soil

Treatments	N_2 (%)	P_2O_5 (%)	K_2O (%)
Coffee pulp	1.62	0.18	4.00
Poultry manure	1.91	0.83	1.80
Neem cake	2.20	0.70	1.60
Farm yard manure	0.40	0.30	0.20
Forest soil	0.41	0.16	0.19

Maximum growth of shoot and root was recorded in plants treated with coffee pulp. It was noted that coffee pulp enhanced the overall growth and root mass of plants. Poultry manure has got negative effect on growth of plants (Tables 2 & 3).

Table 2. Effect of organic soil amendments and chemical fertilizers on shoot mass of *P.capsici* inoculated black pepper

Treatment	wt (g)*	Dry wt (g)*
Coffee pulp	07.976	02.212
Poultry manure	03.120	00.771
Neem cake	03.112	00.806
Farm yard manure	03.622	01.105
NPK	03.442	01.169
Control	04.962	01.324
Absolute control	12.370	02.622
CD at 5%	02.950	00.760

* Average of 10 replications

Phytophthora infection on root (root rot) was almost negligible in plants treated with coffee pulp (10%) and maximum root rot was recorded in plants treated with chemical fertilizers (94.5%) (Table 3). Root rot incidence in plants treated with poultry manure (89.5%) was on par with chemical fertilizers. DPI of

Table 3. Effect of organic soil amendments and chemical fertilizers on root mass of *P.capsici inoculated* black pepper

Treatment	Fresh wt. (g)*	Dry wt. (g)*	Root rot (%)*
Coffee pulp	05.362	01.462	10.0
Poultry manure	00.957	00.285	89.5
Neem cake	01.917	00.869	18.2
Farm yard manure	02.171	00.685	57.0
NPK	02.011	00.651	94.5
Control	01.946	00.796	24.5
Absolute control	10.184	01.888	00.0
CD at 5%	01.430	00.62	23.1

* Average of 10 replications

Phytophthora in amended soils showed that, chemical fertilizers were not preventing the proliferation of pathogen and it was on par with control (1024) and least number of propagules were noted in coffee pulp treated soil (4) (Table 7).

Neem cake enhanced fungal population (212.06 x 10^3) in soil, followed by poultry manure (161.4 x 10^3) and coffee pulp (71.0 x 10^3) but NPK did not support the fungal multiplication (44.5 x 10^3) (Table 4).

Table 4. Effect of organic soil amendments and chemical fertilizers on fungal population (cfu 10^3)in rhizosphere of *P.capsici* inoculated black pepper

Treatment	15 days after amendment application	At the time of uprooting
Coffee pulp	071.000	137.433
Poultry manure	026.867	161.400
Neem cake	130.867	212.067
NPK	018.533	044.500
Farm yard manure	015.533	044.500
Control	018.733	050.400
Absolute control	019.967	058.667
CD at 5%	003.143	009.405

* Average of 3 plates

Fifteen days after the amendment application, poultry manure showed highest number of bacterial population but finally it decreased. Though the soil with farm yard manure gave less number of bacterial count initially (11.8 x 10^6), at the time of concluding the experiment, the population was maximum (201 x 10^6). In chemical fertilizer treated soil, the bacterial population was on par with control (2 & 1 x 10^6, respectively) (Table 5). There was an increment in actinomycetes population in soil treated with farm yard manure (4.6 x 10^5) and least number of actinomycetes propagules were noted in control (1 x 10^5) (Table 6).

Table 5. Effect of organic soil amendments and chemical fertilizers on bacterial population in rhizosphere of *P.capsici* inoculated black pepper.
(CFU= Coloniesx10^6)*

Treatment	15 days after amendment application	At the time of uprooting
Coffee pulp	04.200	012.000
Poultry manure	26.300	006.967
Neem cake	08.767	027.533
Farm yard manure	11.867	201.967
NPK	02.000	011.167
Control	01.200	001.400
Absolute control	01.300	002.000
CD at 5%	01.595	007.866

* Average of 3 plates

The DPI of *P.capsici* monitored from all the treatments and the influence of DPI on root rot was noticed. However it is intriguing that FYM which showed DPI 8 showed 57% root rot, where as neem cake 512 as DPI but showed 18% root rot, this might be due to enhanced bacterial population in the former. Root rot incidence in plants treated with poultry manure and neem cake are on par with chemical fertilizers. DPI of *Phytophthora* in amended soils showed that, neem cake and chemical fertilizers were not preventing the growth of this pathogen and it was on par with untreated control plants. Least number of propagules were noted in coffee pulp treated soil (4) (Table 7).

Table 6. Effect of organic soil amendments and chemical fertilizers on actinomycetes population in rhizosphere of *P.capsici* inoculated black pepper. (CFU= Colonies x 10^5)*

Treatment	15 days after amendment application	At the time of uprooting
Coffee pulp	02.200	10.100
Poultry manure	02.200	03.067
Neem cake	00.000	00.867
Farm yard manure	01.000	19.633
NPK	00.000	00.200
Control	00.333	00.100
Absolute control	00.000	00.000
CD at 5%	00.226	00.887

* Average of 3 plates

Table 7. Disease potential index (DPI) of *P.capsici* in amended soils

Treatments	DPI		pH
	Initial	Final	
Coffee pulp	2048	4	5.3
Poultry manure	2048	512	7.5
Neem cake	2048	1024	6.3
Farm yard manure	2048	8	6.9
NPK	2048	1024	5.5
Control	2048	1024	6.0
Absolute control	0000	0000	6.0

The present study clearly showed that, neem cake enhances the fungal population in soil (212.067 x10^3), followed by poultry manure (161.400x10^3) and farm yard manure (152.067 x10^3) but NPK was not conducive for fungal multiplication (044.500 x10^3) and it enhanced the root rot of black pepper. There is a general feeling among black pepper farmers' that chemical fertilizers are enhancing the disease incidences which needs scientific explanation based on the data.

In neem cake amended soil, the fungal microflora was enhanced. The better protection might be due to increased antagonists and also possible indirect effect on host defense mechanism. This needs further investigation. Since DPI of *P.capsici* in neem cake treated soil was comparatively higher (1024) and root rot was less compared to control, the mechanism needs further investigations. Poultry manure has shown root rot suppression in *P.nicotianae* (Tsao & Oster 1981), in contrast to severe root rot (89.5%) recorded in black pepper.

Addition of different soil amendments enhances the microbial population (Nesbitt *et al.* 1979, Lumsden *et al.* 1983, Rattink 1983, Weltzien 1990) growth of the plants and multiplication of antagonists (Nam *et al.* 1988, Linderman 1989). *Phytophthora* population was reduced in mustard, castor, neem and mahna cake amended soil (Singh & Vyas 1984). The soil with compost of pine bark and hard wood bark had suppressed *Phytophthora* population (Spring *et al.* 1980, Spencer & Benson 1982). Different soil borne diseases caused by *Pythium* sp., *Fusarium* sp., *Phytophthora* sp. and *Plasmopara* sp. in crucifers were reduced by soil amendments (Huang 1991). It was also reported that soil amendments would help in reduction of *P.cinnamomi* population (Hoitink *et al.* 1977) and *P.cactorum* (Rana & Gupta 1985) in infected fields. In *Vigna mungo* fields, increment of yield and antagonistic population againt root rot pathogen was noticed after application of amendments (Chandrasekaran *et al.* 1995). In the present study it was found that coffee pulp amendment greatly reduced the root rot and enhanced the overall growth of the plants. Incidentally coffee pulp supported good growth of *Trichoderma* (Sarma & Anandaraj 1999).

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References

Chandrasekaran A, Gangadharan K & Rathanasamy R 1995. Efficacy of organic amendments and biocontrol agents on root rot of *Vigna mungo* (L.) Hepper (Abstr.). Paper presented in Global Conference on Advances in Research on Plant Diseases and their Management. 12-17 February 1995. Udaipur, India. p159.

Hoitink H A J, Vandoren D M Jr & Schmitthnner A F 1977. Suppression of *Phytophthora cinnamomi* in a composted hard wood bark potting medium. Phytopath. 67 : 561-565.

Huang J W 1991. Control of soil borne crop diseases by soil amendments. Plant Protection Bulletin 33 : 113-123.

Linderman R G 1989. Organic amendments and soil borne diseases. Canadian Jr. of Plant Pathology. 11 : 180-183.

Lumsden R D, Lewis J A & Millner P D 1983. Effect of composted sewage on several soil borne pathogens and diseases. *Pytopath.* 73 : 1543-1548.

Nam C G, Jee H J & Kim C H 1988. Studies on biological control of *Phytophthora* blight of red pepper.II. Enhancement of antagonistic activity by soil amendment with organic materials. Korean J. of Plant Prot. 4 : 313-318.

Nesbitt H J, Malajczul N & Glen A R 1979. Effect of organic matter on the survival of *Phytophthora cinnamomi* Rands in soil. Soil Biology and Biochemistry. 11 : 133-136.

Rana K S & Gupta V K 1985. *In vitro* and *in vivo* efficacy of systemic and protectants fungicides against *Phytophthora cactorum*. Indian J. of Mycology and Plant Pathology. 13 : 272-276.

Rattink H 1983. The influence of bark and some soil amendments on the development of soil fungi. Mededelingen Van de Faculteit Land bouw wetens chappen, Rijkuniversiteit Gent. 48 : 699-703.

Rosas Romero M, Teliz ortiz D, Garcia Espinosa R & Salazar Garcia S 1986. Effect of cowdung, lucerne and metalaxyl on the population dynamics of *Phytophthora cinnamomi* Rands, causal agent of Avocado (*Persea americana* Mill) root rot. Ravista Mexicana de Fitopatologia. 4 : 114-123.

Sarma Y R & Anandaraj M 1999. Final report of DBT project "Development, Production and Demonstration of Biological Control Agents Under Integrated Pest Management IPM". Indian Institute of Spices Research, Calicut, Kerala, India.

Singh R & Vyas K M 1984. Inflluence of certain oil cakes on betel vine *Phytophthora*. Indian Phytopath. 37 : 359-361.

Sivasithamparam K 1981. Some effects of extracts from tree bark and saw dust on *Phytophthora cinnamoni* Rands. Australasian Plant Pathology. 10 : 18-20.

Spencer S & Benson D M 1982. Pine bark, hard wood bark compost and peat amendment effects on development of *Phytophthora* spp and lupin root rot. Phytopath. 72 : 346-351.

Spring D E, Ellis M A, Spotts R A, Hoitink H A J & Schmithenner A F 1980. Suppression of the apple collar rot pathogen in composted hard wood bark. Phytopath. 70 : 1209-1212.

Tsao P H & Oster J J 1981. Relation of ammonia and nitrous acid to suppression of *Phytophthora* in soils amended with nitrogenous organic substances. Phytopath. 71 : 53-59.

Weltzien H C 1990. The use of composted materials for leaf disease suppression in field crops. Monograph - British Crop Prot. Council. No.45 : 115-120.

Endophytic bacteria: its disease suppressive and growth promotive activities in ginger (*Zingiber officinale* Rosc.)

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Abstract

Ginger (*Zingiber officinale* Rosc.) is the second important cash crop of Sikkim, after large cardamom. It is widely grown by small and marginal farmers in about 3000 ha as monocrop or as intercrop along with maize and mandarin orange. A number of pathogens and pests cause considerable damage to the ginger crop. Different pesticides are being used extensively to control the disease problems in ginger which caused economical and ecological problems. To overcome these problems, integrated disease management approaches are found more feasible. Biocontrol being important component of integrated disease management in ginger, isolation and field testing of biocontrol agents were initiated. Different endophytic bacterial strains were isolated from different parts of Sikkim. Two pot culture experiments were conducted to study the effect of four isolates of endophytic bacteria on growth of the crop and suppressiveness against *Pythium*, *Fusarium* and *Pratylenchus*. All the four endophytes tested enhanced tillering, overall growth of the plants and suppressed the pathogens and disease incidences.

Key words: disease suppression, endophytes, ginger, growth promotion, rhizome rot

Introduction

Ginger (*Zingiber officinale* Rosc.) is a rhizomatous spice crop and is used as vegetable, dried ginger as well as for medicinal purposes. Ginger is mainly cultivated in temperate region where good rainfall is received. The production of ginger is mainly hampered by different diseases and pests. The main diseases affecting the production are soft rot (*Pythium* spp.), dry rot (*Fusarium oxysporum* alone and along with *Pratylenchus coffeae*) and bacterial wilt (*Ralstonia solanacearum*). Since ginger is being consumed as raw vegetable, the use of toxic and expensive agrochemicals to control the diseases are not economically and ecologically feasible. Extensive use of pesticides in agriculture invited environmental and health concerns and thus considerable interest was noticed among researchers to find out alternative approaches for the management of diseases.

Disease suppressive as well as growth promotive endophytic rhizobacteria (PGPR) are getting greater attention now a days due to their eco-friendly nature and these endophytic bacterial isolates are predominant in tissues of most of the crops. Endophytic bacteria and other organisms co-exist with the tissues of the host without causing any harm to the hosts.

Bacterial endophytes have been defined by Kado (1992) as "bacteria that reside within living plant tissues without doing substantive harm or gaining benefit other than securing residency". According to Hallmann *et al.* (1997) "any bacterium as an endophyte if it can be isolated from surface-disinfected plant tissue or extracted from inside the plant, and if it does not visibly harm the plant".

Recent research demonstrated that bacterial endophytes can improve the plant growth and reduce disease symptoms caused by several pathogens (Chen *et al.* 1995, Frommel *et al.* 1991, Kloepper *et al.* 1992, Pleban *et al.* 1995, Van peer & Schippers 1989).

In the present study, different bacterial endophytes were isolated from healthy tissues of ginger, collected from different parts of Sikkim (India) and tested for their efficacy on growth promotive and disease suppressive activities.

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Materials and methods

Endophytes

Healthy ginger samples were collected from different parts of Sikkim where there is no disease incidence was noticed. Ginger rhizomes were washed thoroughly with tap water initially to avoid all the soil particles adhered to the rhizomes. The healthy areas of rhizomes were cut into small pieces with cortical tissues, surface sterilized with 0.1% mercuric chloride and washed thoroughly with sterile distilled water for 4 times.

Ginger pieces (10 per plate) were plated on PSA containing 5, 10 and 20 per cent sucrose. For each treatment 10 plates were maintained and were incubated at low temperature for 24 hrs to see whether any other bacteria as contaminants growing or not. The plates were discarded where other contaminant bacteria were noticed within 24 hrs of incubation. The inoculated plates were incubated at 28°C for 72 hrs. Different bacterial isolates appeared in the medium were isolated according to their colony characters and numbered. Total 10 isolates were obtained and most predominant 4 isolates were used for the pot culture studies.

Endophytic bacterial isolates were purified using Nutrient Agar (Hi-media) medium. Single colonies were re-isolated from the purified cultures of endophytes and used for mass multiplication. Nutrient broth prepared and distributed into 250 ml. flasks @ 50 ml. per flask and were sterilized at 120°C and 15 lb pressure for 30 minutes. The sterilized and cooled nutrient broth was inoculated with different isolates of endophytes collected from actively growing 24 hrs old cultures. The inoculated flasks were incubated at 28°C for 48 hrs and used for pot culture studies.

Host

Ginger variety 'Bhaisey' was used for the study. Ginger seed rhizomes with single sprout (35-50 g) were planted in 5 l buckets, filled with sterile potting mixture consisting of garden soil and sand at the ratio of 3:1. For each bucket 3 ginger pieces treated with endophytic bacterial isolates were planted, irrigated on alternate days with boiled and cooled water and for each treatment five buckets were maintained.

Effect of endophytic bacterial isolates on growth of ginger

For the treatment of seed pieces, at the time of planting, bacterial culture broth was prepared. Nutrient broth was used for mass multiplication of endophytic bacterial isolates. Fifty ml of nutrient broth was added into each flask and sterilized for 30 minutes at 120°C and 15 lb pressure. Single bacterial colonies collected from 24 hours old cultures with the help of a sterile loop (isolate wise) and inoculated the sterilized-cooled nutrient broth, in flasks. For each isolate, 10 conical flasks were maintained. The inoculated flasks were incubated at 28°C for 48 hrs. After 48 hrs of incubation, 100 ml. bacterial suspension was prepared from each flask with sterile distilled water and soaked the ginger seed pieces for half an hour (isolate wise) and planted in buckets as described above as per treatment. Plants without any bacterial isolates served as absolute control. Different growth parameters viz. number of tillers and height of the plants were recorded and analyzed statistically (MICROSTAT).

Effect of endophytic bacterial isolates on ginger diseases

Endophytic bacterial isolates were isolated with ginger seeds and planted as described above. For each treatment 5 buckets with three ginger plants were maintained. For each pathogen, 5 buckets with 3 ginger plants were maintained as control. Two months after planting, the pathogens (*Pythium*, *Fusarium* and *Pratylenchus*) were added into the rhizosphere of potted plants as per the treatment. Virulent isolates of *Pythium* sp and *Fusarium oxysporum*, mass multiplied in potato broth (50 ml/ 250 ml. flask) and *Pratylenchus*, mass multiplied in carrot callus were used for the experiment.

Virulent isolates of *Pythium* sp. and *Fusarium oxysporum* were isolated from infected ginger rhizomes and purified on PDA. Potato broth (200 g potato and 20 g dextrose) prepared and distributed in 250ml conical flasks @ 50 ml/flask and sterilized for 30minutes at 120°C and 15 lb pressure. The broth was inoculated with 0.5 cm culture discs collected from edges of 48 hrs old actively growing cultures. For each pathogen, 15 flasks were maintained. The inoculated flasks were incubated at 28°C for 10 days. From each flask, 100 ml of the mycelial suspension was prepared with sterile distilled water and applied at the rhizosphere of the ginger plants as per the treatment @ 30 ml/bucket. For inoculation of nematodes, 200 nematodes were applied per bucket. All the plants were irrigated on alternate days and different parameters such as rhizome and root rot (%), weight of root and rhizome were recorded and analyzed statistically (MICROSTAT).

Results and discussion

It was noticed that all the four isolates of endophytic bacterial isolates promoted the overall growth of the plants (Table 1) compared to control. Other pot culture experiment with different pathogens used, it was noticed that all the endophytic bacterial isolates suppressed the disease incidence (Table 2).

Table 1. Effect of endophytic bacterial isolates on growth of ginger

Isolate	No. of tillers*	Height (cm.)*
Endo-1	09.40	71.00
Endo-2	10.40	67.00
Endo-3	10.80	74.00
Endo-4	08.40	70.00
Absolute control	03.80	65.00
CD at 5%	03.512	15.636

* Average of five plants

The increased number of tillering was noticed where the endophytic bacterial isolates were applied. Maximum number of tillering was noticed where endophyt 3 and 2 were applied (10.8 & 10.4 respectively) compared to control (3.8) which is statistically significant (Table 1). Statistically no difference in height was noticed in any treatment, but increase in height was noticed wherever the endophytes were applied compared to control. The data supported the findings of many workers, who reported the growth promotive activities of PGPR. The enhancement of growth in potato by PGPR proved, when potato seed pieces were dipped into PGPR suspension (10^9 cfu) immediately before planting in field soils, significantly increased in plant growth occurred in 2 weeks after emergence (Kloepper

Table 2. Effect of endophytic bacterial isolates on ginger pathogens

Treatment	Rhizome rot (%)*	Root rot (%)*	Rhizome weight (g)*	Root weight (g)*
Endophyte-1+*Pythium* sp.	25.0	50.0	105.0	020.0
Endophyte-1+*Fusarium oxysporum*	02.5	05.0	118.0	055.0
Endophyte-1+*Pratylenchus coffeae*	00.0	00.0	220.0	025.0
Endophyte-2+*Pythium* sp.	00.0	00.0	305.0	150.0
Endophyte-2+*Fusarium oxysporum*	00.0	00.0	228.0	100.0
Endophyte-2+*Pratylenchus coffeae*	00.0	00.0	200.0	100.0
Endophyte-3+*Pythium* sp.	20.0	10.0	155.0	045.0
Endophyte-3+*Fusarium oxysporum*	10.0	80.0	135.0	040.0
Endophyte-3+*Pratylenchus coffeae*	10.0	10.0	165.0	040.0
Endophyte-4+*Pythium* sp.	00.0	00.0	275.0	150.0
Endophyte-4+*Fusarium oxysporum*	00.0	00.0	235.0	100.0
Endophyte-4+*Pratylenchus coffeae*	00.0	00.0	232.0	112.0
Pythium sp	55.0	55.0	112.0	028.0
Fusarium oxysporum	25.8	50.0	115.0	025.0
Pratylenchus coffeae	15.0	21.0	136.0	026.0
CD at 5%	03.543	07.080	028.524	021.295

* Average of five plants.

et al. 1980). Endophytic bacterial isolates have been reported in association with the growth promotion of several crops, including tomato, lettuce (Bashan *et al.* 1989, Nowak *et al.* 1995, Van Peer & Schippers 1989) potato (Frommel *et al.* 1991, Sturz 1995, Van Peer & Schippers 1989) corn (Hinton & Bacon 1995, Lalande *et al.* 1989) cucumber (Van Peer & Schippers 1989, Kloepper *et al.* 1992, Nowak *et al.* 1995) rice (Hurek *et al.* 1994) and cotton (Bashan *et al.* 1989).

No rhizome rot infection was noticed where endophyte 2 and 4 were applied, whereas in control, high rhizome rot and root rot was noticed, *Pythium* (55.0 & 55.0% respectively), *Fusarium* (25.8 and 50% respectively), *Pratylenchus* (15 & 21% respectively). Maximum yield of rhizome was noticed where endophyte-2 (305 g) and 4 (275 g) were applied. Recently, many workers reported the efficacy of PGPR on disease suppression. *Psudomonas syringae* pv. *lachrymans* and *Erwinia tracheiphila* infections in cucumber could reduce by the application of mixed PGPR (Raupach & Kloepper 1998) and reduction in cucumber mosaic virus infection was noticed where PGPR was applied (Raupach *et al.* 1996).

Chanway (1996) reported that some endophytic bacterial strains stimulate host plant growth by acting as biocontrol agents, either through direct antagonism of microbial pathogens or by inducing systemic resistance to disease causing organisms.

From these two experiments, it can be concluded that the endophytic bacterial isolates are able to suppress the disease incidence and enhance over all growth of the plants. It is very important to note that, wherever the endophytic bacterial isolates were used, the growth and regeneration of root system is high and this might help the plants from infection.

References

Bashan Y, Ream Y, Levanony H & Sade A 1989. Non specific responses in plant growth, yield and root colonization of noncereal crop plants to inoculation with *Azospirillum brasilense*. Can. J. Bot. 67 : 1317-1324.

Chanway C P C 1996. Endophytes, they are not just fungi! Can. J. Bot. 74 : 321-322.

Chen C C, Bauske E M, Musson G, Rodriguez Kabana R & Kloepper J W 1995. Biological control of Fusarium wilt on cotton by use of endophytic bacteria. Biol. Control 5 : 83-91.

Frommel M I, Nowak J & Lazarovits G 1991. Growth enhancement and developmental modifications of *in vitro* grown potato (*Solanum tuberosum* ssp. *tuberosum*) as affected by a non-fluorescent *Pseudomonas* sp. Plant Physiol. 96 : 928-936.

Hallmann J, Quadt-Hallmann, Mahaffee W F & Kloepper J W 1997. Bacterial endophytes in agricultural crops. Can. J. Microbiol. 43 : 895-914.

Hinton D M & Bacon C W 1995. *Enterobacter cloacae* is an endophytic symbiont of corn. Mycopathol. 120 : 117-125.

Hurek T, Reinhold-Hurek B, Van Montagu M & Kellenberger E 1994. Root colonization and systemic spreading of *Azocarcus* sp. Strain BH 72 in grasses. J. Bacteriol. 176 : 1913-1923.

Kado C I 1992. Plant pathogenic bacterial. In The Prokaryotes. Edited by A Balows, HG Trupers, M Dworkin, W Harder & KH Schleifer. Springer - Verlag, New York. pp. 660-662.

Kloepper J W, Wei G & Tuzun S 1992. Rhizosphere population dynamics and internal colonization of cucumber by plant growth promoting rhizobacteria which induce systemic resistance to *Colletotrichum arbiculare*. In Biological control of plant diseases. Edited by ES Tjamos, Plenum Press, New York. pp. 185-191.

Kloepper J W, John Leong, Martin Teintze & Milton N Schroth 1980. Enhanced plant growth by siderophores produced by growth - promoting rhizobacteria. Nature. 286 : 885-886.

Lalande R, Bissonnette N, Coutlee D & Antoun H 1989. Identification of rhizobacteria from maize and determination of their plant growth promoting potential. Plant Soil 115 : 7-11.

Nowak J, Asiedu S K, Lazarovits G, Pillay V, Stewart A, Smith C & Liu Z 1995. Enhancement of *in vitro* growth and transplant stress tolerance of potato and vegetable plantlets co-cultured with a plant growth promoting pseudomonad bacterium. In Ecophysiology and Photosynthetic *in* *vitro* cultures. Edited by F Carre & P Chagyardieff. Commissariat al energies atomique, France. pp. 173-179.

Pleban S, Ingel F & Chet I 1995. Control of *Rhizoctonia solani* and *Sclerotium rolfsii* in the green house using endophytic *Bacillus* spp. Eur. J. Plant Path. 101 : 665-672.

Raupach G S & Kloepper J W 1998. Mixtures of plant growth promoting rhizobacteria enhance biological control of multiple cucumber pathogens. Phytopath. 88: 1158-1164.

Raupach G S, Liu L, Murphy J F, Tuzun S & Kloepper J W 1996. Induced systemic resistance in cucumber and tomato against cucumber mosaic cucumovirus using plant growth promoting rhizobacteria (PGPR). Plant Dis. 80 : 891-894.

Sturz A V 1995. The role of endophytic bacteria during seed piece decay and potato tuberization. Plant Soil. 175 : 257-263.

Van Peer R & Schippers B 1989. Plant growth responses to bacterization with selected *Pseudomonas* spp. Strains and ehizosphere microbial development in hydroponic cultures. Can. J. Microbiol. 35 : 456-463.

Antimicrobial activity of essential oils from aromatic plants

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Abstract

The essential oils of *Artemisia annua, Mentha arvensis, M. spicata, Ocimum sanctum* and *Cymbopogon martinii* are evaluated for their toxic behaviour by calculating growth inhibition of germinating wheat seeds. At lower concentration (250 ppm) the toxicity was recorded upto 82.67% in *O.sanctum* oil followed by *M.arvensis* (80%) and *C. martinii* (76.34%). However, at higher concentration (1000 ppm) all the oils expressed maximum (100%) toxicity.

Interestingly some of the oils also showed antigrowth characters against certain plant pathogenic fungi. *A. annua* showed 54.25% growth inhibition of *Fusarium fusiformis* at 1000 ppm concentration whereas *O. sanctum* caused as low as 11.25%. The *Alternaria alternata* inciting blight diseases expressed comparatively less sensitivity. *A. annua* oil inhibited 33.11% growth at 1000 ppm concentration which was followed by *M. spicata* and *C. martinii.* These are also known to contain antibacterial activity. The concentration of essential oil causing 50% growth inhibition (IC^{50}). Simply to express, the higher the values represents the lower the activities. *Bacillus subtilis* determined 13.88 x 10^2% IC^{50} value of *M. arvensis* whereas for *B. cereus* 7.57 x 10^2% IC^{50} value of *O. sanctum* recorded.

It is evident that the biological activity of essential oil could be successfully explored for protecting storage contaminants/infestation of microbe's at least to valuable seeds during storage. Further, it may protect the crops from plant pathogens up to some extent. Hence, essential oils, if applied appropriately could be effective prophylactic agents.

Key words: Antimicrobial activity, essential oils.

Introduction

The essential oils have biochemically highly disease composition and increasingly finding importance as a major source of fragrances, flavours and therapeuntics. The available literature contain wide range of primary/ secondary plant metabolites which are finding their utility in the fields like clinical toxicology, food and pharmaceuticals industries etc. There is a possibility of finding new growth inhibitory activity to microorganisms.

In view of seed significant and interesting use the unexplored activity we opted to study its effect on plant pathogenic micro organisms causing various plant diseases. The essential oils of some aromatic plants namely *Artemisia annua, Mentha arvensis, M.spicata, Ocimum sanctum* and *Cymbopogon martini:* against some common contaminants comprising bacteria and fungi.

Materials and methods

The essential oils were obtained from *A. annua, M. arvensis, M. spicata, O. sanctum* and *C. martinii* plants. Cultures of *Alternaria alternata, Fusarium fusiformis, Bacillus subtilis* and *B. cereus* were isolated from various sources, identified and maintained in the Division of Microbiology and Plant Pathology, CIMAP, Lucknow.

The bacterial inoculum was raised on nutrient and potato dextrose broths (pH 10) and incubated for 48 hrs. at 25±2°C. The inoculum of fungi was prepared on PDA after 15 days of incubation.

The essential oil, tested at three concentrations using DMSO and distilled water 50, 75 and 100% solutions, were sterilized through 22 µm membranes filters. Their efficacy for fungi and bacteria were separately determined.

Bacterial inoculum (2ml) was added to 250 ml cool and warm PDA and plated. Sterilized filter paper discs loaded with essential oils of different concentrations were separately placed in petriplates and then incubated for 24 hrs.

500 ml of sterilized and warm PDA in conical flasks added with 10 ml essential oil poured in petriplates. The same procedure was repeated with every concentration of essential oils. Five mm discs of 15 days old culture were utilized as inoculum. Each plate was inoculated with single disc of inoculum. Inoculated plates were incubated for 20 days.

Result and discussion

The growth inhibitory effect of some essential oils were determined on some micro organisms and the results are given in Table 1. Essential oils inhibit the growth of micro organisms to variable extents. Upto 75% concentration of essential oil, it was non inhibiting in all the oils against *B. cereus*. At 100% concentration it inhibits the growth ranging from 2.5 to 2.8%. The *O. sanctum* shows a little higher (3.3%) inhibition. Correspond-

Table 1. Percentage growth inhibition of *B. subtilis* caused by essential oils at various concentrations

Treatment	Inhibition value 2r (cm)		Relative value		IC^{50}
	concentration		concentration		(%)
	75%	100%	75%	100%	
A. annua	NI	1.4	-	2.8	17.25 x 10^2
M. arvensis	NI	1.8	-	3.6	13.88 x 10^2
O. spicata	1.4	1.3	-	2.6	19.23 x 10^2
O. sanctum	NI	1.7	-	3.4	14.70 x 10^2
C. martinii	NI	1.6	-	3.2	15.62 x 10^2
Control	NI	NI	-	-	-

NI = No inhibition
2r = Radius of the radial growth
IC 50 = Concentration of essential oil causing 50% growth inhibition

Table 2. Percentage growth inhibition of *B. cereus* caused by some essential oils at various concentrations

Treatment	Inhibition value 2r (cm)		Relative value		IC^{50}
	concentration		concentration		(%)
	75%	100%	75%	100%	
A. annua	NI	2.6	-	5.2	9.61 x 10^2
M. arvensis	NI	2.8	-	5.6	18.92 x 10^2
O. spicata	1.4	2.5	2.8	5.0	10.00x 10^2
O. sanctum	NI	3.3	-	6.6	7.57 x 10^2
C. martinii	NI	2.6	-	5.2	9.61 x 10^2
Control	NI	NI	-	-	-

NI = No inhibition
2r = Radius of the radial growth
IC 50 = Concentration of essential oil causing 50% growth inhibition

The *A. annua, O. sanctum* and *C. martinii* oils showed 17.25, 14.70 and 15.62 IC50 values, respectively. The IC50 for *B. cereus* was recorded 10.00 x 10^2% for *M. spicata*. However, the activity in *O.sanctum* oil was much higher showing IC50 value 7.57 x 10^2%. It was determined 9.61, 8.92 and 9.61 x 10^2% concentrations of *A. annua, M. arvensis* and *C. martini,* respectively.

The essential oils possessed antifungal activity. The IC50 values of *M. annua* was very high (156.25 ppm) at 48 hrs of incubation which comes down to 29.13 ppm concentration at 120 hrs of incubation. The *A. annua* oil possessed highest antifungal activity because its IC50 value ranged between 4.69 ppm and 10.71 ppm. The activity of rest of the treatment observed in between. The *O. sanctum* oil inhibited the growth of *A. alternata* showed highest activity. Its IC50 value beginning from 22.96 and recorded to 8.5 ppm at 120 hrs of incubation. *M. spicata* oil inhibited the growth upto some extend and hence showed low IC50 values.

Efficacy of various essential oils in the management of root-knot disease in black henbane

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Abstract

Glasshouse experiment was conducted to determine the efficacy of essential oils of various aromatic plants viz. *Cymbopogon martinii*, *C. winterianus*, *Mentha arvensis* and *Ocimum basilicum* on the reproduction potential of root-knot nematode, *Meloidogyne incognita* and on growth of black henbane (*Hyoscyamus niger*). It was found that population of *M.incognita* was considerably reduced by all the oils when tested at higher concentrations though the maximum suppression was observed with the oil of *C. martinii*. As a result, a significant increase in number of leaves, fresh and dry weights of the plants were observed. However, higher doses of *O. basilicum* and *C. winterianus* i.e. 2ml 7kg^{-1} soil were found to be phytotoxic. It is suggested that use of essential oils would serve as a wise option instead of nematicides for environmentally safe management of nematode diseases of arable crops.

Key word : black henbane, essential oil , root-knot nematode, management

Introduction

Black henbane, *Hyoscyamus niger* L., is one of the most important tropane alkaloid bearing plants in India and is cultivated on a large scale for obtaining its alkaloids viz. hyoscyamine, atropine, scolopolamine and hyoscine. These alkaloids are used in the cure of several diseases like epilepsy, mania, chronic dementia, paralysis, asthma etc. The plant is highly prone to root knot nematode, *Meloidogyne incognita* and causes severe damage to the crop. Plants are important source of naturally occurring aromatic compounds including monoterpenols which have been investigated for the control of certain plant diseases (Bauske *et al.* 1993 Vokou *et al.* 1993) and are also reported to inhibit the reproduction of nematode on some economically important plants (Sangwan *et al.* 1990 Abd-Elgawad and Omer 1995, Elliott *et al.* 1986). Due to the hazardous effect of chemical pesticides on environment and contamination of ground water resources, now it has become difficult to get a new chemical nematicide registered. Therefore, there is an urgent need to consider an alternative way to combat this devastating pathogen on agricultural crops. Keeping this in mind, an experiment was designed to manage the population of *Meloidogyne incognita* through essential oils of various aromatic crops viz. *Ocimum basilicum*, *Cymbopogon martinii*, *C. winterianus* and *M. arvensis* on black henbane.

Materials and methods

Seeds of *Hyoscyamus niger* were sown in sterilized soil and 21 days old seedlings were transplanted into earthen pots containing sterilized potting mixture (sand, soil, compost 7:2:1). After three days of planting, oils of various aromatic crops viz. *M. arvensis*, *O. basilicum*, *C. martinii* and *C. winterianus* @ 0.5, 1.0 and 2.0 ml pot^{-1} (containing 8 kg soil) were drenched in to the rhizosphere. After three days of drenching roots, plants were inoculated with 1000 freshly hatched second stage larvae of *Meloidogyne incognita* (Kofoid and White) Chitwood obtained from infested brinjal roots (*Solanum melongena* L. pusa purple long) maintained in glasshouse. There were five replicates of each treatment. After inoculation, pots were arranged in glasshouse in randomised complete block design.

Observations were recorded on development of the disease, growth and yield of plants. After 90 days of inoculation, the experiment was terminated and data on different growth parameters viz. root/shoot fresh and dry weights and the root gall indices were calculated on a scale 0-4, where 0 = no infection or root galling, 1 = slight infection (1-25%), 2 = moderate infection (26-50%), 3 = severe infection (51-75%) and 4 = very severe infection (76-100%). Nematode population from the soil was isolated by Cobb's sieving and decanting technique along with Baermann funnel (Southey 1986) and nematode population in root was estimated by macerating the root tissues in a warring blender (Southey 1986). Data were analysed by analysis of variance as described by Cochran & Cox (1957). Significant differences were tested among the treatments by critical difference (CD) test at the 5% probability level.

Results and discussion

Results (Table 2) indicate that the root knot nematode, *M.incognita* multiplied at a much faster rate (5.6 times) on *H. niger* planted in untreated- inoculated pots (controls). It was found that the nematode population was suppressed significantly in all the plants drenched with essential oils but maximum reduction was recorded at the highest dose (2.0 ml pot^{-1}) of *C. martinii* (RKI=1.00, Rf=1.6) followed by *C. winterianus* (RKI =1.33, Rf =1.7), *M. arvensis* (RKI =1.33, Rf = 2.2) and of *O. basilicum* (RKI = 1.33, Rf = 1.8) (Table 2). The plant growth (dry root/shoot weight) of *H. niger* improved as a result of nematode suppression because of the application of essential oils. The highest increase

Table 1. Effect of different concentrations of essential oils of various aromatic crops on growth parameters of *Hyoscyamus niger* L.

Treatment	Fresh weight (g)*			Dry weight (g)*			No. of leaves/ plant*
	Root	Shoot	Total	Root	Shoot	Total	
Untreated –Unino.	6.8	32.2	39.0	1.5	6.2	7.7	41.3
Untreated-Inoc	4.5	22.8	27.3 (-30.0) **	1.1	3.3	4.4 (-42.8) **	39.0
M. arvensis oil 0.5 ml–Inoc.	7.9	22.9	30.8 (-21.0)	1.8	3.5	5.3 (-31.1)	50.6
M. arvensis oil 1.0 ml–Inoc.	9.4	36.7	46.1 (+81.2)	2.0	6.4	8.4 (+9.0)	63.6
M. arvensis oil 2.0 ml–Inoc.	12.0	52.7	64.7 (+65.8)	3.1	7.3	10.4 (+35.0)	72.6
O. basilicum oil 0.5 ml-Inoc.	11.2	49.8	61.0 (+56.4)	2.7	6.9	9.6 (+24.6)	86.6
O. basilicum oil 1.0 ml-Inoc.	11.2	76.5	87.7 (+124.8)	2.6	8.9	11.4 (+48.0)	123.3
O. basilicum oil 2.0 ml-Inoc.	8.6	49.8	58.4 (+49.7)	2.0	7.0	9.0 (+16.8)	116.0
C. winterianus oil 0.5 ml-Inoc.	11.0	46.5	57.5 (+47.4)	2.7	7.3	10.0 (+29.8)	112.0
C. winterianus oil 1.0 ml-Inoc.	11.9	64.2	76.1 (+95.1)	2.9	8.4	11.3 (+46.7)	94.3
C. winterianus oil 2.0 ml-Inoc.	10.0	56.6	66.6 (+70.7)	2.3	7.5	9.8 (+27.2)	88.0
C. martinii oil 0.5 ml-Inoc.	12.3	43.5	55.8 (+43.0)	3.1	6.5	9.6 (+24.6)	79.7
C. martinii oil 1.0 ml-Inoc.	13.8	66.3	80.1 (+105.3)	3.7	8.8	12.5 (+62.3)	83.6
C. martinii oil 2.0 ml-Inoc.	14.2	77.4	91.6 (+134.8)	3.8	9.1	12.9 (+67.5)	106.3
C.D. (P=0.05)	*0.690*	*1.301*	*1.991*	*0.193*	*0.362*	*0.555*	*12.645*

Inoc. = Inoculated with 1000 *M.incognita* larvae pot^{-1}

* = Each value is an average of five replicates.

** = Percent increase (+) or decrease (-) over untreated - uninoculated control.

in dry weight (Table 1) occurred in *C. martinii* (67.5%) followed by *M. arvensis* (35%), *C. winterianus* (27.2%) and *Ocimum basilicum* (16.8%) when drenched @ 2 ml pot^{-1}. Appreciable enhancement in herb yield was also recorded in case of *O. basilicum* (48%) oil when treated @1 ml pot^{-1}. However the higher doses (2 ml/ pot^{-1}) appears to be toxic to the plant as the enhancement was only to the tune of 16.8%.

H. niger, an important medicinal plant is highly susceptible to *M .incognita* as indicated by nematode multiplication in untreated-inoculated plants (Table 2). It is clear from the above results, that the application of essential oils in the soil effectively reduced the nematode population and showed significant improvement in plant growth. These results are in conformity with the observations of others using different plants and phytochemicals (Soler *et al.* 1993). Inhibition of nematode population in *H. niger* may be due to its toxic effect on root –knot nematode as oils contain nematotoxic compounds (Pandey *et. al.* 2000).

With growing awareness about the harmful effects of chemical pesticides, the essential oils could be exploited as safer alternatives to hazardous pesticidal chemicals in the management of root-knot nematodes.

References

Abd-Elgawad M M & Omer E A 1995. Effect of essential oils of some medicinal plants on

Table 2. Effect of different concentrations of essential oils of various aromatic crops on reproduction potential, root-knot galling of *Meloidogyne incognita* on *Hyscyamus niger* L.

Treatment	Nematode population				Root-knot Index (RKI)*
	Soil*	Root*	Total*	Reproduction factor (Rf=Pf/Pi)	
Untreated –Unino.	-	-	-	-	-
Untreated-Inoc.	1900	3654	5554	5.6	4.00
M. arvensis oil 0.5 ml–Inoc.	1600	2718	4318	4.3	2.33
M. arvensis oil 1.0 ml–Inoc	1400	2053	3453	3.5	1.66
M. arvensis oil 2.0 ml–Inoc.	1200	1020	2220	2.2	1.33
O. basilicum oil 0.5 ml-Inoc.	1680	2460	4140	4.1	2.00
O. basilicum oil 1.0 ml-Inoc.	1040	985	2025	2.0	1.33
O. basilicum oil 2.0 ml-Inoc.	1000	820	1820	1.8	1.33
C. winterianus oil 0.5 ml-Inoc.	1420	2040	3460	3.5	2.33
C. winterianus oil 1.0 ml-Inoc.	1200	1440	2640	2.6	1.66
C. winterianus oil 2.0 ml-Inoc.	800	870	1670	1.7	1.33
C. martinii oil 0.5 ml-Inoc.	1060	1600	2660	2.7	2.00
C. martinii oil 1.0 ml-Inoc.	860	1000	1860	1.9	1.66
C. martinii oil 2.0 ml-Inoc.	700	900	1600	1.6	1.00
C.D. (P=0.05)	151.130	113.063	200.102	-	0.030

*Each value is an average of five replicates.

phytonematodes. Anz. Schadlingskde Pflanzenschutz Umwelttschutz 68 : 82-84.

Bauske E M, Kloeppe J W & Rodriguez-kabana R 1993. Effects of naturally occurring aromatic compounds on parasitic nematodes in cotton. Phytopathology 83: 1400.

Bauske E M, Rodriguez-Kabana R & Kloepper J W 1994. Effects of naturally occurring aromatic compounds on *Pythium* root-rot of cotton. Phytopathology 84 : 1139.

Cochran W G & Cox G M 1957. Experimental Designs. Vol.II. John Wiley and Sons. Inc., New York, U.S.A. pp 11.

Elliott A P, Griesbach J A & Iglierchio D R 1986. Evaluation of neem oil extracts in the development of *Meloidogyne incognita, M. hapla* and *M. javanica*. Journal of Nematology 18 : 606.

Soler A, Rodriguez-Kabana R , Weaver C E, King P S & M C Inroy J A 1993. Monoterpenes of natural origin for control of phytoparasitic nematodes. Phytopathology 83 : 1351.

Vokou D S, Vareltzidou & Katinakis P 1993. Effects of aromatic plants on potato storage: Sprout suppression and antimicrobial activity. Agriculture Ecosystems and Environment 47 : 223-235.

Southey J F 1986. Laboratory methods for work with plant and soil nematodes. Mins. Agric. Fish. Food HMSO, London pp 202.

Coconut water amended coirpith - a conducive medium for mass multiplication of biocontrol agent *Trichoderma* spp.

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Abstract

Exploitation and recycling of naturally available agricultural waste is an important component of sustainable disease management. In the present work we have used the commonly available agricultural waste media such as coirpith and coconut water as growth and carrier medium for multiplication of fungal biocontrol agent *Trichoderma* spp. The raw coirpith was decomposed for two months using *Pleurotus platypus* and urea. In order to study the proliferation and population dynamics of *Trichoderma*, three strains of *Trichoderma* viz., *T.viride*, *T.viride* albino mutant and *T.harzianum* P26 were used. In partly decomposed and sterilized coconut coirpith, the population of *Trichoderma* increased dramatically from 10^4 colony forming units (cfu) to 10^7 cfu per gram of coirpith in 10 days. However, the population decreased in un-sterilized coconut coirpith and got stabilized at 10^4 cfu per gram of coirpith after 50 days of growth. When the coirpith was enriched with coconut water, the multiplication of *Trichoderma* was observed in both sterilized and un-sterilized medium. The increase in *Trichoderma* population was from 10^3 cfu per gram to 10^7 cfu per gram in five days in sterilized coirpith amended with coconut water. Experiments were also performed to know the effect of coir extract (aqueous extract) on multiplication of *Trichoderma*. There was no significant change in the population of *Trichoderma* in extract / liquid coir extract throughout the incubation period. Exponential multiplication in coirpith medium could be due to versatile nature of *Trichoderma* for carbon nutrient and also due to major and minor nutrients available in coir compost. From the results it is clear that the coconut water + coirpith medium could be exploited for mass multiplication of *Trichoderma* for management of soil borne diseases of plantation crops.

Key words : coconut water, coirpith, mutants, *Trichoderma*

Introduction

Major diseases of spice crops such as black pepper, cardamom and ginger are caused by soil-borne fungal and bacterial plant pathogens belonging to the genera *Pythium*, *Phytophthora*, *Ralstonia* and *Rhizoctonia* (Sarma *et al* 1994). The importance of biological and ecological methods of disease management in sustainable agriculture need not be overemphasized. Progress in biological disease control using introduced microorganisms in the past years prompted many researchers, administrators and farmers to incorporate such strategies in the integrated disease management. The success of biological control of soil-borne plant pathogens depends mainly on the ability of the introduced microorganism to competitively colonize the rhizosphere region of host plant which is influenced by the availability of nutrient from the substrate or carrier medium through that the BCA is applied. (Papavizas & Lewis 1981). Several techniques have been employed for the multiplication and delivery of biocontrol agents. For example, biocontrol agents have been applied in liquid (Marois *et al.* 1982), in organic matters (Kumar & Marimuthu 1997), as seed or seed piece treatment (Cotes *et al.* 1996) and in vermiculite or in clays such as pyrax (Fravel *et al.* 1983).

Several agricultural waste have been successfully used for growth of biocontrol organisms like *Trichoderma* sp, *Pseudomonas* etc. (Kausalya & Jeyarajan 1990, Anandaraj & Sarma 1997, Suseela Bhai *et al.* 1994, Kumar & Marimuthu 1997). The byproducts of coir industry such as coir dust or coirpith and mature coconut water which are being thrown out as waste have been successfully used as a multiplication medium. The uses of composted coconut coirpith as a organic manure is well documented (Nagarajan *et al.* 1985).

In the present work the effect of mature coconut water amended decomposed coconut coirpith on growth and multiplication of *Trichoderma* sp. has been studied. Experiments were performed in sterile and nonsterile coirpith medium with three strains of *Trichoderma* for precise quantification of population.

Materials and methods

Preparation of decomposed coconut coirpith (DCCP)

The DCCP was prepared by inoculating the raw coconut coirpith with *Pleurotus platypus* (Theradimani and Marimuthu 1992). Two months old compost was used for the study.

Preparation of coconut water amended coirpith

Mature coconut water collected from Calicut was mixed with coirpith at a ratio of 4:1 (Moisture content after adding coconut water was 20%). The mixture (50g) was autoclaved for 1 hour at 121°C.

Multiplication and sporulation of Trichoderma *in coconut water, in shake and still cultures*

50ml of mature coconut water was inoculated with 500 µl of conidial suspension of *T.harzianum* or *T.virens* in 100ml flasks. The flasks were incubated at 24°C or 30°C in shaker (150 rpm) or in a BOD incubator. Population of *Trichoderma* was enumerated after 2 and 5 days of incubation using *Trichoderma* selective medium (Elad & Chet 1982).

Preparation of Trichoderma *inoculum*

Three strains of *Trichoderma* viz., *T.viride* NRLM, *T.viride* NRL, and *T.harzianum* P-26 were used to monitor the population proliferation in composted coconut coirpith. The descriptions of the strains are mentioned in (Table 1).

Trichoderma strains were grown on *Trichoderma* selective medium (Elad and Chet 1982) and discrete colonies of *Trichoderma* were used for preparation of conidial suspension in sterile distilled water. One ml of conidial suspension was inoculated in 50g of coirpith and mixed thoroughly. After inoculation the coirpith was incubated at 30°C for fifty days.

Enumeration of Trichoderma *from coirpith*

Population of *Trichoderma* in sterile and nonsterile coirpith was estimated immediately after inoculation and also at every 10 days interval up to 50 days. 5g of coirpith was suspended in 45 ml of sterile distilled water and was shaken well in a orbital shaker for 30 min. at 200rpm. Ten fold dilution was prepared to obtain 10^{-4} to 10^{-5} dilutions of coirpith suspension. One ml of aliquot from diluted suspension (10^{-4} or 10^{-5}) was plated on selective medium and the petri plates were incubated for 7 days at 30°C. Enumeration was also performed

Table 1. Characters of *Trichoderma* spp. used for enumeration studies.

Strain	Species	Phenotype	Host	Antagonistic to
NRLM	*T.viride*	White colonies	Mung bean Albino mutant obtained using uv irradiation.	*Macrophomina phaseolina*
NRL	*T.viride*	Dark green colonies	Mung bean	*M. phaseolina*
P-26	*T.harzianum*	Whitish- light green colonies	Black pepper	*Phytophthora capsici.*
P-12	*T.virens*	Whitish- dark green colonies	Black pepper	*Phytophthora capsici*

in unamended coirpith and also in unsterile coirpith.

Effect of coir extract on multiplication of Trichoderma

In order to study the effect of aqueous extract of coirpith on growth and survival of *Trichoderma*, 1ml of conidial suspension was inoculated in 20ml coir extract and the flasks were incubated in orbital shaker at 150rpm. The coir extract was prepared by homogenizing 200g of DCCP in 200ml distilled water in polytron homogenizer (Kinematica, Switzerland) at 25,000 rpm for 30min. The resultant extract was used for studying the survival of *Trichoderma.*

One ml of extract, immediately after inoculation and after every 10 days interval up to 40 days, was ten fold diluted to obtain 10^{-3} to 10^{-4} dilution and 1ml was plated on TSM. Number of colony forming units was calculated after 7 days.

Nutrient analysis of decomposed coconut coirpith

The nutrient composition of the coir compost was determined by total digestion of the material by diacid mixture & micronutrients by standard procedures (Jackson 1967, Hesse 1971). Organic carbon content was measured by wet oxidation method (Jackson 1967).

Results and discussion

Many substrates have been evaluated and found suitable for mass multiplication of *Trichoderma* (Prakash *et al.* 1999, Sawant & Sawant 1990). The most ideal substrate is one which support maximum growth and sporulation in short time; which is cheaply available and is environment friendly. Since coconut based agricultural waste is available plenty in Southern states viz., Kerala, Karnataka, Tamilnadu and Andhra Pradesh, studies were conducted to know the suitability of two products from coconut viz., coirpith and coconut water for mass multiplication of biocontrol agent *Trichoderma*. In mature coconut water both *T.harzianum* and *T.virens* multiplied exponentially. Between 2 and 5 days after inoculation, *T.harzianum* sporulated to the order of 10^7 to 10^9 cfu per ml of liquid medium. The increase in number of propagules (cfu) is 3.8 to 21.1 fold for P 26. Similarly the multiplication of *T.virens* P 12 is in the order of 10^7 to 10^9 under all incubation conditions. Increase in population is 3.8 to 417.1 fold for P 12. (Table 2).

Table 2. Multiplication of *Trichoderma* sp. in autoclaved coconut water

Incubation	*T.harzianum* P 26			*T.virens* P 12		
	2 DAI*	5 DAI	Ratio**	2DAI	5 DAI	Ratio
Still culture 24°C	97.3×10^6 $(18.39)^F$	2053×10^6 $(21.45)^A$	21.1	0.917×10^6 $(13.66)^K$	383×10^6 $(19.73)^{DE}$	417.7
Shake culture 24°C	54.4×10^6 $(17.81)^{FG}$	205×10^6 $(19.147)^E$	3.8	15.25×10^6 $(16.13)^{HI}$	467×10^6 $(19.96)^{CD}$	30.6
Still culture 30°C	100.0×10^6 $(18.42)^F$	787×10^6 $(20.48)^{BC}$	7.9	80.75×10^6 $(18.20)^F$	303×10^6 $(19.52)^{DE}$	3.8
Shake culture30°C	8.83×10^6 $(15.99)^{HI}$	50×10^6 $(17.39)^G$	5.7	15.67×10^6 $(16.55)^H$	145.7×10^6 $(21.10)^{AB}$	9.3
Shake culture 35°C	2.5×10^6 $(14.60)^I$	35.0×10^6 $(17.34)^G$	14.0	5.33×10^6 $(15.46)^I$	76.7×10^6 $(18.14)^F$	14.4

* Days after inoculation

**Increase in propagule = Population at 5 DAI / Population at 2 DAI

Figures in the paranthesis are natural log transformed

Data with same letter designations are not significantly different according to Duncan's Multiple Range Test at p=0.05

Accurate quantification of fungal population in complex organic matter is possible with the help of genetically marked strains. In the present work a mutant strain of *T. viride* that is distinct from wild type strain was used to study the population proliferation. This strain enabled us to differentiate it from locally available native strains. Use of genetically marked strains have been suggested for precise tracking of introduced microorganisms in soil and other agricultural environment.

When *Trichoderma* was inoculated in sterilized coirpith the population of NRLM has increased from 15.6 x 10^4 to 9.7 x 10^6 cfu per gram of coirpith in 10 days (Fig. 1a). Similarly the population of *T.viride* wild type and *T.harzianum* P 26 has increased from 10^4 to 10^6 cfu per gram (Fig. 1b & 1c). After 50 days of incubation the population was stabilized at 10^4 or 10^6 cfu which indicates the shelf life of *Trichoderma* in sterile coirpith. Availability of large quantity of macro and micronutrients from coirpith (Nagarajan *et al.* 1985) and absence of competing microorganisms might have contributed for the successful colonization of *Trichoderma* in sterile coirpith. When *Trichoderma* was inoculated in unsterile coirpith the population declined from 10^5 cfu to 10^4 cfu per gram of coirpith. Decline in the population of *Trichoderma* in unsterile coirpith could be due to the presence of large variety of fast growing bacteria and other fungi (Table 3). The difference in the population of *Trichoderma* in sterilized and unsterilized media clearly indicate the poor competitive nature of *Trichoderma*. This finding supports the view of Adams (1990) who observed poor competence of *Trichoderma* in rhizosphere of plants. However, the population was stabilized at (3.5 to 6.9 x 10^3) 10^3cfu after 50 days of inocubation.

Population of *Trichoderma* increased exponentially when the fungus was inoculated in coconut water amended coirpith. The data on the population of *Trichoderma* in coconut water amended coirpith is presented (Fig. 2a to 2c). The colony forming units (cfu) of *Trichoderma* increased from 10^3 to 10^5 or 10^7 in 5 days of incubation in sterilized medium. It is interesting to note that even in unsterilized medium the population increased to 10^5 cfu per gram of coirpith. After 40 days the population of *Trichoderma* was stabilized at 10^4 cfu per gram of unsterilized coirpith and 10^6 cfu per gram of sterilized coirpith. Multiplication of *Trichoderma* spp. in coconut water amended coirpith could be due to nutritive liquid endosperm. In another study,

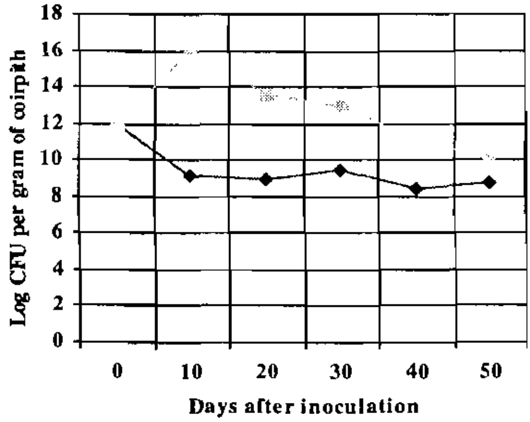

Fig 1a. Population dynamics of *T. viride* NRLM in decomposed coconut coir pith

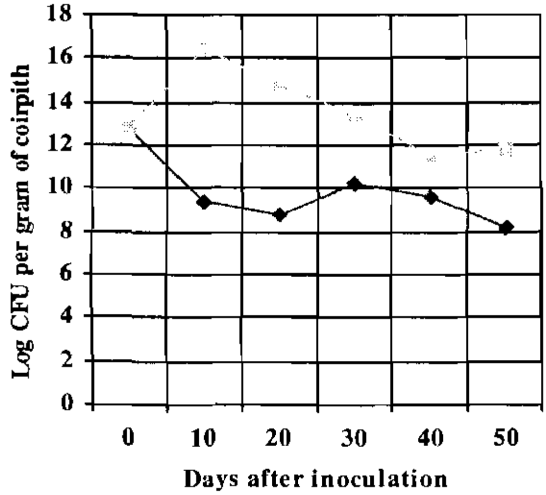

Fig 1b. Population dynamics of *T. viride* NRL in decomposed coconut coir pith

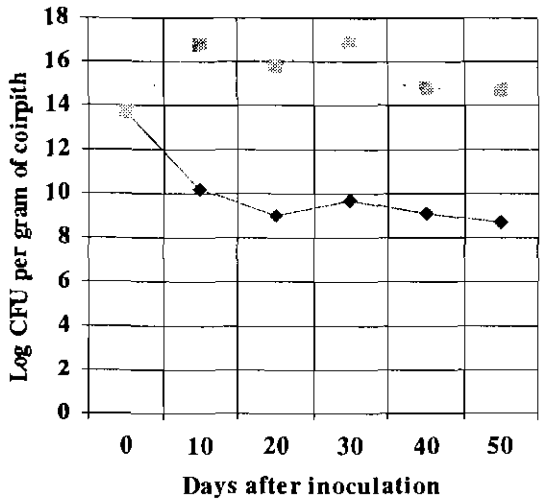

Fig 1c. Population dynamics of *T. harzianum* P 26 in decomposed coconut coir pith

Unsterile coirpith Sterile coirpith

Table 3. Population of indigenous fungi isolated from coconut coirpith (10 DAI)

Coir pith	Population of fungi (cfu x 10^4)
DCCP uninoculated	2.502 (10.13)[c]
DCCP + *T.viride* (Albino)	5.94 (10.98)[a]
DCCP + *T.viride* (wild type)_	3.49 (10.44)[b]
DCCP _+*T.harzianum*	4.01 (10.59)[b]
Autoclaved DCCP + *T.viride*	0 (0)[d]
Autoclaved DCCP + *T.viride*	0 (0)[d]
Autoclaved DCCP + *T.harzianum*	0 (0)[d]

* Days after inoculation

Figures in the paranthesis are natural log transformed
Data with same letter designations are not significantly different according to Duncan's Multiple Range Test at p=0.05

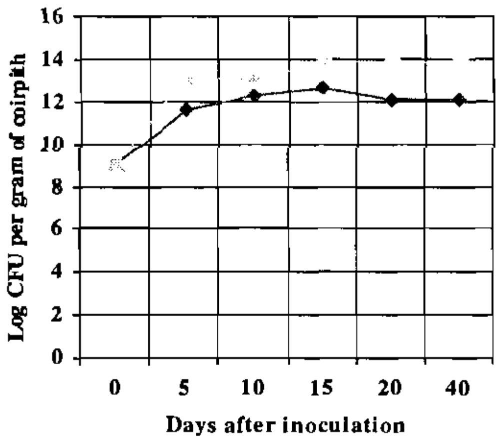

Fig. 2a Population dynamics of *T. viride NRLM* in coconut water amended coirpith

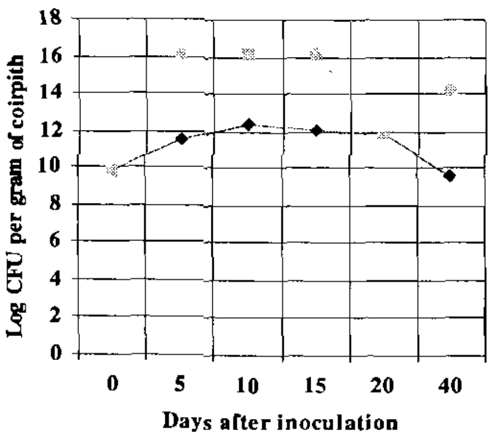

Fig. 2b Population dynamics of *T. viride NRL* in coconut water amended coirpith

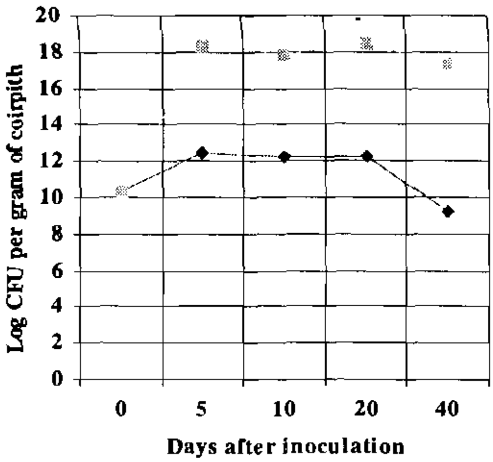

Fig. 2c Population dynamics of *T. harzianum P 26* in coconut water amended coirpith

Unsterile coirpith **Sterile coirpith**

population of 156 x 10^4 and 165 x 10^4 cfu per ml of coconut water was obtained for *T.harzianum* and *G.virens* respectively (Anandaraj & Sarma 1997). The nutrient rich coconut water might have contributed for exponential multiplication of *Trichoderma* in coconut water amended coirpith.

Experiments were conducted to study the effect of aqueous extract of coirpith on population of *Trichoderma.* There was no multiplication of *Trichoderma* in coir extract. The initial population of 10^5 cfu per ml of extract has declined to 10^4 cfu per ml of extract after 40 days of incubation (Fig. 3). Very high concentration of phenols in the aqueous extract could be one of the possible reasons for failure of *Trichoderma* to grow in the extract.

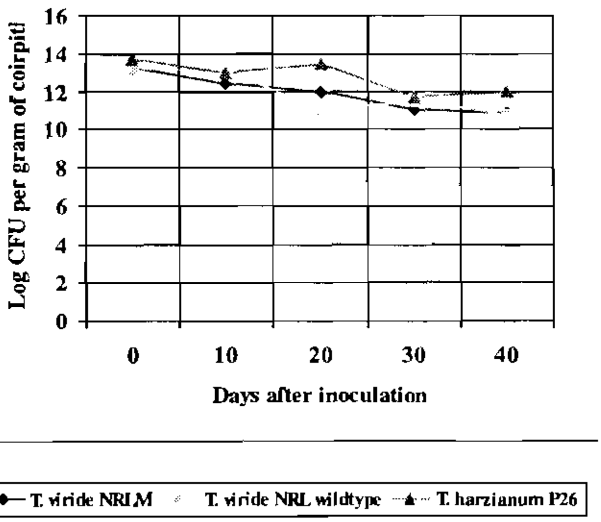

Fig. 3. Population dynamics of *Trichoderma* spp. in aqueous extract of coir pith.

In sterilized coirpith multiplication of *Trichoderma* indicate its versatility for carbon nutrition. The data on nutrient content of DCCP (Table 2) reveals its value as a organic manure and also as a mass multiplication medium for *Trichoderma.* On incubation the C/N ratio of the raw coir compost (8.96) has been brought down to the lowest of 7.72. The rate of reduction was high in sterilized decomposed coirpith as compared to unsterilized which could be due to exponential multiplication of *Trichoderma* in sterile coirpith. P 26 strain was highly efficient in both unsterilized and sterilized medium in utilizing the carbon source. The *Trichoderma* inoculated coir composts recorded increased 'P' availability after 50 days of incubation with highest availability in P 26 inoculated treatment (250 ppm). The 'P' solublisation capacity of P 26 might be the reason. Slight reduction in the contents of K,Ca, Mg and Zn in *Trichoderma* inoculated coir compost as compared to uninoculated control corroborate with the high

Table 4. Nutrient content of DCCP inoculated with *Trichoderma* spp.

Treatment	C/N	P (ppm)	K %	Ca %	Mg %	Fe	Mn ppm	Zn	Cu
DCCP*	8.96	180	0.48	0.11	0.13	320	10.5	10	3.2
DCCP +*T.viride* (albino)	8.11	230	0.42	0.06	0.10	288	11.0	8	5.0
DCCP +*T.viride* (Wild type)	9.76	180	0.44	0.08	0.12	499	11.4	9	4.2
DCCP-P 26 + *T.harzianum* (P-26)	7.79	240	0.45	0.09	0.12	479	12.1	7	4.5
Autoclaved DCCP + *T.viride*	7.76	190	0.44	0.085	0.12	470	11.2	9	4.5
Autoclaved DCCP+ *T.viride*	10.7	200	0.48	0.11	0.11	439	10.7	6	4.4
Autoclaved DCCP + *T.viride*	7.72	250	0.35	0.07	0.10	619	11.3	8	4.0

* Decomposed coconut coirpith.

rate of proliferation of *Trichoderma* population in those treatments (Table 4). Fe & Cu content in the coir compost due to higher proliferation of *Trichoderma,* there by release. From the results it is clear that the coconut water amended coirpith can be exploited for mass multiplication of *Trichoderma* that can be used for disease management in plantation and spice crops in India.

References

Adams P B 1990. The potential of mycoparasites for biological control of plant diseases. Ann. Rev. Phytopathol. 28 : 59-72.

Anandaraj M & Sarma Y R 1997. Mature coconut water for mass culture of biocontrol agents. J. Plantn. Crops. 25 : 112-114.

Cotes A M, Lepoivre P & Semal J 1996 Correlation between hydrolytic enzyme activities measured in bean seedlings after *Trichoderma koningii* treatment combined with pregermination and the protective effect against *Pythium splendens.* Eur.J. Plant Pathol. 102 : 497-506.

Elad Y & Chet I 1982. Improved selective media for isolation of *Trichoderma* spp. or *Fusarium* spp. Phytoparasitica 11 : 55-58

Fravel D R, Papavizas G C & Marois J J 1983 Survival of ascospores and conidia of *Talaromyces flavus* in field soil and Pyrax (Abstr.) Phytopathology 73 : 821.

Hesse P R 1971. Soil Chemical Analysis. John Murray (Pvt.) Ltd. London. 520P.

Jackson M L 1967. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 498 P.

Kousalya G & Jeyarajan R 1990. Mass multiplication of *Trichoderma* spp. J. Biol. Control 4 : 408-414.

Kumar A & Marimuthu T 1997. Decomposed Coconut Coirpith – Conducive Medium for Colonization of *Trichoderma viride.* Acta Phytopathologica et Entomologica Hungarica 32(1-2) : 51-58.

Marois J J, Johnston S A, Dunn M T & Papapvizas G C 1982. Biological control of Verticillium wilt of eggplant in the field. Plant Dis. 66 : 1166-1168.

Nagarajan R, Manickam T S & Kothandaraman G V 1985. Manurial value of coirpith. Madras Agricultural Journal 72 : 533-535.

Papavizas G C & Lewis J A 1981 Introduction of new biotypes of *Trichoderma harzianum* resistant to benomyl and other fungicides. Phytopathology 74, 1171-1175

Prakash M G, Vinay Gopal K Anadaraj M & Sarma Y R 1999. Evaluation of substrates for mass multiplication of fungal biocontrol agents *Trichoderma harzianum* and *T. virens* Journal of Spices and Aromatic crops 8 (2) : 207-210

Sarma Y R, Anandaraj M & Venugopal M N 1994. Diseases of spices crops In: K L Chadha & P Rethinam (Eds.) Advances in Horticulture Vol 10, Plantation and spice Crops Part 2 (pp. 1015-1057). Malhotra Publishing House, New Delhi.

Sawant & Swant S D 1990. Coffee fruit skin and cherry husk as substrates for mass multiplication of *Trichoderma harzianum* an antagonist of citrus *Phytophthora.* Indian Phytopathology 4 : 336 (Abst.).

Suseela Bhai R, Joseph Thomas & Naidu R 1994. Evaluation of carrier media for field application of *Trichoderma* spp. in cardamom growing soils. J. Plantn. Crops 22 : 50-52.

Theradimani M & Marimuthu T 1992. Utilization of *Pleurotus* spp. for decomposing coconut coirpith. Mushroom Res. 1 : 49-51.

Status of fungal foliar diseases of black pepper in Kerala

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Abstract

Black pepper in India is affected by diseases caused by fungi, bacteria, mycoplasma, algae nematodes and phanerogamic parasites. Foot rot and slow wilt were the most important diseases of pepper because of their severity. In a survey conducted in the southern districts of Kerala, leaf spots caused by various fungi were observed. Among the fungal pathogens isolated from the pepper plantations of the four southern districts of Kerala viz., Thiruvananthapuram, Quilon, Alleppey and Pathanamthitta, the pathogens *Phytopthora capsici* and *Colletrotrichum gloeosporioides/C.capsici* ranked first. Severe infection of pepper berries were also observed due to *Colletrotrichum* spp. A marked increase in the incidence of leaf blight/spot/berry infection due to *Colletrotrichum* was seen in the pepper plantations surveyed. The next ranked important pathogens were *Penicillium* sp and *Fusarium* sp. Some of the fungal pathogens encountered in this study were not observed earlier. The study throws light on the emerging deseases problems of this important spice crop which warrants for a co-ordinated approach for plant disease management.

Keywords : *Colletortrichum gloeosporioides, C. capsici, Fusarium* sp, *Penicillium* sp , *Phytophthora capsici*

Introduction

Black pepper (*Piper nigrum.* L) is the largest foreign exchange earner among the spice crops of India. Pepper is mainly cultivated as an inter/mixed crop and to a limted extent as a monocrop. Though India ranked top in black pepper production in the world, its position dwindled in recent years and the per hactare production is the lowest. Ravages due to diseases and pests, high cost of production and consequent neglect of the crop by the farming community are some of the constraints in black pepper production.

More than seventeen fungi have been reported affecting pepper in India (Sarma *et al.* 1991). Of these a few have been indentified as causative organisms of major diseases. The most important among the diseases of pepper in India are Phytophthora foot rot (quick wilt) and stow decline (slow wilt). Detailed studies were made an these two diseases.

Materials and methods

A survey was conducted in the pepper plantations of southern and central parts of Kerala during 1999 - 2000 to study the various diseases of pepper. Diseased plant samples viz. leaves/spickes were collected at fortringhtly intervels from the pepper plantations of the above areas. Ten random samples were collected from three plantations from each location. The locations from which the collections were made and the various pathogens assssociaated with the samples presented in Table 1.

Isolation of the pathogens was done following the standard procedures. Isolations were made on Potato Dextrose Agar medium. After three days of incubation at room temperature, the pathogens were subcultured in PDA slants for further studies.

Results and discussion

A total of 120 infected leaf and berry samples were collected. The results are given in Table 1. The isolation studies revealed that 80 per cent of the total samples were associated with *Colletotrichum gloeosporioides,* the pathogen causing the anthracnose of pepper. In certain cases association of *C. capsici* (in 4 samples) were also observed. Mixed infection of *C. gloeosporioides* and *C. capsici* were also found in some of the plantations. The pathogen infeted almost all the varieties observed.

The foliar infection *Colletotrichum* spp. varied from

Table 1. Prevalence of foliar pathogens on black pepper in Kerala

District	Pathogen associated
Thiruvananthapuram	*Colletrotrichum gloeosporioides, C. capsici, Phytophthora capsici, Pencillium, Pestalotia* sp.
Quilon	*C. gloeosporioides, C. capsici Pestalotia* sp. *Fusarium* sp. *Curvualria* sp.
Alleppey	*Phytophtora capsici, C. gloeosporioides Cylindrocladium* sp.
Ernakulam	*C. gloeosporioides, Fusarium* sp. *Curvualaria* sp.
Pathanamthitta	*C. gloeosporioides, C. capsici Cyliudrocladium* sp., *Pestalotia* sp.

minute brown or black specks to large blighted areas, almost resulting in severe defoliation. Pin head like acervuli of the fungus were also seen in the blighted areas. In certain cases papery white centers were also observed in the blighted areas, which breaks resulting in shot - hole symptoms.

The pathogen also affects the spikes and berries. If the infection is in the early stages of spike fornation, die-back symptoms were observed. On the berries, sunken areas were observed which later resulted in hollow shrivelled berries. Spike shedding and berry shedding were the other symptoms observed. The damage on the berries resulted in 100 per cent. yield loss.

In nurseries the infection is severe on the foliage and young stems. Early infections resulted in defoliation, blackening of the stem which later dry up. Occurrence of *C. gloeosporioides* on black pepper was reported earlier by serveral workers. (Menon 1974, Nambiar *et al.* 1978)

The other furgal pathogens isolated during the survey include *Phytophthora capsici.* (30%), *Penicillium* sp (20%), *Pestalotia* sp. (20%) . *Cylimdrocladium* sp (10%) and *Fusarium* sp (20%). Thus it is seen that anthracnose of pepper is more common among the pathogens isolated during the investigations.

Acknowledgement

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References

Menon K K 1974. Survey of Pollu (hollow berry diseases) and root diseases of pepper. Ind. J. Agric. Sci. 19 : 89 - 136.

Nambiar P K V, Pillay V S, Sasi Kumar S & Chandy K C 1978. Pepper reserach at Panniyoor - a Resume. J. Plantn. Crops 6 : 4 -11.

Sarma Y R, Ramachandran N & Anandraraj M 1991. Black Pepper diseases in India. Proc. on Diseases of black pepper 55 - 101.

Evaluation of biopesticides for the management of shoot borer (*Conogethes punctiferalis* Guen.) on ginger (*Zingiber officinale* Rosc.)

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Abstract

Two commercial products of *Bacillus thuringiensis* namely, Bioasp (0.25%, 0.50% and 0.75%) and Dipel (0.1%, 0.2% and 0.3%) were evaluated along with malathion (0.1%) in the field at Peruvannamuzhi (Kerala) for the management of shoot borer (*Conogethes punctiferalis*), a major insect pest of ginger (*Zingiber officinale*). The trials indicated that all the treatments were effective in reducing the damage caused by the shoot borer on shoots of ginger, when compared to control. Spraying Dipel 0.3% (five sprays at 21-day intervals during July-October) was the most effective treatment resulting in significantly lower percentage of infested shoots on the crop.

Key words: *Bacillus thuringiensis*, biopesticide, *Conogethes punctiferalis*, ginger, management, shoot borer, *Zingiber officinale.*

Introduction

The shoot borer (*Conogethes punctiferalis* Guen.) (Pyralidae : Lepidoptera) is the most widespread and serious insect pest of ginger (*Zingiber officinale* Rosc.) in India. The larvae of the pest bore into shoots and feed on internal tissues resulting in yellowing and drying of infested shoots (Koya *et al.* 1991). In spite of the serious damage caused by the shoot borer, very few studies have been undertaken for the management of the pest. The present recommendation for the management of the pest is based on application of conventional insecticides such as malathion 0.1% (Koya *et al.* 1998). A number of predators and parasites are active in the field where ginger is grown (Devasahayam 1996). In view of the harmful effects of insecticides on natural enemies and non-target organisms and the likelihood of deposition of pesticide residues in the produce, attempts were made to develop alternate methods for the management of the pest utilizing commercial products of *Bacillus thuringiensis.*

Materials and methods

The trials were undertaken in the field at the Experimental Farm of Indian Institute of Spices Research, Peruvannamuzhi (Kozhikode District, Kerala) for two seasons during 1995-97. Two commercial products of *Bacillus thuringiensis* namely, Bioasp (0.25%, 0.50% and 0.75%) and Dipel (0.1%, 0.2% and 0.3%) were evaluated along with malathion (0.1%) (present recommendation). The trial was laid out in a Randomized Block Design with a plot size of 4 beds per treatment and replicated four times. Five rounds of sprayings were undertaken at 21-day intervals during July-October. The first round of spraying was initiated once the occurrence of the first symptom of pest attack was noticed on the plants. The biopesticides/ insecticide were sprayed with a rocker sprayer to run-off levels. A control without spray was also maintained. The percentage of shoots damaged by the pest was recorded during November at crop maturity during both the years and the data subjected to combined analysis.

Results and discussion

All the treatments were effective in reducing the pest infestation on the shoots when compared to control (Table 1). Among the various treatments, spraying Dipel 0.3% was the most effective resulting in significantly lower percentage of infested shoots on the crop, followed by malathion 0.1%.

Commercial biopesticides based on *B. thuringiensis* are being widely used for the control of many lepidopterous pests especially on horticultural crops (Singh & Narasimham 1991). The present study is the first alternative approach for the management of shoot borer on ginger without use of conventional insecticides. The use of biopesticides would help in conserving natural enemies and other non-target organisms and would also result in pesticide residue-free produce.

Table 1. Evaluation of commercial products of *Bacillus thuringiensis* against shoot borer of ginger

Treatment	% shoots damaged
Bioasp 0.25%	13.0 d
Bioasp 0.50%	12.3 d
Bioasp 0.75%	9.3 c
Dipel 0.1%	9.7 c
Dipel 0.2%	8.7 c
Dipel 0.3%	5.0 a
Malathion 0.1%	7.2 b
Control	27.3 e

Means separated by DMRT at $P < 0.05$

Acknowledgements

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References

Devasahayam S 1996. Biological control of insect pests of spices. In: Anandaraj M & Peter K V (Eds.) Biological Control in Spices (pp. 33-45). Indian Institute of Spices Research, Calicut.

Koya K M A, Devasahayam S & Premkumar T 1991. Insect pests of ginger (*Zingiber officinale* Rosc.) and turmeric (*Curcuma longa* Linn.) in India - a review. J. Plantn. Crops. 19 : 1-13.

Singh S P & Narasimham A U (Eds.) 1991. Proceedings, Indo-USSR Joint Workshop on Problems and Potentials of Biocontrol of Pests and Diseases, National Centre for Integrated Pest Management, Bangalore.

Session V

Post Harvest Technology

Post harvest management of turmeric for higher recovery of curcumin

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Abstract

Traditionally turmeric is processed by boiling whole rhizomes in water after harvest for about 45 minutes to one hour followed by sun drying which normally takes about 10 to 12 days depending upon the place of cultivation. A study was carried out at the Indian Cardamom Research Institute, Myladumpara during 1998 and 1999 seasons to evaluate the effect of different processing techniques on the recovery of total curcumin for two of the high yielding varieties with high curcumin content viz, Prabha and Prathibha, collected from Peruvannamuzhy farm of the Indian Institute of Spices Research, Calicut. There were four treatments consisting of sun drying of whole rhizomes with and without boiling in water, sun drying of rhizomes cut into thin slices with and with out boiling in water. Analysis of total curcumin for the study was carried out in the Quality Evaluation and Upgradation Laboratory of the Spices Board. Moisture content, time taken for drying as well as dry recovery were also recorded. The results indicated that sun drying of rhizomes cut into thin slices and boiling in water gave on an average curcumin recovery of 7.31 and 7.29 percentage for Prabha and Prathibha varieties respectively in comparison to 6.39 percentage recovery (for both the varieties) under the normal method of sun drying whole rhizomes after boiling in water. The percentage increase in total curcumin for the former treatment over the latter during 1998 were 11.6 and 14.5 for Prabha and Prathibha varieties respectively. The respective percentages for 1999 period were 17.6 and 13.8. The study also indicated that though a reduction in dry recovery was observed with slicing of rhizomes, it invariably reduces the drying time from a normal period of 10 to 12 days taken for whole rhizome to about 4 to 5 days taken by the sliced rhizomes. The higher recovery of total curcumin can well compensate for the reduction in dry recovery.

Introduction

In India turmeric is cultivated in an area of 1.56 lakh hectares with a total production of 5.98 lakh tonnes (1998-1999). Out of this production, 36,522 tonnes (6.10 per cent) was exported with an earning of Rs. 124.5 crores during that period. In the International market, Indian turmeric is valued for its comparatively higher curcumin content (di-cinnamoyl methane), which imparts yellow colour to the product. It is estimated that value added products such as oils, oleoresins, curcumin etc. constitute about 20 to 30 percent of the total export of spices in our country at present. Traditionally, fresh turmeric rhizomes, after harvest are cleaned and processed by boiling in water, drying in sun and finally polishing. Boiling in water is done to destroy the vitality of fresh rhizomes, to gelatinize starch to break down curcumin containing cells and to reduce the drying time (Purseglove *et al.* 1988). Curcumin is extracted from the cured rhizomes of turmeric. The present paper discusses the results of a study on the post harvest management of turmeric for higher recovery of curcumin.

Materials and methods

The study was carried out at the Indian Cardamom Research Institute, Myladumpara during 1998 and 1999 seasons to evaluate the effect of different processing techniques on the recovery of total curcumin for two of the high yielding varieties with high curcumin content viz, Prabha and Prathibha (Sasikumar *et al.* 1996) collected from Peruvannamuzhy farm of the Indian Institute of Spices Research, Calicut. The treatments consisted of four methods of processing turmeric rhizomes (fingers) replicated four times. They are sun drying of whole rhizomes without boiling in water, sun drying of rhizomes cut into thin slices (one to two mm thick) without boiling in water, sun drying of whole rhizomes after boiling in water and sun drying of rhizomes cut into thin slices and boiling in water. Boiling and sun drying of rhizomes under respective treatments were carried out as per common procedures. Analysis of total curcumin was carried out in the Quality Evaluation and Upgradation Laboratory of the Spices Board, Kochi. Moisture content, time taken for drying as well as dry recovery were also recorded under the study.

Results and discussion

The moisture content of dried samples, dry recovery and days taken for drying are presented in table 1.

Then show that there was a decline in moisture content by 0.7 percent in Prabha variety when the rhizomes were sliced, boiled and sun dried compared to boiling and sun drying. The reduction noticed in moisture percentage was more (1.2) in the case of Prathibha, variety. The dry recovery was less for the former treatment in both the varieties (19.2 and 17.7 per cent for Prabha and Prathibha respectively) when compared to 19.8 and 18.4 percent for these varieties recorded for the latter treatment i.e. sun drying whole rhizome after boiling in water. Thus there was a reduction in dry recovery of 0.6 percent in the case of Prabha and 0.7 per cent in the case of Prathibha variety for the treatment where the rhizomes were sliced, boiled and sun dried. However, this reduction can be compensated to a certain extent by the increased recovery in curcumin content.

The method of curing i.e. cutting into thin slices, boiling in water and sun drying has taken only lesser number of days (4 to 5) for drying which is shorter by 6 to 7 days taken in case of drying whole rhizomes after boiling in water. Sampathu *et al.*(1988) observed a reduction in drying period in turmeric when boiling of rhizomes was done. Purseglove *et al.* (1988) have reported that mechanically slicing the rhizomes after boiling was found to reduce significantly the drying time and gave a product, which was somewhat easier to ground. The reduction in moisture content, dry recovery and drying time observed in the present study may be due to increase in surface area of the slices.

Results of analysis of total curcumin content for both the years under each treatment are presented in table 2a and the data on pooled analysis in table 2b.

It can be seen that sun drying of rhizomes cut into thin slices and boiling in water gave on an average curcumin

Table 1. Moisture content (%), dry recovery (%) and days taken for drying (range)

Variety	Treatment	Moisture (%)	Dry recovery (%)	Days taken for drying
Prabha	Sun drying with out boiling	11.3	20.3	15-18
	Slicing, sun drying without boiling	11.1	19.5	5-6
	Sun drying after boiling	10.7	19.8	10-12
	Slicing, sun drying after boiling	10.0	19.2	4-5
Prathibha	Sun drying with out boiling	12.1	19.2	17-20
	Slicing, sun drying without boiling	11.7	18.8	5-6
	Sun drying after boiling	10.5	18.4	10-12
	Slicing, sun drying after boiling	9.3	17.7	4-5

Table 2a. Total curcumin content (%) under different treatments

Variety	Year of study	Sun drying without boiling in water	Slicing, Sun drying with-out boiling in water	Sun drying after boiling in water	Slicing, sun drying after boiling in water
Prabha	1998	6.74	7.60	6.97	7.78
	1999	6.12	6.53	5.81	6.83
	Mean	6.43	7.07	6.39	7.31
Prathibha	1998	6.46	7.03	6.67	7.64
	1999	6.45	6.66	6.10	6.94
	Mean	6.46	6.85	6.39	7.29

Table 2b. Pooled analysis of total curcumin

Treatment	Prabha	Prathibha
Sun drying without boiling in water	6.43	6.46
Slicing, sun drying without boiling in water	7.07	6.85
Sun drying after boiling in water	6.39	6.39
Slicing, sun drying after boiling in water	7.31	7.29
C.D (P=0.01)	0.46	0.17

recovery of 7.31 and 7.29 per cent for Prabha and Prathibha varieties respectively in comparison to 6.39 per cent recovery (for both the varieties) under the traditional method of processing turmeric viz. sun drying of whole rhizome after boiling in water. The percentage increase in total curcumin for the former treatment over the latter during 1998 were 11.6 and 14.5 for Prabha and Prathibha varieties respectively. The respective percentages for 1999 period were 17.6 and 13.8. Boiling of rhizomes helps to gelatinize starch and break open the curcumin containing cells and thereby giving higher recovery of curcumin. In this experiment, the highest curcumin contents were recorded when rhizomes were cut into thin slices, boiled and sun dried. This could probably be due to breakage of more cells while slicing and boiling of such slices in water.

References

Purseglove J W, Brown E G, Green C L & Robbins S R J 1988. Turmeric. In: Spices- Vol.2. Tropical Agricultural Series, Longman, London.

Sampathu S R, Krishnamurthy N, Sowbhagya H B & Shankaranarayana M L 1988 Processing aspects of turmeric. In: Proceedings of National Seminar on Chillies, Ginger and Turmeric, Hyderabad, Andhra Pradesh. 11-12, Jan.1988.

Sasikumar B, Johnson K George, John Zachariah T, Ratnambal M J, Nirmal Babu K & Ravindran P N 1996. IISR Prabha and IISR Prathibha-two new high yielding and high quality turmeric (*Curcuma longa* L.) varieties. J.Spices and Aromatic Crops 5 (1) : 41-48.

Volatile constituents of *Cinnamomum zeylanicum* Blume fruit oil

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Abstract

Cinnamomum zeylanicum Blume (syn. *C.verum* J.S.Presl.) is cultivated widely in south India. The essential oils obtained from the matured and unripened fruits of *C. zeylanicum* Blume grown in Bangalore analysed by Gas chromatography and Gas chromatography-mass spectroscopy indicated the presence of more than 90 constituents. The major constituents of the oil are α-pinene, β-pinene, limonene, linalool, β-terpineol, (E)-cinnamyl acetate, (Z)-cinnamyl acetate, α–humulene, α-muurolene, γ-muurolene, δ-cadinene, γ-cadinene and cubenol. Variation in the composition of the essential oils, at two different stages, of the fruits is presented.

Key words: *Cinnamomum zeylanicum*, essential oil, fruit oil, Lauraceae, mono terpenes, sesquiterpenes.

Abbreviations:

GC = Gas chromatography

GC-MS = Gas chromatography – mass spectrometry.

Introduction

The genus *Cinnamomum* is an important source of spices and essential oils which were traded since antiquity. Cinnamon and its products, due to their delicate flavor are widely used in food, liquors, pharmaceuticals and cosmetics. *Cinnamomum zeylanicum* Blume (syn. *C. verum* J.S. Presl), popularly known as cinnamon in the trade, is widely cultivated in Sri Lanka and in some parts of south India. The bark and leaf of the plant are widely used as spices throughout the world. Angmor *et al.* (1972) and Wijesekera *et. al.* (1974) first reported the chemical composition of leaf, stem bark and root bark oils of *C. zeylanicum* using GC methods. According to Senanayaka *et al.*(1978) and Mallavarapu *et al.* (1995) the essential oils from the leaves are of two types - one having eugenol and the other having benzyl benzoate as the main constituent. Senanayaka *et al.* (1978) and Nath *et al.* (1996) reported the oils of the stem bark also as two types - one having (E)-cinnamaldehyde and the other having benzyl benzoate as the major constituents in the oils. The fruits of this plant are also having a pleasant sweet spicy aromatic odour. Recent report on the oil obtained from the fruit oil (Jayaprakasha *et al.* 1997) from different locations in south India indicated the presence of β-caryophyllene and (E)-cinnamyl acetate as major constituents. Chemical examination of the essential oil, obtained from unripened and matured fruits of cinnamon grown in Bangalore, using GC and GC/MS, indicated the presence of more than 90 components. The composition of the fruit oils at different stages is reported in this paper.

Materials and methods

The dark purple ripened fruits and full grown green fruits of *C. zeylanicum* plants grown in the CIMAP Field Station at Bangalore were collected during May 1999. The voucher specimen is deposited in CIMAP Field Station, Bangalore. The freshly collected fruits were crushed and subjected to hydrodistillation in Clevenger-type apparatus for 6 h. The pale yellow oil was obtained in 0.45 and 0.6% yield, respectively. The pleasant sweet smelling oils were dried over anhydrous Na_2SO_4 and stored at 4°-5°C in refrigerator until analysed.

Analysis

GC analysis was carried out on a Perkin-Elmer 8500 gas chromatograph equipped with FID using BP-1 (diethyl polysiloxane) column (30 m x 0.32 mm i.d. and 0.25 micron m film thickness) and nitrogen as carrier gas at 10 psi inlet pressure. Temperature program-

Table 1. Composition of *Cinnamomum zeylanicum* Blume fruit oils

Kovat's index	Name of the compound	Unripened fruit	Ripened fruit
838	(Z)-3-hexenol	0.06	0.06
924	Tricyclene	0.02	0.06
935	α-Pinene	11.47	11.52
947	Camphene	1.31	3.16
976	β-Pinene	10.51	5.64
983	Myrcene	1.31	1.72
994	α-phellandrene	0.79	0.65
1003	δ-3-carene	0.04	0.02
1008	p-Cymene	0.14	0.34
1011	α-terpinene	0.25	0.06
1021	Limonene	2.96	3.87
1029	*(z)*-β-Ocimene	0.08	0.14
1040	*(E)*- β-Ocimene	0.12	0.24
1049	γ-terpinene	0.10	0.17
1076	terpinene-4-ol	0.45	0.81
1082	Terpinelone	0.35	–
1085	Linalool	5.28	–
1101	*endo*-fenchol	0.34	0.05
1130	β-terpineol	2.91	0.08
1135	Citronellal	0.10	0.07
1147	Isobomeol	0.36	0.55
1158	Borneol	0.09	0.0
1165	terpinen-4-ol	0.92	1.08
1206	Nerol	1.34	0.14
1241	(E)-cinnamyl aldehyde	1.48	0.12
1241	Geraniol	0.04	–
1258	linalyl acetate	0.03	0.05

Table 1 (contd.)

Kovat's index	Name of the compound	Unripened fruit	Ripened fruit
1325	Eugenol	0.11	0.04
1343	thymol acetate	0.25	0.03
1369	(Z)-cinnamyl acetate	2.00	1.91
1386	β-elemene	0.83	0.11
1413	(E)-cinnamyl acetate	7.11	8.62
1420	β-caryophyllene	0.04	0.19
1432	*(E)*-methyl cinnamate	0.05	0.96
1449	(E)–β–farnesene	0.16	1.56
1451	α-amorphene	1.40	1.31
1458	α-humulene	1.84	2.38
1473	γ-muuurolene	0.41	0.31
1486	germacrene-D	0.55	1.95
1488	α-patchoulene	0.55	0.27
1502	α-muurolene	0.04	8.22
1513	γ-cadinene	8.05	23.48
1521	δ-cadinene	19.15	1.40
1527	*cis*-calamene	1.07	2.33
1543	β-elemol	1.81	–
1552	(E)-nerolidol	0.09	0.14
1555	Caryophyllene alcohol	0.05	0.49
1567	Spathulenol	0.22	0.56
1576	Caryophyllene oxide	0.09	0.05
1581	Globulol	0.09	0.29
1599	humulene epoxide I	0.36	0.42
1606	humulene epoxide II	0.05	0.12
1612	*epi*-cubenol	0.48	0.52
1624	Cubenol	4.23	5.52
1636	α-muurolol	1.29	1.71

ming was done from 60°-220°C at 5°C/min (BP-1 column). The split ratio was 1:80. GC/MS analysis was carried out on Hewlett-Packard 5890 gas chromatograph interfaced with a quadrupole mass spectrometer MSA 5970 using fused capillary column HP-1 (25m x 0.33 µm film thickness). Oven temperature, the injector and detector temperatures were maintained same as in GC analysis. Helium was used as carrier gas.

Component identification was done by comparison of their Kovats retention indices on BP-1 column (relative to C8-C23 alkanes) with literature values, peak enrichment on co-injection with authentic samples wherever possible and by comparison of the mass spectra of the peaks with the published data. Peak area percentages were calculated on BP-1 column without the use of correction factors.

Results and discussion

The chemical composition of the essential oil of the fruits of the unripened and ripened fruits of *C. zeylanicum* were summarized in Table 1. Nearly 55 compounds of the oil accounting for more than 96% of the oils were identified. The oil is mostly composed of monoterpenes, sesquiterpenes and very small portion of phenolic compounds and other phenyl propanoids. The major constituents of the oil are α-pinene, β-pinene, α-muurolene, γ-cadinene, δ-cadinene, cubenol and α-muurolol. There is a significant decrease is observed in the contents of β-pinene, α-phellandrene, β-terpineol, linalool, citronellal, nerol, (E)-cinnamaldehyde, eugenol, thymol acetate, β-elemene, α-amorphene, γ-muurolene, α-patchoulene, δ-cadinene, β-elemol from unripened stage to ripening stage. Similarly a considerable increase in the case of camphene, myrcene, *p*-cymene, limonene, both isomers of β-ocimene, terpinene-4-ol, isoborneol, β-caryophyllene, (E)-cinnamyl acetate, (E)-methyl cinnamate, (E)-β-farnesene, α-humulene, germacrene-D, α-muurolene, γ-cadinene, *cis*-calamene, caryophyllene alcohol, spathulenol and α-muurolol is observed. The present study indicates the higher concentration of mono- and sesquiterpenoids and lower concentration of phenolic and phenyl propanoids in the fruit oil.

The composition of cinnamon fruit oil in the present study widely differed from that reported earlier. It is interesting to note the significant decrease in the percentage of eugenol, benzyl benzoate, β-caryophyllene, camphor and (E)-cinnamyl aldehyde in the fruit oil when compared with the oils reported earlier from other parts.

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References

Adams R P 1995. Identification of Essential Oil Components by Gas Chromatography/Mass Spectroscopy. Allured Publ. Corp., Carol Stream Il.

Angmor J E, Dicks D M, Evans W C & Sintr D K 1972. Planta Med. 21 : 416-20.

Jayaprakasha G K, Rao L J & Sakariah K K 1997. Chemical composition of the volatile oil from the fruits of *Cinnamomum zeylanicum Blume.* Flav. Fragr. J. 12 : 331-333.

Mallavarapu G R, Ramesh S, Chandrasekhara R S, Rajeswara Rao B R, Kaul P N & Bhattacharya A K 1995. Investigation of the essential oil of cinnamon leaf grown at Bangalore and Hyderabad. Flav. Fragr. J. 10 : 239-242.

Nath S C, Pathak M G & Baruah A 1996. Benzyl benzoate, the major component of the leaf and stem bark oil of *Cinnamomum zeylanicum* Blume. J. Essent. Oil Res. 8 : 327-328.

Senanayaka U M, Lee T H & Wills R B H 1978. Volatile constituents of cinnamon *(Cinnamomum zeylanicum) oils.* J. Agric. Food Chem. 26 : 822-824.

Wijesekera R O B & Jayewardene A L 1972. Proc. International Conf. Spices, TPI, London pp. 159-67.

Wijesekera R O B, Jayawardene A L and Rajapakse L S 1974. Volatile constituents of leaf, stem and root oils of cinnamon *(Cinnamomum zeylanicum)* J. Sci. Food Agric. 25 : 1211-20.

Chemical composition of essential oil of *Cymbopogon flexuosus* from Central India

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Abstract

The essential oil of *Cymbopogon flexuosus* (Lemon grass) collected from Chhindwara (M.P.) was isolated by hydrodistillation. The oil was analyzed by GC/MS. The essential oil of *C. flexuosus* obtained from this region was determined by GC/MS for the first time. Twenty eight compounds representing 99.9 percent of the oil were identified. The major constituents of the oil are citral (31.52%), Z-citral (28.82%), linalool (4.82%) and geranyl acetate (3.57%).

Keywords : citral, Z-citral, *Cymbopogon flexuosus*, essential oil composition, lemon grass

Introduction

Lemongrass (*Cymbopogon flexuosus* (Steud,) Wats) is one of the most important essential oil bearing crops of India. The oil obtained from the leaves of lemon grass is widely used in soap, perfumery and as a source of citral, a chemical used in perfumery and flavour industries and also as a raw materials for the manufacture of vitamin A. Now a days, it is under cultivation in some parts of Assam, Kerala, Orissa, U.P. and Punjab. The cultivation is also being started in some parts of M.P. Essential oil yield and oil quality in *C. flexuosus* is known to be influenced by various environmental factors, like temperature, water, salinity and micronutrient deficiencies (Farooqui *et al.*1985, Hearth *et al.* 1979, Sangwan *et al.* 1993). The leaves are used in herbal teas in different parts of India (Hussain 1994). Seasonal influences on the quality and yield on lemon grass has been reported earlier (Handique *et al.* 1984).

Considerable natural variability also exists in lemon grass at the chemotypic level which could also be exploited. There is still need for suitable varieties for the cultivation of lemon grass in various agro-climatic zones. For such type of programmes, it is essential to have a knowledge of genetic variability present in the existing material.

So far, no detailed study of the essential oil quality (chemical composition) of the oil produced in this region of M.P. was undertaken earlier. Hence, the present investigation was carried out to analyze the composition of the essential oil of lemon grass produced in Satpura region of Madhya Pradesh.

Materials and methods

The herb of *Cymbopogon flexuosus* for investigation was collected from the hilly region of Chhindwara, M.P. situated at 21°.44' North latitude, 78°.82' East longitude and 470 m altitude.

Essential oil

Fresh herb (leaves) of *C. flexuosus* was hydrodistilled in a Clevanger apparatus for 6 hrs. The distilled essential oil was collected and dried over anhydrous sodium sulphate for GC-MS analysis.

GC-MS analysis

The volatile oil was analyzed by GC-MS for its chemical composition. GC-MS data were obtained on Hewlett Packard GC-MS model H.P. 5996 coupled with computer library of 80,000 compounds and fitted with a WACOT SE-30 (methyl silicon gum) capillary column of 12 m × 0.22 mm.

Other conditions were maintained as below

Carrier gas	-	Helium
Flow rate	-	40 ml/sec.
Injector temperature	-	230°C
Chromatographic temp.	-	40°C to 250°C with rising rate 10°C/min.
Scan parameter	-	40-800 mass range

The constituents were identified by comparison with those of given in the computer library coupled with the

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GC-MS instruments and reported in literature.

Results and discussion

The oil content was found to be 0.45% on fresh weight basis. Twenty eight constituents were identified as a result of GC-MS examination of the oil (Table 1). Citral (31.52%) and Z-citral (28.82%) were found to be the major constituents. The other constituents were linalool (4.82%), geranyl acetate (3.57%), pulegone (3.43%), trans-caryophyllene (2.84%), neryl propionate (2.64%), globulol (2.29%), trans-fernesol (2.19%), β-myrcene (2.17%), isopulegone (1.92%), 6-methyl-5-hepten-2-one (1.86%), neryl acetate (1.85%), Cis, trans-fernesal (1.55%), 1,2-benzanedicarboxylic acid (1.54%) and 3-octyne (1.23%). The total citral content was found to be 60.34%.

The quality of oil under study appears to be similar to those from Lucknow, Jammu and Kerala. The range of values reported for important constituents of the lemon grass oil from different states of India are presented in Table 2. The data on minimum and maximum concentrations of citral showed that the Jammu oil recorded the highest value of citral (95.89%) (Verma *et al.* 1987), however, the value of citral was found lower in Chhindwara (60.34%). The citral concentration in the essential oil of Kerala (local variety) was 82% (Pillai 1955). A geranyl acetate rich chemotype OD- 468 was also identified in Kerala (Samuel *et al.* 1996). Geranyl acetate was found to be 79.8% while citral-a and citral-b was 6.3% and 4.4% respectively. A genetically improved clone-CIMAP/LS.48 (var. Pragati) was developed by CIMAP, Lucknow which contains 88.4% citral (Sharma *et al.* 1987) while a different variety GRL-1 was developed by Patra *et al.* (1990) which has 94.73% geraniol. The essential oil of Malwa region was reported to contain 82% of citral (Gupta 1997). Volatile oil obtained from the *C. flexuosus* grown in North Eastern India does not contain citral. GC-MS analysis of the essential oil showed the presence of elimicin (53%), limonene (11.6%), β-ocimine (7.6%) and camphene (4.1%) (Sarma 1999). Another variety BLI-1 was also identified from N.E. India which contain geraniol (35.4%), citronellol (24.1%), geranial (13.6%) and neral (10.3%) (Nath *et al.* 1994). Bhattacharya *et al.* (1998) reported a genotype of *C. flexuosus* which contain geraniol (53.11%) and neral (33.21%).

The above observed variability in the essential oils of

Table 1. Chemical composition of essential oil of *Cymbopogon flexuosus*

Compound	Percentage
3-hexyne-2,5-diol	0.20
6-methyl-5-hepten-2-one	1.86
Linalool oxide (2)	0.42
β-myrcene	2.17
Linalool	4.82
Trans-caryophyllene	2.84
3-octyne	1.23
Pulegone	3.43
2-undecanone	0.98
Trans-pinocarveol	0.54
Geranyl acetate	3.57
Z-citral	28.82
Citral	31.52
Cis-farnesol	0.46
Neryl acetate	1.85
(+)-trans-Isolimonene	0.57
Myrtanol	0.14
Globulol	2.29
2,3-Dimethyl-6-methoxy heptan-2-ol	0.99
Neryl propionate	2.64
Isopulegone	1.92
Trans- fernesol	2.19
3-Butyn-2-ol,2-methyl	0.32
Cis, trans-fernesal	1.55
2,6-octadiene,4-methyl	0.51
1,6-heptadiene,3,5-dimethyl	0.39
10-demethylsqualene	0.23
1,2-Benzenedicarboxylic acid	1.54

Table 2. Comparative chemical composition of lemon grass oils produced in different states of India.

	Chemical components in percentage											
Location	Citral	Citral-a	Citral-b	Geraniol geranial*	Geranyl acetate	Limonene	Myrcene	Elimicin	Camphene	Nerol/ neral*	Citro-nellol	Reference
Assam (Jorhat)	-	-	-	-	-	11.6	-	53	4.1	-	-	Sarma *et al.* 1999
BLI-1	-	-	-	30.5	- 13.6*	-	-	-	-	10.3*	24.1	Nath *et al.* 1994
Kerla	-	6.3	4.4	2.9	79.8	4.5	3.1	-	-	-	-	Samul *et al.* 1996
(OD-19)	85-90	-	-	-	-	-	-	-	-	-	-	Nair *et al.* 1979
Local var.	76.4	-	-	-	-	-	-	-	-	-	-	Pillai 1955
Malwa 1987 Region (M.P.)	82	-	-	-	-	-	-	-	-	-	-	Gupta
Jammu (Citral)	95.89	62.17	33.72	-	-	-	-	-	--	-	-	Verma *et al.* 1989
RRI-16	75-80	-	-	-	-	-	-	-	-	-	-	Atal & Bradu
1973												
Lucknow (Pragati)	88.4	53.6	24.8	-	-	-	-	-	-	-	-	Sharma *et al.* 1987
GRL-I	-	-	-	94.73	0.65	0.09	1.26	-	-	-	-	Patra *et al.* 1990
Hyderabad	-	-	-	53.11	-	-	-	-	-	13.21	-	Bhattacharya *et al.* 1998

C. flexuosus produced at geographically diverse locations is indicative of wide genetic differences. There were significant differences in the composition of essential oils between genotypes of different regions.

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References

Atal C K & Bradu B L 1973. Proceedings of first work shop, All India co-ordinated improvement project on medicinal and aromatic plants held at Bangalore, 17th to 19th Nov. 164-168.

Bhattacharya A K, Kaul P N & Rajeshwara Rao B R 1998. Effect of prolonged storage on the quality of lemon grass (*Cymbopogon flexuosus*(Nees Steud) Wats.) essential oil, Journal of Essential oil Bearing Plants 2-3 : 104-109.

Farooqi A H A, Mishra A, Bansal R P & Luthra R 1985. Effect of micronutrient deficiencies on enzyme activities and oil component in *Cymbopogon flexuosus* (Steud) Wats. Indian J Plant Nut. 4 : 77-84.

Gupta R S 1987. Trial cultivation of some medicinal and aromatic plants in Malwa region of M P part II analysis of essential oils. Indian Perfumer 31(4) : 370-374.

Handique A K, Gupta R K & Bordolai D N 1984. Variation of oil content in lemon grass as influenced by seasonal changes and its genetic aspects Indian Perfurmer 28 : 54-63.

Herath H M W, Iruthayatha E E & Ormrod D P 1979. Temperatureeffect on essential oil composition of *Citronella* selections. Econ.Bot. 33 : 425-430.

Hussain A 1994. Essential oil plants and their cultivation, Central Institute of Medicinal and Aromatic Plants, Lucknow.

Nair E V G, Nair K C & Chinnamma N P 1979. Field experiments with micronutrients on yield of grass and oil and citral content of oil of East Indian lemongrass, *Cymbopogon flexuosus* variety OD-19. Indian Perfumer 23 : 55-58.

Nath S C , Saha B N, Mathur R K & Leclercq R A 1994. The chemical composition of the essential oil of *Cymbopogon flexuosus* (Steud) Wats growing in North eastern India. J. Essential oil Res. 6 : 85-87.

Patra N K, Srivastava R K, Chauhan S P, Ahmad A & Misra L M1990. Chemical features and productivity of a geraniol rich variety (GRL-1) of *Cymbopogon flexuosus*. Planta Medica 56 : 239-240.

Pillai K P 1955. Lemongrass cultivation in Travanocore Cochin state. Proc. Symp. on Essential Oils and Aromatic Chemicals at FRI, Dehradun 1955. (Published by CSIR, New Delhi, 1958), pp 74-77.

Samuel Mathew, Gim Jose Chittattu & Thomas J 1996. A lemongrass chemotype rich in geranyl actate. Indian Perfumer 40 (1) : 9-12.

Sangwan R S, Farooqi A H A, Bansal R P, Singh & Sangwan N 1993. Interspecific variation in physiological and metabolic responses of five species of *Cymbopogon* to water stress. J. Plant Physiol. 152 : 618-622.

Sarma K K, Nath S C & Leclercq P A 1999. The essential oil of a variant of *Cymbopogon flexuosus* (Nees ex Steud) Wats from Northeast India, J. Essential oil Res. 1(3) : 381-385.

Sharma J R, Lal R K, Misra H O & Naqvi A A 1987. A genetically improved clone-CIMAP/LS. 48 (var.Pragati) of lemon grass(*Cymbopogon flexuosus*) developed. Pafai J. 11 : 13-19

Verma V, Sobti S N & Atal C K 1987. Chemical composition and Inheritance pattern of five *Cymbopogon* species. Indian Perfumer 31(4) : 293-303.

Gas chromatographic evaluation of *Curcuma* essential oils

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Abstract

Gas chromatographic analysis of essential oils from *Curcuma longa*, *C. amada* and *C. caesia* rhizomes grown in India are carried out. Rhizome oils of *C. longa* and *C.amada* are similar as compared to turmeric leaf and *C. caesia* rhizome oil. Except for *C. caesia*, all the other three oils are devoid of anethole and camphor is also significantly higher in *C. caesia* oil than *C. longa* and *C. amada*.

Introduction

The genus, *Curcuma* consists of various species which are perennial, aromatic herbs with fleshy rhizomes, among which *Curcuma longa*, *Curcuma amada* and *Curcuma caesia* are economically very important. *Curcuma longa* commonly used as a spice is well known for its medicinal values in the Indian traditional system of medicine (Srimal 1997). The essential oil of turmeric rhizomes was extensively studied and the main constituents were found to be ar-turmerone, turmerol and atlantone (Zwaving & Bos 1992). The leaf is a waste product during post harvest operations of turmeric crop. It is usually used as fuel and green manure. The leaf is aromatic and contains essential oil, but much work has not been done on its analysis and its uses. *Curcuma amada* also belongs to family Zingiberaceae commonly known as amada. Besides the medicinal use of the rhizome, it has extensive application in the preparation of sweetmeats, chutneys and pickles because of its mango-like aroma (Rao *et al.* 1989). Rhizomes of *C. caesia* commonly known as 'Kalihaldi', are used for sprain and bruises and also employed as a cosmetics.

This analysis is continuation of our investigation on Zingiberaceae plants.

Materials and methods

Fresh green leaf of turmeric (*C. longa)* and rhizomes of *C. amada*, *C. longa* and *C. caesia* were collected from 7-8 month old plants grown in experimental field of Aromatic and Medicinal Plants Garden of Regional Research Laboratory, Orissa.

Gas chromatographic analysis was carried out in Perkin Elmer auo system, filled with capillary column carbowax (20m x 50m) flux ionisation detector, Okodata 320 recorded digital computer DEC station fed with Turbochrom-3 software and Nitrogen as carrier gas. Major volatile constituents were identified on the chromatogram by comparing their retention time with authentic compounds.

Results and discussion

Both α -pinene and β-pinene are present in all the four essential oils (Table 1) and it is found to be more in turmeric leaf oil and α -pinene impart a floral odour to the oil. β-phellandrene is significantly higher in leaf oil, whereas it also present in amada rhizome oil (6.85%). Linalool is found to be in a very low concentration in all the rhizome oils but a major constituent of turmeric leaf oil. 1,8-Cineole and geraniol are not in rhizome oils, but these are major constituents of leaf oil.

Cis-β-ocimene is a major component in all the rhizome and leaf oil and comparatively higher in amada oil (18.792%). Cis-β-ocimene was earlier reported by Gholap & Bandyopadhyay (1984) as a major contributor to green odour of raw mango of *C. amada*. Camphor, Caryophyllene, Berneol anethole and an unknown component of 17.617% are significantly higher in *C. caesia* oil. Whereas *C.caesia* oil is devoid of ar-turmerone a major component of *C. longa* (30.547%) and *C. amada* (29.126%) and also turmerone in *C. longa* (11.334%) and *C. amada* (10.806%).

Acknowledgements

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Table 1. Composition of essential oils from 3 species of *Curcuma*

	C. longa leaf	*C. longa* rhizome	*C. amada* rhizome	*C. caesia* rhizome
α - pinene	1.447	0.519	0.490	0.405
β - pinene	2.285	0.770	0.720	0.607
β - phellandrene	12.613	-	6.856	-
1, 8 Cineole	10.742	-	-	-
Cis-β-ocimene	13.760	9.763	18.792	14.548
Linalool	11.958	1.350	1.301	0.992
Camphor	1.404	-	0.333	7.773
Caryophyllene	-	1.023	1.754	3.153
Geraniol	6.723	-	-	-
ar-turmerone	-	30.547	29.126	-
Turmerone	-	11.334	10.806	-
Borneol	-	1.483	-	4.304
Anethole	-	-	-	21.79
Unknown	-	-	-	17.617
Camphene	-	-	-	1.671

References

Gholap A & Bandyopadhyay C 1984. Characterization of mango-like aroma in *Curcuma amada* Roxb. J.Agric Food Chem. 32: 59-64.

Srimal R C 1997. Turmeric: a brief review of medicinal properties. *Fitoterapia* LXVIII, 6: 483-493.

Srinivasa Rao A Rajanikanth B & Seshadri Ramachandran 1989. Volatile aroma components of *Curcuma amada* Roxb. J.Agic. Food Chm. 37: 740-743.

Zwaving J H & R Bos 1992. Analysis of the essential oils of five *Curcuma* species. Flavour and Fragrance J. 7: 19-22

Distribution of curcuminoids during rhizome development in turmeric (*Curcuma longa* L.)

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Abstract

Curcumin, the coloring principle in turmeric (*Curcuma longa* L.) consists of three compounds - Curcumin I (Curcumin), Curcumin II (Demethoxy curcumin) and Curcumin III (Bisdemethoxy curcumin). These compounds are present in varying amounts in rhizomes and possess different medicinal properties. The three curcuminoids have been separated from turmeric and estimated quantitatively by TLC, based on the absorption maxima of the compounds at 428, 423 and 418 nm respectively.

The distribution of the pigments has been observed individually in mother, primary and secondary rhizomes during different stages of growth. In all the three types of rhizomes, bisdemethoxy curcumin and demethoxy curcumin decrease with maturity with a corresponding increase in curcumin (methylated form). This indicates that the process of methoxylation of curcumin II & III to yield curcumin I is maximum at 180 DAS (Days After Sowing) , which continues upto maturity. Higher content of curcumin was seen in primary and secondary rhizomes as compared to mother rhizomes. An analysis of the pooled rhizome samples showed maximum content of curcumin I at 180 DAS (63.9 % of pigments present in oleoresin), while it was lower (53.3%) at full maturity with a concomittant increase in curcumin II and III. The progressive formation of curcuminoids during rhizome development is discussed.

Key words : biosynthesis, curcumin, curcuminoids, rhizomes, turmeric

Abbreviations:

BDC = Bis Demethoxy Curcumin

DC = Demethoxy Curcumin

C = Curcumin

DAS = Days After Sowing

Introduction

Turmeric (*Curcuma longa* L.) is a perennial, herbaceous tropical plant and belongs to the family of Zingiberaceae and indigenous to Southern Asia. The plant reaches upto a height of 1 meter and has got a thick fleshy underground rhizome. These rhizomes have two distinct parts, the mother or primary rhizome which is an egg shaped extension of the stem and several multi-branched cylindrical rhizomes growing downward from the mother rhizome, known as secondary rhizomes. Finger like growths from the secondary rhizomes are also seen which are called tertiary rhizomes.

Curcumin, the colouring principle in the rhizome is distributed throughout in all types of rhizomes. The pigment exists as a mixture of three compounds, Curcumin I (Curcumin/C), Curcumin II (Demethoxy curcumin/DC) and Curcumin III (Bisdemethoxy Curcumin/BDC). The term 'curcumin' has now become a misnomer and curcuminoids are currently used to represent the dye.

Turmeric possesses a large array of medicinal properties.(Govindarajan 1980) In fact, the biological activity of turmeric has been mentioned elaborately in the traditional systems of Indian medicine, which is mainly attributed to the pigment system of the plant

(Srimal 1997, Tonneson 1986, Sharma 1976). Of late, it has been observed that the extent of biological properties of the three curcuminoids varies among themselves. (Verghese 1999). Thus, the anti-inflammatory activity follows the order BDC> C> DC (Rao *et al.* 1982, Sharma 1976). Turmeric has been identified as a nutraceutical or anticarcinogen (Hans 1995, Tonneson 1986). The anticarcinogenic potential is due to its ability to scavenge oxides and peroxides (Soudamini & Kuttan 1985). Most recent observations suggest that BDC is the most effective anti promoter among the curcuminoids. (Verghese 1999) It is also more effective than C & DC in tumor reducing and antioxidant properties (Toda *et al* 1995).

Eventhough the individual curcuminoids differ in their biological activity, there exists a synergestic functioning of the compounds. It is reported that the proportion of C, DC and BDC exists in a definite proportion in the rhizome, which can influence its bioprotective functioning (Majeed 1995). Thus the 'curcumin C 3 – complex' as it is rightly called, possesses a collective effect of all the curcuminoids. The present study was undertaken to observe the distribution of the three curcuminoids at various stages of plant growths of turmeric so as to get a preliminary information on the *in vivo* synthesis of these compounds.

Materials and methods

Turmeric rhizomes (Var. Alleppy) were sown in the field. The leaves, roots and the fresh rhizomes were sampled at 30 day intervals, starting from 120 DAS (Days After Sowing) upto 240 DAS. The rhizomes were harvested ,separated into mother, primary and secondary rhizomes, boiled for one hour in a water bath and dried.

About 5-10 g of the turmeric powder was filled in a column (30 mm x 20 cm) and extracted with acetone overnight to get the oleoresin. A weighed amount (100 mg) oleoresin was redissolved in acetone and 100 ml samples were applied to TLC plates coated with silica gel G (1 mm thickness.) Chloroform: Methanol (95%) was used as the solvent system. Three major spots observed in the chromatogram were compared with that of synthetic curcumin. The spots were scraped out, eluted with alcohol and absorption maxima were measured in an UV Visible Double beam spectrophotometer. (ASTA,1985) The amounts of Curcumin I, II and III were expressed as percentage of oleoresin.

Results and discussion

The absorption maxima of the curcuminoids are given in table 1. The composition of individual curcuminoids in oleoresin of turmeric is given in fig 1. The distribution of curcuminoids in total pigment is given in table 2.

Table 1. Absorption maxima of curcuminoids

Curcuminoids		Absorption maxima (nm)
Curcumin I	Curcumin	428
Curcumin II	Demethoxy curcumin	423
Curcumin III	Bis Demethoxy Curcumin	418

Table 2. Percentage distribution of curcuminoids in rhizomes during development

Days after sowing	Curcumin I	Curcumin II	Curcumin III
120	57.95	20.31	21.73
150	57.45	21.34	21.2
180	63.87	16.36	19.77
210	53.3	22.4	24.86
240	58.32	21.56	20.12

The results show that curcumin (curcumin I), which forms the major portion of the curcuminoids, is distributed uniformly in mother, primary and secondary rhizomes only in the initial stage (120 DAS). As the rhizomes develop, the primary and secondary rhizomes contain higher proportion of curcumin (61.8-73.6 %) as compared to mother rhizomes (46.4 %). At full maturity, however, primary rhizomes had the highest content. This indicates that at later stages there was a lower production of curcumin II and III, which are the two demethoxy forms. These compounds probably substantiate by providing the methyl acceptor to the final methylated form.

Curcumin II (Demethoxycurcumin), which is structurally similar to Bis demethoxy curcumin (Curcumin III), except for an additional methoxy group ($-OCH_3$) was maximum in mother rhizomes at 150 DAS, while the

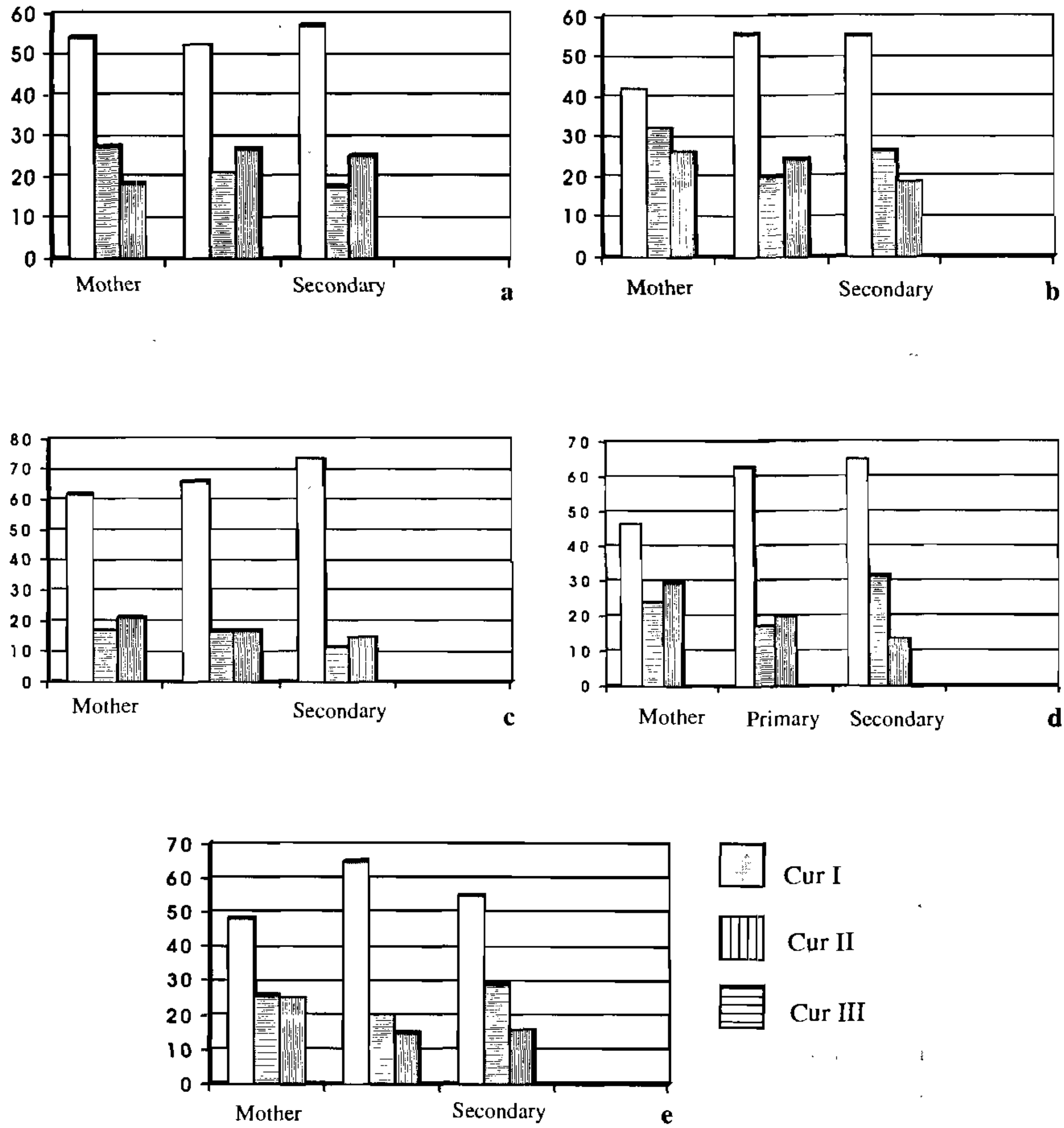

Fig. 1. Three curcuminoids in rhizomes at different stages of crop growth, a. 120 DAS, b. 150 DAS, c. 180 DAS, d. 210 DAS, e. 240 DAS.

secondary rhizomes also possessed a higher level at full maturity. In all other stages, the compound was at low concentration and varied from 11- 24 % in all three types of rhizomes. Except for the initial stage, Bisdemethoxy curcumin was highest in mother rhizomes and lowest concentration was seen in secondary rhizomes. According to the existing hypothesis, on the biosynthesis of curcumin (Geissman 1969) which mainly involves the union of two cinnamate moieties with a malonyl compound with subsequent hydroxylation and serial methylation to form the final product.

The fact that the two demethoxy forms of curcumin (II & III) were seen at a lower level in the rhizomes, with a correspondingly high curcumin I indicates the conversion of the fully methylated form at the expense of these compounds.

Curcuminoids in the pooled rhizome samples exhibit a similar pattern, where maximum levels of curcumin I was observed at 180 DAS. The only difference was that DC and BDC are present in equal proportion, except at stage III & IV ,where it was proportionately low as compared to curcumin I.

The present results indicate that the methylated form of curcuminoids is maximum at later stages, which is correlated with the lower concentration of the two other forms. Further studies on biosynthetic enzymes are needed to confirm this.

References

ASTA 1985. Official Analytical Methods of the American Spice Trade Association, Third Edition, P 40.

Geissman T A & Crout D H G 1969. Organic chemistry of secondary plant products. Freeman Cooper, San Fransisco.

Govindarajan V S 1980. Turmeric- Chemistry, Technology and Quality. In : *CRC* Critical Reviews in Food science and Nutrition 12 : 199.

Hans R 1995. Recent Progress in the study of anticancer drugs originating from plants and traditional medicine in China. Chinese Medical Journal 108 : 729.

Majeed M, Badmev V & Rajendran R 1999. US patent 5, 861, 415, July 19.

Rao T S, Basu N & Siddiqui H H 1982. Anti -inflammatory activity of curcumin analogues. Indian J. Med.Res. 75 : 574-579.

Sharma O P 1976. Antioxidant activity of curcumin and related compounds. Biochem Pharmac. 25 : 1811.

Soudamini K K & Kuttan R 1989. Inhibition of chemical carcinogeneis by curcumin. J. Ethnopharmacology. 27(1-2) : 227.

Srimal R C & Dhawan B N 1973. Pharmacology of diferuloyl methane (curcumin), a nonsteroidal anti inflammatory agent. J.Pharm. Pharmac. 25 : 447.

Tonneson H H 1995. Chemistry, Stability and Analysis of curcumin, a naturally occuring drug model. Oslo. 1986 : 15.

Verghese J 1999. Curcuminoids- the magic dye of *Curcuma longa* L. rhizome. Indian Spices 36(4) : 574.

Major chemical constituents of nut, mace and leaf of *Myristica fragrans*

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Abstract

Nutmeg *Myristica frangrans* Houtt is a very important tree spice, having both industrial and medicinal applications. Nut and mace are commercially important spice products. It is also a unique spice, which causes hallucination if consumed in large quantities. The nutmeg plants maintained at IISR experimental farm, Peruvannamuzhi contained 2-12% oil in nut, 3-15% in mace and 0.5-2% in the leaf. Myristicin and elemicin, two constituents of the oil, known to cause hallucination are present in all the three parts. The concentration of these constituents vary widely in these three parts.

Key words : chemical constituents, elemicin, mace, *Myristica fragrans*, ,myristicin.

Introduction

Nutmeg, *Myristica fragrans* is an important tree spice having lot of applications in industrial and medicinal fields. Nut and mace are commercially very important. Nutmeg is the kernel of the seed and mace is the dried aril that surrounds the single seed within the fruit. It is a spreading evergreen tree, usually dioecious, which is native to Moluccas in the East Indian Archipelago belonging to the family Myristicaceae. Mace is more expensive than nutmeg. Both nut and mace are used as spices and in medicine. The essential oils are similar in both spices. The flavours of them are distinctive. Nutmeg is used in small quantities to flavour mild dishes, cakes, punches and possets. Mace is used to flavour savory dishes, pickles and ketchups.

Nutmeg is known to have stimulative, carminative, astringent and aphrodisiae properties. Oil of nutmeg is used for flavouring food products and liquors, in perfumery, for scenting soaps etc. Nutmeg butter is used as a mild external stimulant. The volatile oil present in both spices contain myristicin and elemicin which are narcotic and poisonous which prevent large scale consumption of it. (Purseglove *et al.* 1981). Being an introduced crop with few seedlings, we cannot expect much genetic variability in the nutmeg trees grown in Kerala. However, variability was seen in the secondary metabolites like nutmeg oil, mace oil, starch, protein, leaf oil etc. An attempt has been made to characterise few nutmeg accessions based on the nutmeg butter, volatile oil, leaf oil, myristicin and elemicin levels.

Materials and methods

Nutmeg accessions maintained at Indian Institute of Spices Research, Experimental Farm Peruvannamuzhi were used for the study. The naturally splitting fruits are harvested. The nut and mace are separated and dried under shade. The mace is removed separately and dried. After removal of mace, nutmegs are dried in their shells. The dried kernel and mace are used for the study. Butter was extracted from the kernel using petroleum ether. (Sadasivam Manickam 1992). Saponification value of the butter was estimated. Protein, starch, reducing sugars and phenol content were also estimated. Essential oil was estimated using the hydrodistillation method using Cleavenger trap and oleoresin was extracted using acetone by the cold percolation technique. (ASTA 1968) constituents of the oil were detected in gas chromatograph. Gas Chromatographic profile was carried out in a HS-40 Perkin-Elmer GC equipped with a 1022 GC plus integrator. The column used was SE-30. Oven was programmed from 70-210°C at the rate 5°C/min. The compounds were identified using reports of authentic standards.

Results and discussion

Levels of oil, oleoresin, myristicin and elemicin content in the oil are listed in Table 1. Myristicin and elemicin are known to be the major hallucinogenic compounds present in the oil. The essential oil in the nut ranged from 4.5 to 12.4 % and the mace ranged from 4.9 to 15.8%. Purseglove *et al.* (1981) reported upto 21% oil in nut and mace. Mallavarapu and Ramesh

(1998) reported 4.5% oil in nutmeg and 10.5% in mace. Gopalakrishnan (1992) reported 6.6% in nutmeg and 9.2% in mace. He has carried out the proximate analysis of nutmeg and mace. He has reported myristicin as the major hallucinogenic principle. The variability in myristicin and elemicin in both nut and mace are remarkable. Myristicin content in the nut oil ranged from 1.3 to 17.6% and in the mace oil it ranged from 4.3 to 22%. Elemicin content ranged from 0.6 to 19.8% in nut and 1.9 to 18.4% in mace. Similar observation is evident in nutmeg butter and saponification value. Butter content ranged from 25 to 42% in kernel and the saponification value from 202% to 244%. The butter percentage and saponification value of the same is given in Table 2. Saponification value is an indication of fatty acid present in the fat. The main fatty acid present

Table 1. Levels of oil, oleoresin, myristicin and elemicin in the accessions.

Acc.No.	Ess.oil (%)		Oleoresin (%)		Myristicin in oil (%)		Elemicin in oil (%)	
	Nut	Mace	Nut	Mace	Nut	Mace	Nut	Mace
A4-22	4.5	4.9	13.5	10.8	1.3	4.4	1.7	2.5
A9-79	6.0	6.8	3.6	9.18	10.8	20.4	1.3	1.9
A9-150	12.4	9.7	4.2	7.5	5.3	0.7	0.6	5.9
A9-41	9.0	10.0	4.8	3.2	17.6	22.0	14.2	18.4
A9-72	9.0	11.0	4.2	7.5	7.5	14.2	11.5	17.0
A9-12	9.0	11.0	17.0	5.3	4.4	7.14	12.0	13.3
A9-69	6.0	11.6	7.3	3.1	1.3	-	5.2	-
A9-86	9.9	15.8	4.4	2.5	4.9	4.3	19.8	19.3
Mean	8.2	10.10	7.3	6.1	8.8	10.4	8.3	11.2
S.D.	2.4	3.1	4.7	2.9	5.4	8.4	7.0	7.5

Table 2. Levels of butter and saponification value.

Acc. No.	Butter (%)		Saponification value
	Nut	Mace	Nut
A4-22	24.0	23.0	241.4
A9-79	42.0	18.0	224.0
A9-150	25.0	42.0	220.0
A9-41	29.0	24.0	235.0
A9-72	38.0	27.0	230.0
A9-12	37.0	19.0	202.0
A9-69	27.0	25.0	224.0
A9-86	40.0	19.0	225.0
Mean	32.75	24.63	225.13
S.D.	6.78	7.23	109.0

Table 3. Leaf oil levels and profile in 15 accessions.

Acc. No.	Leaf oil (%)	Myristicin in oil (%)	Elemicin in oil (%)
A11-70 Male	1.5	11.9	0.9
A11-70 Bisexual	2.5	8.5	0.6
A11-70 Female	1.0	3.2	0.4
A11-70 Female	1.2	9.6	1.2
A11-70 Male	1.4	0.3	0.3
O3-Bisexual	1.0	0.8	0.8
A9-17 Bisexual	1.0	7.2	0.4
A4-35 Male	1.0	0.7	1.8
O6-Female	1.25	0.5	0.5
O4-Male	1.25	3.6	5.6
O7-Female	0.99	0.4	0.3
A9-27 Male	1.24	0.7	0.3
A9-25 Female	2.2	11.8	7.2
A9-18 Female	1.25	4.9	0.3
A9-26 Male	0.98	0.7	0.7
Mean	1.3	4.3	1.4
S.D.	0.45	4.4	2.0

Table 4. Total phenol, protein, starch and reducing sugars in nutmeg accessions.

Acc. No.	Protein (%)		Starch (%)	Reducing Sugars (mg/g)	Phenol (mg%)
	Nut	Mace	Nut	Mace	Mace
A4-22	11.5	17.8	25.0	1.3	412 A9-
79	7.4	10.5	30.8	1.5	208 A9-
150	8.9	8.2	26.9	2.8	109 A9-
41	4.5	11.0	32.8	2.2	155 A9-
72	4.5	10.6	37.2	3.0	130 A9-
12	4.8	10.5	35.5	1.45	285 A9-
69	8.8	17.2	31.1	1.86	458 A9-
86	6.2	12.7	27.9	13.34	165
Mean	7.0	12.3	30.9	2.2	240 S.D
2.3	3.2	3.9	0.78	132	

in nutmeg butter is myristic acid. Leaf oil content and the myristicin and elemicin level are presented in table 3. Very good variability exist in the leaf oil and myristicin content. Male and female plants did not show any specific property with regard to these constituents. The variability noticed in protein content, starch, phenol and reducing sugars (Table 4) also establish the fact that good variability exist among the plants for these characters and they can be exploited and shortlisted for better chemical quality.

References

ASTA 1968. Official methods of the American Spice Trade Association, New York.

Gopalakrishnan M 1992. Chemical composition of nutmeg and mace. Journal of Spices and Aromatic Crops 1 : 49 – 54.

Mallavarapu G R & Ramesh S 1998. Composition of essential oils in nutmeg and mace. Journal of Medicinal and Aromatic Plant Sciences 20 : 746 – 748.

Purseglove J W, Brown E G, Green C L & Robins S R J 1981. Nutmeg and mace in Spices Volume I, Longman New York p . 174 – 228.

Sadasivam S and Manickam A 1992, Lipids in Biochemical methods for Agricultural Sciences, Wiley Eastern Limited, Madras, p. 22 – 32.

Major essential oil components of two species of *Syzygium*, *S. travancoricum* and *S. tamilnadensis*

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Abstract

Syzygium travancoricum, a critically endangered plant and *Syzygium tamilnadensis* belonging to the family Myrtaceae are endemic to the south western ghats and require specific 'niche' for their growth i.e fresh water swamps. Due to disturbances and shrinkage in their habitat, their population has been reducing alarmingly and attribution of any economic value in terms of their medicinal property, would add to their conservation value. The leaves possess characteristic aroma and solvent extracts of (hexane and chloroform) leaves exhibit anti-fungal activity. In the present study essential oils from the fresh leaves of the two species were hydrodistilled and the major components have been identified to be trans-ocimene, caryophyllene and copaene.

Keywords: essential oil, *Syzygium tamilnadensis*, *Syzygium travancoricum*

Introduction

Syzygium, a genus represented by herbs and shrubs with over 75 species known in India belongs to the family *Myrtaceae*. The genus is of commercial importance with timber yielding plants like *S. aqueum*, *S. bracteatum*, fruit yielding *S. cuminii* and *S. aromaticum* yielding commercially important clove. The fruits of many species of this genus are edible and some are medicinally important (Anonymous 1956).

The genus Myrtaceae is known well for its rich source of essential oils and in this study two species namely, *Syzygium travancoricum* and *Syzygium tamilnadensis* endemic to the southern western ghats were selected for the analysis of the essential oil content. *Syzygium travancoricum* (a critically endangered spp.) and *Syzygium tamilnadensis* are tall trees (8-10 m), occurring at an altitude of 700-1500m above sea level. *S. travancoricum* prefers a specific 'niche' for its growth i.e. fresh water swamps. The bark of the plants is used in local medicine and the fruits are edible. Habitat destruction due to anthropogenic pressures and neglected conservation practices have resulted in the reduction of their population leading to endangered state. Therefore, any importance attributed to the species will increase the conservational value and in the present study the essential oils were analysed from these two species, the crude solvent extract of which exhibited anti-fungal activity against pathogenic fungi like *Candida albicans*, *Trichophyton mentagrophytes*, *Pestalotiopsis palmarum* and *Aspergillus terreus*.

Material and methods

Leaves of *S. travancoricum* and *S. tamilnadensis* were collected from Wynad area and transported for analysis by taking proper care. Fresh leaves (100g) were hydrodistilled in a Clevenger apparatus for 4h. Colorless oil was obtained in the case of *S. travancoricum* (0.12%) and pale yellow oil from *S. tamilnadensis* (0.1%). GC-MS analysis of the oils was performed in a Shimadzu QP- 5000-GCMS system using CBP1 capillary column (25m length). The identification of the components was done by direct comparison and retention times.

Results and discussion

Among the various components occurring in the leaf essential oil of *S. travancoricum*, trans ocimene has been found to be the main component constituting 69.27% of the oil (Table 1) followed by trans caryophyllene and copaene as other components. The leaf oil from *S. tamilnadensis* contained trans caryophyllene, 6-methyl-2-heptyl ketone, copaene and an unidentified compound represented in Table 2.

Caryophyllene was found to occur in all the species of *Syzygium*, and the ratio of the individual oils may vary from spp. to spp. But in the case of *S. tamilnadensis* an unidentified component (34%) has been found to occur. *S. jambos* leaf oil contained ocimene (4.7%), l-limonene (23.84%) and dl-a-pinene (26.84%). In *S. cuminii*, l-limonene, dipentene and cadalane type

Table 1. Major components of leaf essential oil of *S. travancoricum*

Component	Per cent
Trans Ocimene	69.27
Trans Caryophyllene	11.16
Copaene	2.84

Table 2. Major components of leaf essential oil of S. tamilnadensis

Component	Per cent
Trans Caryophyllene	17.77
Copaene	5.96
6-methyl-2-heptyl ketone	1.04
Unidentified	34

sesquiterpenes were the major components. Eugenol is the major component in clove leaf essential oil (Anonymous 1956). In *S. cordatum* limonene and globulol were the major components (Chisowa *et al.* 1998).

The genus *Syzygium* has been studied extensively for bioactive components and is exemplified by the bacterial and fungicidal effects of clove oil. Yu and Robyt (1998) assessed the inhibition of dental plaque of clove water extracts. The various solvent extracts of *S. aromaticum* and *S. guineense* possessed antibacterial activity against *Shigella, Salmonella typhi, E. coli* and *Enterobacter* a (Ali *et al.* 1996, Tsakala *et al.* 1996). Chattopadhyay *et al.* (1998) reported that *S. cuminii* was the most potent when compared with *S. andamanicum* and *S. samarangense* against bacteria. *S. aromaticum* possessed anti-fungal activity against *Candida albicans, Aspergillus fumigatus* and *Trichophyton mentagrophytes* (Guerin and Reveillere 1985). The hexane extracts of the selected species in the present study possessed anti-fungal properties (Radha *et al.* 1999) indicating that the essential oils could be the active components for the activity exhibited against *Trichophyton mentagrophytes* and *Aspergillus terreus*. The findings from this study support the assumption that the essential oils could be the components (active principles) in the solvent extracts and further study in this direction will add value to these endangered species, promoting their conservation.

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References

Ali Md A, Hussain Md M, Sheikh S & Haque Md. M 1996. Screening of different solvent extracts of clove (flower buds of *Syzygium aromaticum*) for antibacterial activity. Bangladesh J Sci Ind Res. 31:141-146.

Anonymous 1956. The Wealth of India, CSIR publication.

Chattopadhyay D Sinha B K & Vaid L K 1998. Antibacterial activity of *Syzygium* species. Fitoterapia 69 (4) : 365-367.

Chisowa E H, Sakala G, Hall D R & Farman D I 1998 Composition of the essential oil of *Syzygium cordatum* Hochst. ex Krauss. J Essen Oil Res. 10 (5) : 591-592.

Guerin J C & Reveillere H P 1985. Antifungal activity of plant extracts used in therapy. II. Study of 40 plant extracts against 9 fungal species. Annales-Pharmaceutques-Fracaises 43(1) : 77-81.

Radha R, Mohan M S S & Ajith Anand 1999. "Antifungal properties of crude leaf extracts of *Syzygium travancoricum*". In : The "National seminar on the research and development in aromatic plants: current trends in biology, uses, production and marketing of essential oils" at CIMAP, Lucknow, 30-31 July, 1999.

Tsakala T M, Penge O & John K 1996. Screening of antibacterial activity from *Syzygium guineense* (Willd) hydrosoluble dry extract. Ann. Pharm. Fr. 54 : 276-279.

Yu L & Robyt J E 1998. Effects of water soluble constituents of clove on the activities of glucansucrases and the potential for the inhibition of dental plaque formation. Carbohydr. Lett. 3 : 9-16.

Constituent analysis of essential oil of fruits of *Foeniculum vulgare*

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Abstract

Essential oils are widely used in food industry to render the food products more attractive to human taste. Ten genotypes of *Foeniculym vulgare* (dried fruits) were evaluated for essential oil contents and analysed by GLC. The main constituents i.e. anethole, methyl chavicol and fenchone were found to vary in these genotypes. The anethole content ranged from 19.9 to 72%, methyl chavicol ranged from 5.4 to 57% while fenchone content ranged from 4.5 to 13%. The amount of anethole content was higher in indigenous variety RF 101 as compared to variety RF125 which was developed from an exotic collection.

Key words: essential oil, fennel, *Foeniculum vulgare*, oil constituents.

Introduction

Essential oils are widely used in food industry. The main purpose is to render food products more attractive to human taste. They are widely used due to their anti microbial, anti oxidative, colouring, flavouring and preservative properties. The preservative property of spices has been attributed to the presence of some anti microbial principles contained in their oils (Sreenivasa Murthy & Krishana Murthy 1959). Coriander, cumin, fennel, clove etc. are some examples of spices that contain important essential oils used in food industry. They are reported to have anti microbial properties (De *et al.* 1999). Essential oils and their constituents are also used in major aroma chemical industries. Anethole, linalool, geraniol, citronellol etc. are having world wide demand. These constituents can be detected by gas liquid chromato graphy. The amount of these constituents vary from variety to variety. The volatile oil constituents of spices and aromatic plants were earlier reported by Akgul & Bayrak 1988, Afsharypuror *et al.* 1996, Thoppiel 1996, Baser *et al.* 1996 and 1997. In the present study, different genotypes of fennel are analyzed for its constituents to exploit it for value addition purpose.

Materials and methods

The essential oil contents from 10 genotypes of fennel were evaluated using clevenger apparatus (Guenther 1955). These genotypes were received from different states and were grown at agricultural farm, S K N College of Agriculture, Jobner under All India coordinated varietal trial. Essential oils obtained from these genotypes were made moisture free by using anhydrous sodium sulphate and stored in glass vial. These samples were subjected to gas chromatgraph model 4000 (FID) with a stainless steel column packed with SE –30 (10%) deposited over chromosorb w. The initial and final temperature of column was maintained at 100 and 240^0 C. Nitrogen gas was used as carrier. The identity of the constituents was ascertained by comparison of relative retention time compared with that of authentic standard. The % of main components i.e. anethole, fenchone, methyl chavicol, limonene and pinene were recorded.

Results and discussion

The quantity of essential oil constituents varied in different varieties. The percentage of main components i.e. anethole, methyl chavicol, fenchone, limonene and pinene are presented in Table 1. The anethole, methyl chavicol and fenchone varied from 19.9 to 72.1%, 5.4 to 57.3%; and 4.5 to 13%, respectively. Karlson *et al.* (1969) found that the essential oil of sweet fennel contains upto 90% anethole and absence of fenchone imparts for sweet flavour. Baser *et al.* (1977) reported anethole 87.33% as a major constituent in *Foeniculum vulgare* from Uzbekistan. In the present study, a maximum of 72% anethole was found in HF-33 and RF-101 followed by 70% in PF-35, JF-186 and PF-51. Minimum anethole (20%) was recorded in RF-125, a variety developed from exotic material received from Italy. This variety is having highest methyl chavicol i.e. 57% increase as compared to other varieties which contain methyl chavicol in the range of 5 to 10%. The other variety which contains more methyl chavicol is

Table 1. Essential oil constituents in different genotypes of *Foeniculum vulgare*.

Genotype	Origin	Essential oil%	Anethole %	Methyl chavicol %	Fenchone %	Limonene %	B pinene %
HF-33	Haryana	1.4	72.16	5.54	13.09	0.53	5.15
RF-101	Rajasthan	1.4	71.95	5.42	12.12	0.71	6.23
PF-35*	Gujarat	1.4	70.37	8.00	10.80	0.85	6.29
JF-186	Gujarat	1.5	70.30	7.42	11.83	1.00	6.21
PF-51*	Gujarat	1.4	69.50	9.70	9.38	1.09	7.10
Local	Rajasthan	1.3	67.97	9.00	11.44	0.97	6.62
HF-39	Haryana	1.3	67.08	12.41	9.67	0.83	6.90
JF-200	Gujrat	1.4	61.85	10.51	10.66	0.91	8.45
JF-192	Gujrat	1.3	55.90	19.25	11.60	0.86	7.95
RF-125	Rajasthan	2.0	19.90	57.30	4.50	2.42	13.70

* Genotypes received from Bihar.

JF-192. Both the varieties are bitter in taste as compared to other genotypes. It seems that bitterness is due to the presence of high methyl chavicol in these genotypes. Anethole contents in all these genotypes are in the range of 77 to 78%. In these genotypes, most of the methyl chavicol is converted to anethole. However in RF- 125 and JF-192, it may not be converted to anethole to that extent. RF-125 is an early maturing variety compared to other varieties which matures 10 to 15 days early. Bells (1968) has reported that anethole and fenchone contents varied with the stage of development. Anethole has more export value as compare to methyl chavicol.

In summary, the main essential oil constituents of fruits of *Foeniculum vulgare* were found to be anethole, methyl chavicol and fenchone. The amount of these compounds present were found to vary with varieties.

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References

Afsharypuror S, Asgary S & Lockwood G B 1996. Constituents of essential oil of *Achillea wilhelmsii* from Iron. Planta Medica 62 : 77-78

Akgul A & Bayrak A 1988. Comparative volatile oil composition of various parts from Turkish bitter fennel (*Foeniculum vulgare* var. *vulgare*). Food chem. 30 : 319-23.

Baser K H C, Ozek T, Duman H & Guner A 1996. Essential oil of *Pimpinella aromatica* Bieb from Turkey. J.Essential Oil Research 8 : 463-64.

Baser K H C, Ozek T, Nuriddinov, Kh.R, Nigmatullaev A M, Khadizimatov K Kh & Aripov Kh N.1997. Essential oil of *Mediasia macrophylla* Pimen and *Foeniculum vulgare* Mill from Uzbekistan. J.Essential Oil Research 9 : 249-50.

Bells T J 1968. J. Phar . Pharmacol. 20 : 409. Cited: Chem Abstr. 69, 26140, 1968.

De Minakshi, De A K & Banerjee A B 1999. Screening of spices for antimicrobial activity. J. Spices Aromatic Crops 8 : 135-144.

Guenther E 1955. The Essential Oils vol I P. 147, D Van Nostrand Co. Inc. Toronto, New York, London.

Karlson J, Sevensen A B, Chirgova B & Zolotovich G1969. Plant Med 17 : 281.cited : Chem. Abstr.

Kraus A & Hammer Schmidt F J 1980. Dragoco report 27 : 31.

Sreenivasa Murthy V & Krishna Murthy K 1959. Place of spices and aromatics in Indian dietary. Food Sci. 8 : 284-294.

Thoppil J E 1996. Contribution to the study of essential oil biosynthesis in eight varieties of *Ocimum basilicum* L. Acta Pharmaceutica 46 : 195-199.

GC-MS studies on essential oil from *Carum carvi* L.

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Abstract

Caraway (*Carum carvi* L.) seeds for experimental studies were obtained from Kumaon region of U.P. On hydrodistillation seeds gave 3.5 percent oil on dry weight basis. On GC-MS examination the oil was found to contain carvone as major constituent, 81.5 percent. The other constituent identified were citronellyl acetate, dihydro carvone, eugenol, isolimonene and limonene oxide. Constituents found in traces were Δ^3 carene, camphene, carophyllene, carveol, p cymene, dihydro carveol, linalool, p-mentha-2,8-dien-1-ol, myrcene, α-pinene, β-pinene, phellandrene, sabinene, α-terpinene & terpinelene.

Introduction

Caraway (*Carum carvi* Linn) is a member of family Apiaceae , Umbliferae characterized by carminative properties like that of anise , cumin , dill and fennel . It is grown for the medicinal properties of its fruits as well as for its oil. The plant is cultivated in Northern Europe, chiefly in Holland and Central Asia. In Northern Himalayan region it is grown as a summer crop in Kashmir, Kumaon and Garwal at the altitude of 2500 to 4000 meters. The oil of seeds is used as flavouring material in various food articles and in medicines as carminative, stomachic, diuretic and as masking agent for bad testing pharmaceutical preparations. It is also employed in soaps and cosmetics for perfuming. Dry seeds are used in bakery for flavoring .

Lawrence (1980 , 1982) examined caraway oil and identified several compounds . Several other workers reported different compounds from its oil . But no detailed study of the Kumaon essential oil was reported . So the details of CG-MS study of the oil from Kumaon raised crop was undertaken and reported here.

Materials and methods

The seeds for experimental studies were procured from Kumaon region of U.P. On hydro-distillation the seeds gave 3.50 percent essential oil, on dry weight basis, having yellow colour and characteristic aromatic caraway odour.

The oil was examined for its physico-chemical properties and the chemical composition by GC-MS. Physico-chemical properties were examined by the method described by Gunther, Vol I. The oil was examined by GC-MS for its chemical composition. GC-MS data was collected on GC-MS model HP 5996 coupled with computer library of 80,000 compounds and fitted with a WACOT SE-30 (methyl silicon gum)capillary coloumn of 12M´0.22mm .

The other conditions were maintained as below

Carrier gas	-	Helium
Flow rate	-	40ml/sec.
Injector temperature	-	230⁰c
Chromatographic temperature with rising rate	-	40⁰c to 290⁰c
Scan parameter	-	40-800 mass range

Results and discussion

The results of the above observations are given in tables 1 and 2.

On GC-MS examination the oil was found to

Table 1. Physico - chemical properties of caraway seed oil.

Refractive Index$^{15}_{d}$	1.4951
Sp . gravity$^{15}_{15}$	0.9365
Optical rotation $[\alpha]^{15}_{D}$	+78⁰
Sap value	70.00
Sap. value after acetylation	140.00
Carbonyl percentage as carvone	85 percent
Solubility in 90 percent alcohol	1:1

Table 2. The percent composition of the components of the essential oil of *carum carvi* L.

Compound	Percentage
Hydrocarbon	
Δ^3 carene	0.12
Camphene	0.12
Caryphyllene	0.50
p-cymene	0.13
Iso-limonene	2.73
Myrcene	0.12
α-pinene	0.12
β-pinene	0.11
β-phellandrene	0.20
Sabinene	0.16
α-terpinene	0.08
Terpinolene	0.10
Oxide	
Limonene oxide	4.36
Alcohol	
Carveol	0.32
Dihydro carveol	0.21
Linalool	0.10
p-mentha-2,8-diene-1-ol	0.52
Ketone	
Carvone	81.5
Dihydro carvone	3.91
Ester	
Citronellyl acetate	0.62
Phenol	
Eugenol	2.09

contain 21 compounds. Carvone was the major constituent. Other constituents with minor on entrations were caryphyllene 0.50, carveol 0.32, citronellyl acetate 0.62, dihydro carveol 0.2, dihydrocarvone 3.91, eugenol 2.09, isolimone 2.73, limonene oxide 4.36, linalool 0.10, p-mentha-trans-2, 8-dien-1-ol 0.52. The oil also contained several hydrocarbons like Δ^3 carene, p-cymene, camphene, myrcene, α-pinene, β-pinene, β-phellandrene, sabinene and α-terpinene and terpinolene in small amounts. Carvone is the chief constituent of the oil and its flavour and odour is manily contributed by it. Indian Pharmacopoeia prescribed the concentration not less than 53 percent and not higher than 63 percent. So pharmaceutically the oil may find application after partially removing the carvone content and bringing it to the required level. However it may well find application in flavours as masking agent in bad tasting pharmaceutical preparations and insecticides. Decarvonised oil may be used in scenting laundry products.

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References

Anonymous 1986. Essential oils and oleoresins. A study of selected products and major markets. International Trade Center, UNCTAD/GATT, Geneva, p. 208.

Brog-Karison A K & Valterova I 1994. Volatile compounds from flowers of six species in the family Apiaceae. bouquets for different pollinators. Photochemistry 35(1) : 111-19.

Copra R N, Chopra I C & Nayer S L 1956. Glossary of Indian Medicinal Plants, CSIR, New Delhi, p-53.

Guenther E 1950. The Essential Oils, Vol IV. D. Van Nostrand Co.Inc. New York, P 752.

Gunther E 1972. The Essential Oils, Vol.I, D. Van Nostrand Co. Inc. New York, p. 229-348.

Handa K I, Chopra I C & Sobti S N 1957. Aromatic Plant Resources of Jammu and Kashmir. J. Science Ind. Res. 16A(5) : 1-28.

Lawrence B M 1980. Newtrends in essential oils. Perfumer Flavorist 5(4) : 6-16.

Lawrence B M 1982. Progress in essential oils. Perfumer Flavorist 7 : 20-21.

Salveson A, Baerheim-Svendson A 1976. Gas liquid chromatographic separation and identification of the constituent of caraway seed oil. Plant Med. 30 : 93-96.

The Wealth of India 1950. Vol 2, C.S.I.R, New-Delhi, p.89.

Toxopeus H & Boawmeester H J 1992. Improvement of caraway essential oil and carvone production in the Netherland, Ind. Crops Prod. 1(2-4) : 295-301.

Schantz M V & Ek B s 1971. On the formation of essential oil in caraway, Sci. Pharm. 39(2) : 82-101.

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