“Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems.”

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B.Sc. (Hons.) Horticulture

MASTER OF SCIENCE IN HORTICULTURE

(PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS)

DEPARTMENT OF PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS

HORTICULTURAL COLLEGE AND RESEARCH INSTITUTE

ANANTHARAJUPET - 516 105, Y.S.R DISTRICT, ANDHRA PRADESH

Dr. Y.S.R. HORTICULTURAL UNIVERSITY

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BY

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THESIS SUBMITTED TO

Dr.Y.S.R. HORTICULTURAL UNIVERSITY

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN HORTICULTURE

(PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS)

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July, 2015

DECLARATION

I, **Mr. B.MAHENDER,** hereby declare that the thesis entitled "**Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems"** submitted to Dr. Y.S.R. Horticultural University, Venkataramannagudem for the degree of Master of Science in Horticulture (Plantation, Spices, Medicinal and Aromatic crops) is the result of original research work done by me. I declare that no material contained in the thesis has been published earlier in any manner.

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CERTIFICATE

Mr. B. MAHENDER has satisfactorily prosecuted the course of research and that the thesis entitled "**Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I certify that neither the thesis nor its part thereof has been previously submitted by him for a degree of any university.

Place: ANANTHARAJUPET **(Dr. P.SYAM SUNDAR REDDY)**

Date : **Chairman**

CERTIFICATE

This is to certify that the thesis entitled "**Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems"** submitted in partial fulfillment of the requirements for the degree of Master of Science in Horticulture (Plantation, Spices, Medicinal and Aromatic crops) of Dr. Y.S.R Horticultural University, Venkataramannagudem, is a record of the bonafide research work carried out by **Mr. B.MAHENDER** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigation have been duly acknowledged by the author of the thesis.

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Date: ***B. Mahender....***

LIST OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF PLATES

LIST OF APPENDICES

:

List of symbols and abbreviations

%	:	Per cent
@	:	At the rate of
^{0}C	:	Degree Celsius
AOAC	:	Association of Analytical Communities
B:C ratio	:	Benefit cost ratio
CD	:	Critical difference
cm	:	Centimetre
cm^2	:	Square centimetre
cv.	:	Cultivar
DAP	:	Days after planting
dm^2/plant	:	Decimeter square per plant
dsm^{-1}	:	Decisiemens per meter
et al.	:	And others
etc.	:	And so on; and other people / things
Fig.	:	Figure
FRBD	:	Factorial Randomised Block Design
FYM	:	Farm Yard Manure
g	:	Gram
g/lit	:	Grams per litre
ha^{-1}	:	Per hectare
i.e.,	:	That is
kg	:	Kilograms
Kg/plot	:	Kilograms per plot
kg/ha	:	Kilograms per hectare
kg/m^2	:	Kilograms per square meter
ℓ	:	Litre
LAI	:	Leaf area meter
m	:	Meter

m^2	:	Square meter
m^{-2}	:	Per meter square
MD	:	Man days
ml	:	Millilitre
ml/lit	:	Millilitre per litre
mm	:	Millimeter
MSL	:	Mean sea level
MT	:	metric tonnes
No.	:	Number
NPK	:	Nitrogen, Phosphorus and Potassium
NS	:	Non-significant
NVEE	:	Non volatile ether extract
$Plant^{-1}$	:	Per plant
p^H	:	Puissance de hydrogen
$Rs.ha^{-1}$	:	Rupees per hectare
$Rs.\ t^{-1}$	:	Rupees per tonne
S.Em ±	:	Standard error mean
t	:	Tonne
t/ha	:	Tonne per hectare
$t\ ha^{-1}$	:	Tonne per hectare
viz.,	:	Namely
W.P	:	Wettable powder

Name of the author	**:**	B. Mahender
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ABSTRACT

The present experiment is a series of two separate experiments conducted simultaneously under coconut and mango cropping system during May to December-2014 at Horticultural College and Research Institute farm, Dr.Y.S.R. Horticultural University, Anantharajupet, Y.S.R. Dist., Andhra Pradesh. Each experiment was laid out in a randomized block design with factorial concept with three seed rhizome sizes of ginger *viz.,* 20 g, 30 g and 40 g and five plant spacings *viz.,* 25 cm X 15 cm, 25 cm X 25 cm, 30 cm X 20 cm, 30 cm X 30 cm and 40 cm X 20 cm. Fifteen treatment combinations were replicated thrice.

Under coconut cropping system, among the seed rhizome sizes, rhizome size of 40 g recorded maximum number of tillers per plant (2.97, 10.55 and 11.51), plant height (16.68 cm, 43.25cm and 67.87 cm) and number of leaves per plant (12.01, 104.52 and 115.36) at 30, 120 DAP and at harvest. Leaf length, leaf breadth, leaf area and leaf area index were found to be significantly maximum under 40 g seed rhizome size (18.94 cm, 2.07 cm, 21.70 cm^2 and 3.59 respectively). Similarly 40 g seed rhizome size took least number of days to first sprouting and 50 percent sprouting. Among yield and yield attributing parameters, rhizome length (15.82 cm), rhizome breadth (15.89 cm), yield per plant (204.01 g), yield per plot (3.29 kg), yield per hectare (27.41 t) and harvest index (61.53%) were found to be maximum with 40 g rhizome size. Quality parameters *viz.,* essential oil content (1.83%), oleoresin content (7.87%), starch content (30.36%) and crude fibre content (4.90%) were also observed to be maximum from 40 g seed rhizome size.

Similarly under mango cropping system seed rhizome size of 40 g recorded maximum number of tillers per plant (3.24, 8.57 and 12.25), plant height (22.17 cm, 63.33 cm and 97.93 cm) and number of leaves per plant (16.24, 93.61 and 137.47) at 30, 120 DAP and at harvest. Leaf length, leaf breadth, leaf area and leaf area index were found to be significantly maximum from 40 g seed rhizome size (23.71 cm, 2.46 cm, 28.18 cm^2 and 4.57 respectively). Days to first sprouting and days to 50 percent sprouting was lowest from 40 g rhizome size. Among yield

and yield attributing parameters, maximum rhizome length (17.03 cm), rhizome breadth (17.16 cm), yield per plant (206.88 g), yield per plot (3.08 kg), yield per hectare (25.69 t) and harvest index (60.35%) were recorded with 40 g rhizome size. Quality parameters were also observed to be maximum from 40 g seed rhizome size.

Among different plant spacings, 30 cm X 30 cm spacing showed maximum values for number of tillers per plant (2.64, 10.93 and 11.64) and number of leaves per plant (10.69, 104.47 and 106.09) at 30, 120 DAP and at harvest under coconut cropping system. Leaf length, leaf breadth and leaf area (18.96 cm, 2.09 cm and 22.13 cm^2) were highest with 30 cm X 30 cm spacing. However, highest leaf area index (5.25) was recorded from spacing of 25 cm X 15 cm. Days to first sprouting (12.78) and days to 50% sprouting (20.67) were reported to be lowest from 30 cm X 30 cm spacing. However, the plant height was highest (16.34 cm, 42.47 cm, and 65.07 cm) from a closer spacing of 25 cm X 15 cm at 30, 120 DAP and at harvest. With regard to yield and yield attributing parameters, maximum rhizome length (14.90 cm), rhizome breadth (14.67 cm) and yield per plant (203.02 g) were observed from a wider spacing of 30 cm X 30 cm. Whereas, yield per plot (3.17 kg), yield per hectare (26.40 t) and harvest index (60.37%) were recorded from closest spacing of 25 cm X 15 cm.Quality parametrs were also found to be good under 30 cm X 30 cm spacing.

Similarly under mango cropping sysytem, 30 cm X 30 cm spacing showed maximum values for number of tillers per plant (3.00, 8.36 and 12.36) and number of leaves per plant (14.64, 97.02 and 135.20) at 30, 120 DAP and at harvest. Leaf characters were highest with 30 cm X 30 cm spacing. However, leaf area index (6.61) was highest from spacing of 25 cm X 15 cm. Days to first sprouting (10.11) and days to 50% sprouting (19.11) were minimum from 30 cm X 30 cm spacing. Plant height was maximum (21.20 cm, 63.40 cm, and 98.20 cm) from a closer spacing of 25 cm X 15 cm at 30, 120 DAP and at harvest. Maximum rhizome length (16.54 cm), rhizome breadth (17.12 cm) and yield per plant (200.93 g) were observed from a wider spacing of 30 cm X 30 cm. Whereas, yield per plot (3.09 kg), yield per hectare (25.77 t) and harvest index (58.93%) were recorded from closest spacing of 25 cm X 15 cm. The data on quality parameters showed indifferent values with plant spacing.

Among the interactions 40 g seed rhizome size with 30 cm X 30 cm plant spacing recorded highest yield per plant (215.40 g and 220.80 g) under both coconut and mango cropping system respectively. However rhizome yield per plot and yield per hectare were found to be maximum (4.57 kg, 38.06 t and 3.67 kg, 30.56 t) from a closer spacing of 25 cm X 15 cm with 40 g seed rhizome size.

The highest benefit cost ratio of 4.68 and 4.30 were obtained with 20 g rhizome size with 40 cm X 20 cm spacing and 20 g rhizome size with 30 cm X 20 cm spacing under coconut and mango cropping system respectively.

Chapter-I

Introduction

Chapter I

INTRODUCTION

India is admired as ‘Spice bowl of the World’ for production of variety of spices with superior quality. From the time immemorial spices has been used for various purposes. There are records about various spices and its properties especially in the ‘Vedas’ as early as 6000 BC. India is well known for the trade, since the period of exploration of sea routes, because of its varieties of spices having superior quality, which attracted foreigners to India.

Ginger or Adrak (*Zingiber officinale* Rosc.) belonging to the family Zingeberaceae is one of the major herbaceous tropical underground stem spice originated in South-East Asia. The distinct flavour, aroma and pungency of ginger is due to oleoresins and volatile oils. Ginger rhizome contains 2-3% proteins, 0.9% fats, 2.4% fibre, 12.3% carbohydrates and is good source of vitamins, minerals and trace elements.

Ginger is commercially cultivated in many tropical and subtropical countries like India, China, Taiwan, Phillipines, Sierra-Leone, Jamaica, Fiji, Mexico, Queensland (Australia), Brazil and Nigeria. India is the largest producer of dry ginger in the world. Indian dry ginger is known in the export market as ‘Cochin ginger’ and 'Calicut ginger’. In India, ginger is cultivated in an area of 1.33 lakh hectares with an annual production of 6.55 lakh MT, contributing approximately 30 to 40 per cent of the world production (Anonymous, 2014-15). The major producing states are Karnataka, Assam, Kerala, Meghalaya, Arunachal Pradesh, Mizoram, Orissa, Sikkim and West Bengal and some parts of Andhra Pradesh under different planting conditions.

In Andhra Pradesh, 4786 hectare area is under ginger cultivation producing 95.72 thousand MT of ginger (Anonymous, 2012-13). The productivity of ginger in Andhra Pradesh is 20 tonnes per hectare. Medak, Rangareddy, Srikakulam and some parts of Visakhapatnam are the major ginger growing regions in Andhra Pradesh.

Ginger has underground rhizome which are very much branched resembling the shape of an irregular hand finger having circular scars all along the length with small scales adhering to them. The inner core of the rhizome is pale yellow with bluish tinge, while the outer is yellow. The auxiliary buds shoot up as leafy stem known as pseudo stem which dies out annually but the plant continues to live through its rhizome. Leaves are sheathing, arranged alternatively, linear lanceolate, gradually acuminate and glabrous. Flowers are born on spike produced in a peduncle different from the aerial leafy stem arising directly from the rhizome. Flowers are numerous, bisexual, irregular, epigynous, yellow in colour with dark purplish spots. Fruits which is seldom produced, is an oblong capsule; seeds are glabrous, fairly large, arillate and perispermous.

The aroma of ginger is pleasant and spicy and the flavor is penetrating, slightly biting due to antiseptic or pungent compounds present in it. Ginger is also used for the manufacture of ginger oil, oleoresin, soft drink like cordials, ginger cocktail and carbonated drinks etc. Ginger preserve and ginger candy prepared from green ginger are quite a favorite of many and are in great demand. A number of alcoholic beverages are prepared from ginger in foreign countries, such as ginger brandy, ginger wine, ginger beer and ginger ales etc.

According to the Ayurvedic system of medicinal, ginger is considered to be carminative, stimulant and given in dyspepsia, anemia, rheumatism, piles, jaundice and curing liver complaints. It is also prescribed as an adjunct to many tonic and stimulating remedies. The veterinary uses of ginger are as stimulant and carminative, in indigestion of horses and cattle, in spasmodic colic of horses and to prevent the griping by purgatives.

Ginger requires warm and humid climate and thrives well from sea level to an altitude of 1500 m above MSL. A well distributed rainfall of 150 to 300 mm during growing season and harvesting are required for the crop. Lateritic loamy soils are preferred for higher yields.

Development of suitable production technology to boost the crop yield is essential as the yield potential of the variety alone is not sufficient for increasing the yield (Yadav *et al.* 2013). Seed rhizome size, plant spacing and

planting methods are the important aspects of production system of ginger. It is well documented that rhizome sizes, planting methods and plant spacing have significant influences on the growth and yield of ginger (Monnaf *et al.* 2010).

Ginger is propagated vegetatively from rhizome and the length and weight of pieces used varies from place to place and variety to variety. The seed rhizome is the economic yield as well as the planting material of ginger. The use of very large seed rhizomes means the loss of the commercial product whereas the use of very small seed rhizome means reduced growth and yield (Hailemichael and Tesfaye, 2008). A direct relationship has been established between the size of planting material and final yield (Timo, 1982). Therefore, selecting the right size of planting material in terms of length and weight is a very critical factor in the cultivation of ginger.

Next to the rhizome size, Plant spacing has been recognized as a factor determining the degree of competition between plants, yield per plant and number of plants per unit area. Finding the optimum plant spacing that produce the maximum yield per unit area under given environmental conditions is of major concern. Inadequate as well as high plant population leads to low productivity with poor quality. Plant spacing had influence on growth, yield and yield components in ginger (Neopaney, 1988).

One of the feasible ways of increasing the farm level income is intercropping (Ghosh and Hore, 2011). Presently the income derived from the coconut and mango mono cropping system is not sufficient to sustain the dependent families of small and marginal farmers in Rayalaseema region of Andhra Pradesh. Growing of ginger in coconut plantation and mango orchard proves profitable without hampering the performance of the main crop and the natural resources i.e., soil, water, air space and solar radiation can be better utilized by raising the ginger as intercrop.

Considering the fact that mango is the major orchard mono crop in the Rayalaseema region of Andhra Pradesh and very little information is available on the optimum seed rhizome size, plant spacing and performance of ginger under coconut and mango cropping system the present research project entitled,

"Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems" was undertaken with the following objectives:

1. To standardize the seed rhizome size and plant spacing on growth, yield and quality of ginger under coconut cropping system.
2. To standardize the seed rhizome size and plant spacing on growth, yield and quality of ginger under mango cropping system.
3. To study the interaction effect of seed rhizome size and plant spacing under coconut and mango cropping system.

Chapter-II

Review of Literature

Chapter-II

REVIEW OF LITERATURE

Relevant and recent literature available in ginger and turmeric crops pertaining to the present field investigation entitled "Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems" has been reviewed and presented in this chapter under following sub-heads**:**

2.1 Effect of seed rhizome size on growth, yield and quality of ginger

- 2.1.1 Vegetative growth parameters
- 2.1.2 Yield and yield attributing characters
- 2.1.3 Quality parameters

2.2 Effect of plant spacing on growth, yield and quality of ginger

- 2.2.1 Vegetative growth parameters
- 2.2.2 Yield and yield attributing characters
- 2.2.3 Quality parameters

2.3 Interaction effect of rhizome size and spacing on growth, yield and quality of ginger under coconut and mango cropping system

3 Economics of ginger under inter cropping

2.1 Effect of seed rhizome size on growth, yield and quality in ginger

2.1.1 Vegetative growth parameters

Philip (1985) reported non significant variation among different planting materials with regard to different growth parameters *viz.,* plant height, number of tillers per plant, number of leaves per plant, leaf length, leaf breadth and leaf area during his both years of study in turmeric.

Balashanmugam and Vanangamudi (1988) studied the effect of planting material on growth and yield of turmeric cv. Co-1 at TNAU, Coimbatore reported that planting of full mother rhizome gave maximum germination of 94.8 percent as compared to minimum of 67.4 percent due to planting of tertiary

rhizomes. The plants produced by the full mother rhizome were the tallest (162.3 cm) with more number of leaves (23.6) and tillers (4.6).

Singh *et al*. (1988a) while using different planting materials for turmeric reported that various growth traits like plant height and number of leaves per plant were significantly more when mother rhizomes were used as planting material than primary fingers. The results are also in conformity with Singh *et al.* (1988b). Plants raised from full mother rhizomes were taller and had more tillers per plant than the plants raised from fingers (Nel, 1989).

Korla *et al.* (1989) compared different sizes of rhizomes for planting (5-10 g, 10-15 g, 15-20 g and 20-25 g) in a 3 year trial with ginger cv. Local Dharja under Solan conditions and reported that best results with regard to plant height (41.20 cm), number of tillers (7.1), number of leaves (68.60), leaf length (19.60 cm) and leaf breadth (2.7 cm) with a rhizome size 20-25 g.

Govind *et al.* (1993) used different weights of rhizome as planting material in turmeric and reported that 15-24 g weight of rhizomes recorded significantly more plant height, number of leaves per plant, length and breadth of leaves than the 9-14 g weight of rhizomes. Maia *et al.* (1995) while studying the influence of planting material on growth of turmeric reported that plants originated from the primary rhizome (average weight 19 g) had a greater leaf area than the plants originated from secondary rhizomes of 9 g weight.

Rashid *et al*. (1996) while studying the effect of different planting materials (mother, primary and secondary rhizome) on growth and yield of turmeric reported that plant height and number of leaves per plant were significantly more when the mother rhizome were used as planting material whereas primary and secondary rhizome showed no significant variation for these characters.

Yothasiri *et al.* (1997) reported that whole mother rhizome resulted in more rapid growth and development of turmeric rhizome. Mother rhizome took 39 days to 90% rhizome sprouting as compared to 41.47 and 57 days taken by

primary, secondary and tertiary rhizomes respectively.

Blay *et al.* (1998) carried an experiment to study the influence of sett size and spacing on yield of ginger and reported highest leaf area per plant (9143.96 cm^2), leaf area index (4.94) and highest number of shoots per plants (11.00) from 10 g sett size used as a planting material and lowest were recorded from 1 g sett size.

Meenakshi *et al.* (2001a) conducted an experiment to study the effect of planting material on growth of turmeric under medium black soils of Dharwad conditions reported that planting of mother rhizomes had significant influence on vegetative growth parameters like plant height (79.9 cm and 109.9 cm), number of tillers (1.2 and 1.4), number of leaves per plant (9.6 and 11.4) and leaf area (9.56 and 11.28 dm^2/plant) at 120 DAP and 150 DAP respectively as against planting of fingers.

In an experiment conducted by Alam *et al.* (2003) the growth characters like plant height, leaves per clump and tillers per clump are not affected significantly by using different planting material (mother, primary and secondary rhizome) in turmeric.

Hossain *et al.* (2005a) conducted an experiment to study effect of seed rhizome size on growth and yield of turmeric and reported that highest plant height, number of tillers per plant, number of leaves per plant and leaf area with the increased seed rhizome size.

Kumar (2005) observed maximum plant height, number of leaves per plant and tillers per plant when mother rhizome were used as a planting material compared to the primary and secondary fingers in turmeric.

Pratap and singh (2007) conducted an experiment on influence of types of rhizome and plant geometry on growth of turmeric. Results revealed that highest plant height (70.79 cm), maximum number of leaves per main shoot (10.12) and highest number of tillers per main shoot (3.47) at harvest were reported when mother rhizome used as a planting material.

An experiment was conducted to study the effect of rhizome size on growth and yield of turmeric by Hailemichel and Tesfaye (2008). Results revealed that plant height and number of tiller per plant increased with an increase in seed rhizome size (32 g) during three experimental years. Highest number of leaves per tiller was recorded from 32 g seed rhizome size in 1996 and 16 g seed rhizome size in 1997. However, during 1995 size of the seed rhizome did not any significant influence on growth.

Manhas and Gill (2010) conducted an experiment on effect of planting material on growth, yield and quality of turmeric under Punjab conditions reported that highest plant height, number of tillers per plant and number of leaves from 25-30 g sized mother rhizome. It is better than the primary (5-20 g) and secondary finger (5-10g).

Monnaf *et al.* (2010) while studying the effect of rhizome size on the growth and yield of ginger under Bangladesh conditions reported maximum values of vegetative growth parameters *viz.,* plant height (37.64 cm), number of leaves (26.47cm) from 30-35 g rhizome size. While, highest number of tillers per clump (15.94) recorded from 25-30 g rhizome size.

Sengupta and Dasgupta (2011) studied the effect of weight of planting material on growth and yield of ginger cv. Gorubathan in the hilly region of Darjeeling District. Ten different sizes of ginger rhizomes *viz.,* 10 to 100 g with an increase of 10 g were used for planting. The results revealed that rhizome pieces weighing 40 g each were found to be optimum for planting, which resulted in increase in plant height (74.58 cm), number of pseudostem per clump (4.73) and number of leaves (54.79) per plant compared to smaller rhizome size weighing 10, 20 or 30 g.

Manhas and Gill (2012) conducted an experiment on effect of different cultural practices on production of turmeric in Punjab and observed highest number of tillers per plant, leaves per plant and plant height from mother rhizome (25-30 g) using as a planting material where as minimum values were recorded with decreased rhizome size used as a planting material.

Padmadevi *et al.* (2012) conducted an experiment on effect of different grades of rhizomes on growth and yield of turmeric. Results revealed that mother rhizome (45-50 g) recorded significantly the maximum plant height (31.43 cm), number of tillers per plant (2.81), number of leaves per plant (7.20) and highest leaf area (21,012.00 $cm^2 m^{-2}$) than those from lighter finger rhizomes.

2.1.2 Yield attributing characters

Philip (1983) studied the effect of different planting material on growth, yield and quality of turmeric. He reported that the mother rhizomes (the whole mother rhizome and halves of large and medium sized rhizomes) are significantly superior to the finger rhizome with regard to fresh rhizome yield. The increase in yield of green produce per hectare in case of whole mother rhizome (35-44 g) over the finger rhizomes (9-14 g) was 59% and 32% respectively.

Tayde and Deshmukh (1986) observed significantly more number of mother, primary and secondary rhizomes of turmeric were obtained when mother rhizomes were used as planting material. Significantly less fresh rhizome yield was obtained when primary (19.50 t ha^{-1}) and secondary (15.90 t ha^{-1}) rhizomes were used as planting material as compared to full mother rhizome (25.70 t ha^{-1}).

Balashanmugam and Vanangamudi (1988) reported that the highest yield of 43.2 t ha^{-1} was obtained by planting of full mother rhizome which was significantly better than primary (38.35 t ha^{-1}) and secondary finger rhizome (38.0 t ha^{-1}). Govind *et al.* (1993) while studying on turmeric reported that the number and average size (length and thickness of mother as well as finger) of rhizomes were significantly more when mother rhizome were used as planting material than the fingers. Similarly mother rhizome gave significantly more yield per plant and per hectare as compared to finger rhizomes.

Singh *et al.* (1988a) reported that mother corm gave significantly more yield attributing characters and yield (13.47 t ha^{-1}) than when primary rhizomes were planted. Singh *et al.* (1988b) revealed that percentage increase in yield was

36% when mother rhizomes were used as planting material as compared to finger rhizomes.

The experimental findings of Korla *et al.* (1989) revealed that when 5-10 g, 10-15 g, 15-20 g and 20-25 g sized ginger rhizomes were compared in a 3 year trial were compared in a 3 year trial with cv. Local Dharja under Solan condition, rhizome weighing 20-25 g gave the best results with regard to rhizome length (13.3 cm), rhizome breadth (4.7 cm), yield per plant (122.5 g) and yield per plot (3.8 kg).

Planting of full mother rhizome (80-100 g) gave maximum rhizome yield (22.0 t ha^{-1}) as compared to use of finger rhizome (16.20 t ha^{-1}) as planting material (Singh and Kar, 1989). Aoi (1992) reported that with the increase in turmeric rhizome size from 20-29 g to 80-89 g had significant increase in fresh rhizome yield. Similarly Chattopadhyay *et al.* (1990) also reported that increase in the weight of the planting material increases the rhizome yield of turmeric than fingers.

Barholia *et al.* (1992) obtained significantly maximum fresh rhizome yield (18.40 t ha^{-1}) of turmeric when mother rhizomes were used as planting material as against primary (13.40 t ha^{-1}) rhizomes. Similar results of maximum rhizome yield with mother rhizomes were also reported by George (1993) in turmeric.

Number and weight of different rhizomes with different planting materials is an important characteristic influencing the yield in turmeric. Turmeric rhizome yield has direct positive relationship with the weight and size of mother, primary and secondary rhizomes (Singh and Tiwari, 1995).

Rashid *et al.* (1996) reported that weight of mother, primary and secondary rhizome per hill were significantly more when mother corms were used as planting material than primary and secondary cormels in turmeric. The yield of turmeric with mother corm planting (28.67 t ha^{-1}) was 47% higher than from the secondary cormel. Planting of mother corm gave the highest benefit

cost ratio of 2.61 as compared to planting of primary (2.30) and secondary cormel (2.19).

Yothasiri *et al.* (1997) advocated that maximum yield per plant as well as per unit area were obtained when full mother rhizomes were used as planting material than the primary, secondary and tertiary rhizomes. However Govinden and Wong (1995) and Chandra *et al*. (1997) revealed opposite trend that fresh rhizome yield was significantly higher when finger rhizomes were used as planting material as compared to mother rhizomes.

Blay *et al.* (1998) carried an experiment to study the influence of sett size and spacing on yield of ginger and reported highest yield per plant (47.70 g) and yield per hectare (22.06 t ha^{-1}) from 1 g sett size.

Singh *et al.* (2000) concluded that highest rhizome yield (7.36 t ha^{-1}) was realized when whole mother rhizome weighing 70-80 g was used as planting material compared to primary fingers (4.54 t ha^{-1}).

Meenakshi *et al.* (2001b) reported that use of mother rhizomes as the planting material leads to significantly higher fresh rhizome yield than that of finger rhizomes. Planting of mother rhizomes recorded significantly higher yield (13.60 t ha^{-1}) than the fingers (12.0 t ha^{-1}).

Alam *et al.* (2003) studied the response of turmeric planting material in the hilly region of Bangladesh and reported significantly higher fresh rhizome yield (25.04 t ha^{-1}) when mother rhizomes were used as planting material over the primary rhizomes. Similarly highest rhizome yield per clump (329.82 g) obtained when mother rhizomes were used as planting material than the secondary fingers (254.13 g).

Hossain *et al.* (2005a) conducted an experiment to study the effect of seed rhizome size on growth and yield of turmeric reported increased rhizome yield with an increase of seed weight.

Pratap and singh (2007) conducted an experiment to determine the influence of three types of rhizomes *viz.,* mother, primary and secondary

rhizomes on growth and yield of turmeric recorded maximum weight of fresh rhizome per clump (238.34 g), length of mother rhizome (5.17 cm) and rhizome yield (32.44 t ha^{-1}) with the use of mother rhizomes as planting material.

Ghosh *et al.* (2007) studied the effect of rhizome size on yield of turmeric with coconut inter cropping system revealed that maximum weight and dimension of primary and secondary fingers were recorded with higher seed rhizome size (30-35 g) compared to smaller seed rhizome size (20-25 g).

Hailemichel and Tesfaye (2008) conducted an experiment to study the effect of rhizome size on growth and yield of turmeric and reported that, the length of fresh rhizome was significantly affected by seed rhizome size and it increased with an increase in seed rhizome size. Similarly width of fresh rhizome was significantly affected by seed rhizome size and the 4 g treatment produced significantly lower width of rhizome compared to other treatments. Finally fresh rhizome weight per plant and fresh rhizome yield per hectare was significantly affected by seed rhizome size and 32 g treatment produced maximum.

Field investigation by Olojede *et al.* (2009) in turmeric recorded highest yield with mother rhizomes as compared to the primary and secondary rhizomes.

Manhas and Gill (2010) observed similar reports of significantly highest yield per plant and per hectare from mother rhizome while studying the effect of planting materials on growth, yield and quality of turmeric under Punjab conditions.

Similarly Monnaf *et al.* (2010) studied the effect of rhizome size on the growth and yield of ginger recorded higher yield per plant (135.14 g), per plot (4.57 kg) and per hectare (11.30 ton) with 30-35 g rhizome size and lowest with 10-15 g rhizome size.

Ghosh and Hore (2011) carried out an experiment to study the influence of spacing and seed rhizome size of ginger under coconut based inter cropping observed higher yield (13.63 kg) per plot with the bigger seed rhizome (25-30 g) compared to 12.54 kg from smaller seed rhizome (15-20 g).

Sengupta and Dasgupta (2011) studied the effect of weight of planting material on growth and yield of ginger cv. Gorubathan in the hilly region of Darjeeling District with ten different planting material sizes *viz.,* 10 to 100 g. The results revealed that rhizome pieces weighing 40 g each was found to be optimum for planting, which resulted in increase in yield (49.08 t ha^{-1}) compared to smaller rhizome size weighing 10, 20 or 30 g.

Manhas and Gill (2012) conducted an experiment to study the effect of different cultural practices on production of turmeric in Punjab observed highest weight of rhizome per plant (121.0 g) and fresh yield (18.9 t ha^{-1}) with the use of mother rhizome as planting material than primary finger.

Padmadevi *et al.* (2012) conducted an experiment on effect of different grades of rhizomes on growth and yield of turmeric and noticed that highest yield (23.15 t ha^{-1}) was recorded from planting of mother rhizome (45-50g).

Sharma *et al.* (2012) conducted an experiment on the influence of plant spacing and rhizome size on yield of turmeric and reported highest rhizome yield (54.2 t ha^{-1}) with a rhizome size of 75 g.

Singh *et al.* (2014) studied the effect of different planting materials on plant growth, yield and economics of turmeric cv. Erode selection-1 and reported that mother rhizome has recorded the highest finger size (9.06 cm) and yield per plant (389.47 g).

2.1.3 Quality parameters

Philip (1983) reported that different planting materials did not have any significant effect on the curcumin content of turmeric. However, the whole mother rhizomes (25-34 g) recorded the maximum yield of curcumin per hectare (362.5 kg) compared to 15-20 g of finger rhizome (303.4 kg ha^{-1}).

Maia *et al.* (1995) while studying the effect of primary (19 g) and secondary rhizomes (9 g) on quality of turmeric reported that size of propagating material had no effect on the curcumin content of the rhizomes.

In another experiment by Nizam and Jayachandran (1997) to study the effect of seed rhizome size on the quality of turmeric reported that crude fibre and starch content were not significantly influenced by rhizome size. Similar reports of non significant difference in curcumin content due to various types of planting materials was also reported by Shanmugam *et al.* (2000) in turmeric.

Cooray *et al.* (1988) reported that essential oil content of turmeric was higher when mother rhizome is used as planting material compared to the finger rhizomes. Similarly Chempakam *et al.* (2000) revealed higher content of curcumin in primary and secondary rhizomes as compared to the mother rhizomes.

Pino *et al.* (2003) revealed no significant difference in volatile oil content and chemical composition of essential oil obtained from mother and finger rhizomes of turmeric.

Kumar and Gill (2010) reported that oil content and curcumin content of turmeric was higher when mother rhizome is used as planting material compared to the primary and secondary fingers.

Manhas and Gill (2012) conducted an experiment on the effect of different cultural practices on production of turmeric under Punjab conditions and observed significantly more oil (6.84%) from mother rhizomes than primary and secondary fingers.

2.2 Effect of plant spacing on growth, yield and quality of ginger

2.2.1 Vegetative growth parameters

Ponnuswamy and Muthuswami (1981) reported that 45 cm x 20 cm spacing in turmeric produced the maximum plant height and number of tillers per plant as compared 30 cm X 20 cm, 60 cm x 20 cm and 75 cm X 20 cm spacings. Ramachandran and Muthuswami (1984) reported that closer spacing of 30 cm x 15 cm produced taller plants, whereas the wider spacing of 50 cm X 22.5 cm produced more number of leaves as well as more number of tillers per plant in turmeric.

Philip (1985) reported non-significant variation among the spacings with regard to the different growth characters *viz.,* plant height, number of leaves, tillers per plant, and leaf length during the two year study in turmeric. However, breadth of leaf at the center and leaf area showed significant variation among the different spacings. Maximum leaf breadth at the center and leaf area was highest with 30 cm x 30 cm spacing and was significantly higher than spacings of 10 cm X 20 cm, 15 cm X 30 cm, 20 cm X 25 cm, 25 cm X 25 cm and 25 cm X 30 cm.

Balashanmugham and Vanangamudi (1987) conducted an experiment at College of Horticulture, TNAU, Coimbatore to study the effect of different plant populations on growth and yield of turmeric. They observed that growth contributing parameters like number of leaves per plant and number of tillers per plant were highest under the plant population of 1,50,120 plants ha^{-1}, whereas plant height followed the reverse trend and was highest in the plant population of 2,00,160 ha^{-1}.

Neopaney (1988) conducted an experiment on effect of plant spacing on growth and yield of ginger and found that, plant height and number of leaves were maximum at a plant spacing of 20 cm X 20 cm.

Singh *et al*. (1998a) studied the effect of three spacings (20 cm X 20 cm, 25 cm X 20 cm and 30 cm X 20 cm) on growth of turmeric under sodic soils and reported that closer spacing gave maximum plant height whereas maximum plant spread was obtained by wider spacings. However, plant spacing did not show any tangible impact with regard to the increment towards number of leaves per plant.

Medhi and Bora (1993) reported that different plant spacing in turmeric had non-significant effect on plant height, number of leaves per plant and number of tillers per plant. Govind *et al.* (1993) observed that various growth contributing factors like plant height and size of leaves were maximum under widely spaced crop of 30 cm X 30 cm but did not have any significant effect on number of leaves per plant and breadth of leaf.

However, Chattopadhyay *et al.* (1993) while studying the effect of planting distance in the tarai zone of West Bengal reported that turmeric planted at 30 cm X 20 cm gave significantly more taller plants.

Shashidhar and Sulikeri (1996a) studied the effect of plant density on growth and yield of turmeric in Karnataka and reported that the medium spacing (45 cm X 22.5 cm) recorded the highest number of leaves and leaf area (28.60 dm^2) as compared to closer (45 cm X 15 cm) and wider spacing (45 cm X 30 cm). Other growth parameters like plant height (23.20 cm), number of tillers per plant (2.03) were recorded at closer (45 cm X 15 cm) and wider (45 cm X 30 cm) spacings respectively.

Rashid *et al.* (1996) reported that growth factors like plant height and number of leaves per hill in turmeric were not significantly affected by different spacing of 60 cm X 20 cm, 60 cm X 25 cm and 60 cm X 30 cm. Similar results of non significant effect of two spacings (60 cm X 10 cm and 60 cm X 15 cm) on growth parameters of turmeric was also reported by Kaur (2001) under Ludhiana conditions.

In another experiment by Shashidhar *et al.* (1997) to study the effect of different spacings (45 X 15, 45 X 22.5 and 45 X 30 cm) on growth and dry matter production of turmeric cv. Amalapuram, closer spacing of 45 X 15 cm produced the tallest plants (23.2 cm), medium spacing of 45 X 22.5 cm produced plants with highest number of leaves (10.79) and highest leaf area (28.58 dm2) while, wider spacing of 45 X 30 cm produced plants with highest number of tillers (2.03).

Blay *et al.* (1998) carried field experiment to study the influence of sett size and spacing on yield of ginger and observed highest leaf area (5577.55 cm^2) and number of shoots per plant (9.00) from the spacing of 15 X 23 cm. However, highest leaf area index (4.38) was recorded with the spacing of 12 cm X 12 cm and lowest (1.95) was recorded from 15 cm X 23 cm spacing.

Investigations of Bahadur *et al.* (2000) revealed that wider spacing of 50 cm X 40 cm increased the number of tillers per plant (2.43) and leaves per plant

(8.56). Medium spacing (50 X 30 cm) produced highest finger length (6.52 cm) and breadth (6.95 cm). However, the closest spacing of 50 cm x 20 cm produced tallest plants (87.89 cm).

Singh *et al.* (2000) while studying the effect of seed rhizome size and plant spacings on growth and yield of turmeric cv. BSR-1 reported poorest plant emergence and highest tiller number and maximum plant height with whole mother rhizomes spaced at 50 X 40 cm.

Islam *et al.* (2002) while studying the effect of plant spacings (45 X 10 cm, 45 X 20 cm, 45 X 30 cm and 60 X 30 cm) on the production of turmeric reported that plant spacing had significant effect on plant height. The highest number of leaves (10.4) and tillers per hill (5.0) were produced when plants were planted at wider spacing (60 X 30 cm) and it was closely followed by 45 X 30 cm spacing and the lowest was found in closer spacing (45 X 10 cm).

In a field experiment to determine the suitable turmeric cultivar and optimum plant spacing for growth and yield of turmeric by Hore and Chattopadhyay (2003), the cultivar Sugandham recorded the maximum values for vegetative growth parameters with closer spacing of 15 X 15 cm over 30 X 15 cm spacing.

Gill *et al.* (2004) carried out experiment to study the influence of two plant spacing of 60 cm X 10 cm and 60 cm X 15 cm in turmeric and reported that closer spacing produced significantly taller plants (54.5 cm) as compared to wider spacing (47.7 cm).

Investigations of Raut *et al.* (2004) reported maximum plant height (81.62 cm) with a closer spacing of 45 cm X 15 cm in turmeric. However, maximum leaf area (506.68 cm^2) was recorded with a plant spacing of 30 cm X 30 cm.

Kumar (2005) recorded maximum plant height from higher plant densities of 1,66,667 plants ha^{-1} and it was significantly more than lower plant

densities. Number of leaves and tillers per plant was recorded from lower plant density of 83,333 plants ha^{-1}.

Hossain *et al.* (2005b) studied the effect of plant spacing on growth and yield of turmeric. Results revealed that number of tillers per clump was significantly reduced by planting at 20 cm^2 spacing and the spacing of 30, 40, 50, and 60 cm^2 resulted in a similar number of tillers. The spacing of 30 cm^2 recorded maximum length (30 cm) and width (10 cm) of leaf.

According to Gopichand *et al.* (2006), plant height increased with reduction in plant spacing from 50 cm X 50 cm to 25 cm X 25 cm, whereas leaf length, breadth and leaf area showed an increasing trend with closer spacing.

Kandiannan and Chandaragiri (2006) studied the influence of spacing on growth, yield and quality of turmeric and reported maximum plant height, leaf area and leaf area index with closer spacing (30 X 15 cm) compared to medium (45 X 15 cm) and wider spacing (60 X 15 cm).

Pratap and Singh (2007) conducted an experiment on influence of types of rhizome and plant geometry on growth and yield of turmeric and results revealed that maximum plant height (79.67 cm) was recorded at closer spacing (30 X 15cm). Number of leaves per main shoot (10.24) was found to be maximum at medium spacing (30 X 20 cm). However, wider spacing (30 X 30 cm) produced maximum number of tillers per plant.

Similar results of significantly highest plant height and other growth parameters with a spacing of 45 cm X 15 cm were reported by Wakhare *et al*. (2007) while studying the effect of different spacings on growth, yield and quality of turmeric cv. Kesar under black soils of Paria (Gujarat).

The experimental findings of Kandiannan and Chandaragiri (2008) revealed that the closer spacing (30 cm X 15 cm) recorded higher leaf area index followed by medium spacing.

Pandey and Mishra (2009) reported highest plant height with closer plant spacing (30 X 15 cm) and maximum number of leaves per plant with wider spacing (45 X 45 cm).

Pandey *et al.* (2011) conducted an experiment to study the response of plant spacing on yield and yield attributing characters of turmeric at farmer's field of Azamgarh, Uttar Pradesh. The results revealed that the wider spacing (45 X 45 cm) gave the highest value of the growth parameters.

Kiran *et al.* (2013) studied the effect of plant spacing on profitable yield of turmeric and results revealed that there was significant variation among plant spacings for various growth characters. Days to sprouting (87.00) was maximum at a spacing of 30 cm X 10 cm, whereas, days to sprouting (82.00) was minimum at a spacing of 30cm X 50cm. Similarly other growth parameters like plant height (67.73 cm), leaves per plant (8.00), leaf length (27.11cm), leaf diameter (9.19 cm) and number of tillers per plant (5.66) were maximum from 30 cm X 50 cm spacing and lowest from 30 cm X 10 cm spacing.

Modupeola *et al.* (2013) studied the effect of plant density on growth, yield and nutrition value of ginger and reported that widest spacing (45 cm X 45 cm) had recorded the tallest plant compared to closer spacing (25 cm X 50 cm). The closer spacing (25cm X 50cm) produced highest number of leaves and tillers.

Yadav *et al.* (2013) carried out trail on effect of plant spacing on growth and yield characteristics of ginger cv. Mahima at Dapoli, Maharashtra. Results revealed that closer spacing of 25 cm X 15 cm recoded significantly higher plant height (82.39 cm). However, maximum number of tillers (13.91), longest leaf (19.15 cm), broadest leaf (2.16 cm) and highest leaf area (35.37 cm) was recorded from a spacing of 25 cm X 35 cm.

Bhadouria *et al.* (2014) studied the effect of spacing on growth and yield of turmeric at fruit Research Station Kuthulia, Rewa, Madhya Pradesh. Highest Plant height, number of leaves per plant, length of leaves and breadth of leaves were recorded with a spacing of 60 cm X 20 cm under ridge planting method.

Mohamed *et al.* (2014) carried experiment to study the effect of spacing on growth, yield and chemical constituent of turmeric and found that 25 cm spacing between the plants gave the best performance for all the all growth parameters (plant height, no of leaves per plant and highest leaf width) followed by 15cm spacing between the plants .

2.2.2 Yield attributing characters

Rajput *et al.* (1982) reported that yield of turmeric was maximum at closer spacing of 45 cm X 30 cm. Ponnuswamy and Muthuswami (1981) reported that turmeric planted at a spacing of 45 cm X 20 cm gave significantly more yield per hectare as compared to closer spacing of 30 cm X 20 cm and wider spacing of 60 cm X 20 cm and 75 cm X 20 cm.

Philip (1985) reported that maximum fresh rhizome yield of turmeric yield of turmeric was produced in closer spacing of 20 cm X 10 cm.

Neopaney (1988) studied the effect of different plant spacings on growth and yield of ginger revealed that maximum rhizome yield (19.34 t ha^{-1}) was obtained at the planting spacing of 20 cm X 20 cm. However, breadth of rhizome was higher at 15 cm X 30 cm spacing.

Shankaraiah and Reddy (1988) reported that a spacing of 30 cm X 15 cm gave more fresh rhizome yield of turmeric (30 t ha^{-1}) compared to a spacing of 30 cm X 20 cm (27.70 t ha^{-1}) and 20 cm X 20 cm (28.51 ha^{-1}). Aoi *et al.* (1988) while studying the effect of high (80 cm X 20 cm), normal (80 cm X 30 cm) and low (80 cm X 40 cm) planting density of turmeric on yield and yield attributes reported that total rhizome yield increased with increasing plant density.

Okwuowulu (1992) studied the influence of decreasing intra-row spacing on the performance of ginger found that, the fresh ginger yield increased with the decreasing intra-row spacing.

Chattopadyay *et al.* (1993) studied the effect of nine different spacing combinations in turmeric. The highest turmeric yield was produced with a

spacing of 30 cm X 20 cm (25.70 t ha^{-1}) as compared to all other combinations of 10 cm X 20 cm, 15 cm X 20 cm, 20 cm X 20 cm, 10 cm X 30 cm, 15 cm X 30 cm and 40 cm X 20 cm.

Govind *et al.* (1993) reported that total fresh rhizome yield (19.80 t ha^{-1}) in closer spacing of 30 cm X 10 cm was significantly higher due to more accommodation of the plants as compared to wider spacing of 30 cm X 15 cm, 30 cm X 20 cm, 30 cm X 25 cm and 30 cm X 30 cm, but yield per plant was found to highest under widely spaced crop of 30 cm X 30 cm spacing.

Total fresh rhizome yield of turmeric decreased with increase in spacing and it was maximum (23.40 t ha^{-1}) at closer spacing of 45 cm X 20 cm and minimum (18.80 t ha^{-1}) at wider spacing of 45 cm X 40 cm (Medhi and Bora, 1993).

Shashidhar and Sulikeri (1996a) studied effect of plant density on growth and yield of turmeric in Karnataka and reported that spacing of 45 cm X 22.5 cm recorded the highest fresh rhizome yield (22.03 t ha^{-1}) and it was significantly higher than other spacing combinations of 45 cm X 15 cm and 45 cm X 30 cm.

Rashid *et al.* (1996) while studying the productivity and profitability of turmeric cultivars as influenced by spacing under Bangladesh conditions reported no significant effect of spacing on fresh yield of turmeric.

Blay *et al.* (1998) carried an experiment to study the influence of sett size and spacing on yield of ginger. Results revealed that highest yield per plant (30.18 g) with a spacing of 15 cm X 23 cm and lowest (24.76 g) recorded from 12 X 12 cm spacing. However, maximum yield per hectare (17.19 t) was recorded from 12 cm X 12 cm and lowest from 15 cm X 23 cm spacing.

Six different plant spacings (10 X 20 cm, 15 X 30 cm, 20 X 25 cm, 25 X 25 cm, 20 X 30 cm and 30 X 30 cm) were evaluated with turmeric cv. Mannuthy local in Vellanikkara, Kerala conditions. Results revealed that mean fresh yield and mean dry yield (16.76 and 3.88 t/ha) were highest with 25 X 25 cm spacing followed by 20X25 cm (16.60 and 3.80 t/ha respectively) (Valsala *et al.* 1998).

Pandey (1999) studied the response of mango ginger to plant spacing and noticed that, mango ginger yield was highest at a closest spacing of 30 cm X 20 cm compared to 40 cm X 20 cm , 40 cm X 30 cm and 50 cm X 20 cm spacings.

Bahadur *et al.* (2000) while studying the effect of different plant spacings on growth and yield of turmeric found significantly highest fresh yield per plant (189.35 g) with wider spacing (50 X 40 cm). However, highest rhizome yield per hectare (13.21 t) was obtained from a closer spacing of 50 X 20 cm followed by 50 X 30 cm spacing (12.25 t) and lowest (10.35 t) was recorded with wider spacing (50 X 40 cm).

In an experiment conducted by Davanakatti and Sulikeri (2000) noticed that fresh rhizome yield was significantly decreased with the decrease in plant population and highest value (14.16 t ha^{-1}) was recorded at the higher population.

Singh *et al.* (2000) while studying the effect of seed rhizome size and plant spacings on growth and yield of turmeric cv. BSR-1 reported maximum fresh rhizome yield with a spacing of 50 X 20 cm. However Gill *et al.* (2004) reported that plant spacing (60 X 10 cm and 60 X 15 cm) had no significant influence on fresh rhizome yield of turmeric under Ludhiana conditions of Punjab, India.

Carvalho *et al.* (2001) evaluated the effect of spacing in turmeric between furrows (40 cm, 60cm, 75 cm, and 100 cm) and within the planting line (20 cm, 30 cm, 40 cm, and 50 cm) observed that rhizome yield at 210 days was influenced only by the spacing between the plants and 20 cm spacing between the plants recorded the highest yield (30.56 t ha^{-1}).

As reported by Islam *et al.* (2002) under Bangladesh conditions, the highest yield (17.87 t ha^{-1}) of turmeric was obtained with closer plant spacing of 45 cm X 10 cm. While, the lowest yield (13.42 t ha^{-1}) was obtained when planting was done at 60 cm X 30 cm spacing.

In a field experiment to determine the suitable turmeric cultivar and optimum plant spacing for growth and yield of turmeric by Hore and

Chattopadhyay (2003) the cultivar, Sugandham recorded the maximum values for number of primary finger (6.3), number of secondary finger (15.9) and weight of primary finger (106.1 g) with a closer spacing of 15 X 15 cm. The highest fresh rhizome yield (39.17 t ha^{-1}) was obtained from PTS-43 followed by Sugandham (35.97 t ha^{-1}) from the spacing of 15 X 15 cm than the 30 X 15 cm spacing.

Filho *et al*. (2004) studied the effect of plant density on turmeric production and reported that 20 cm plant to plant spacing gave significantly higher yield (24.68 t ha^{-1}) than the plant to plant spacing of 35 cm and 50 cm.

Raut *et al.* (2004) recorded maximum fresh weight of mother rhizome per plant (41.45 g) at a closer spacing of 15 cm X 15 cm in turmeric. However, number of fresh fingers per plant (10.67), weight of fresh fingers per plant (298 g), length of finger (7.92 cm) and girth of finger (7.67 cm) were significantly higher with a wider spacing of 30 cm X 30 cm. The highest weight of fingers per hectare (17.25 t) was recorded at closer spacing of 45 cm X 45 cm and the fingers yield decreased with increased plant spacing.

Silva *et al.* (2004) revealed that turmeric fresh rhizome yield decreased from 25 t ha^{-1} in the 25 cm plant spacing to 18 t ha^{-1} in the 40 cm plant spacing due to less accommodation of plants per hectare.

Kumar (2005) conducted an experiment to study the effect of different agronomic practices of turmeric and noticed that, fresh rhizome yield increased significantly with higher plant density of 1,66,667 plants ha^{-1} compared to wider plant densities of 1,11,111 and 83,333 plants h^{-1}.

Hossain *et al.* (2005b) observed that maximum rhizome size (27 cm) and fresh weight of rhizome were obtained from 30 cm^2 spacing in turmeric. The highest yield per m^2 was obtained with 30 cm^2 spacing, followed by 20 cm^2 spacing, which was significantly reduced at 40 cm^2 plant spacing.

According to Gopichand *et al.* (2006) wider plant spacing provided higher fresh rhizome yield owing to higher number of plantlets.

Kandiannan and Chandaragiri (2006) studied the influence of spacing on growth, yield and quality of turmeric and observed that closer spacing (30 X 15 cm) had highest yield than medium (45 X 15 cm) and wider spacing (60 cm X 15 cm).

Ghosh *et al.* (2007) conducted an experiment to study the effect of spacing and rhizome size on yield of turmeric grown as intercrop in coconut plantation and revealed that highest weight (531.20 g) of clump, length of clump (18.07 cm) and maximum breadth of primary and secondary fingers were recorded with widest spacing (30 cm X 25 cm).

Pratap and singh (2007) conducted an experiment on influence of types of rhizome and plant geometry on growth and yield of turmeric. Among the six types of spacings (30 X 15 cm, 30 X 20 cm, 30 X 30 cm, 45 X 15 cm, 45 X 20 cm and 45 X 30 cm), closed spacing (30 X 15 cm) produced highest rhizome yield (33.50 t ha^{-1}). However, wider spacing recorded maximum weight of fresh rhizome per clump (247.95 g), rhizome length and thickness of mother rhizome.

Zaman *et al.* (2008) noticed that the plant spacing of 40 cm X 20 cm significantly gave the highest yield attributing characteristics which resulted the highest yield (30.81 t ha^{-1}) in turmeric.

Closest plant spacing (30 X 15 cm) gave maximum yield during first and second year and lowest was recorded from wider spacing (45 X 45 cm). However, highest weight of finger per plant recorded from wider spacing (45 cm X 45 cm) (Pandey and Mishra , 2009).

Ghosh and Hore (2011) carried out experiment for economics of coconut based inter cropping as influenced by spacing and seed rhizome size of ginger and noticed highest yield per plot (15.39 kg) with closest spacing 20 cm X15 cm.

Pandey (2011), while studying the response of plant spacing on yield and yield attributing characters of turmeric at farmer's field of Azamgarh, Uttar Pradesh revealed that 30 cm X 15 cm spacing recorded highest rhizome yield while, minimum yield was recorded with a spacing of 45 cm x 45 cm.

Sharma *et al.* (2012) conducted an experiment on influence of plant spacing and rhizome size of turmeric and results revealed that among the different spacings, 25 cm X 30 cm has recorded the highest yield (57.5 t ha^{-1}).

Kiran *et al.* (2013) studied effect of plant spacing on profitable yield of turmeric and results revealed that maximum weight per plant (76.10g) and diameter of the finger (4.220 mm) recorded with a spacing of 30 cm X 50 cm and lowest was recorded from 30 cm X 10 cm spacing. Similarly, the highest yield (21.84 t ha^{-1}) was recorded with a spacing of 30 cm X 50 cm and lowest yield (3.71 t ha^{-1}) was recorded from 30 cm X 10 cm spacing.

Modupeola *et al.* (2013) studied the effect of planting density on growth, yield and nutrition value of ginger and reported that largest rhizome (26.30 cm) was recorded from wider spacing (45 cm X 45 cm) and highest yield (26.8 t ha^{-1}) was obtained when plants were spaced at closer spacing (25 cm X 50 cm) compared to widest spacing (12 t ha^{-1}).

Among the different spacings of ginger, 25 cm x 35 cm spacing recorded the longest rhizome (22.66 cm), broadest rhizome (9.90 cm) and rhizome weight per plant (292.93 g). The total green ginger yield per hectare (31.57 t ha^{-1}) was found to be maximum in closer spacing (25 cm X 15 cm) and lowest (22.50 t ha^{-1}) was recorded by 25 cm X 35 cm spacing (Yadav *et al.* 2013).

Mohamed *et al.* (2014) carried an experiment to study the effect of spacing on growth, yield and chemical constituent of turmeric. Maximum fresh weight of rhizome per plant and highest fresh weight of rhizome per unit area recorded from 35cm spacing between the plant and 15cm spacing between the plants respectively.

Yadav *et al.* (2014) studied the effect of dates of planting on growth, yield and quality of ginger and reported highest harvest index (54.77%) with 25 cm X 15 cm and it was significantly superior over rest of the treatments.

Bhadouria *et al.* (2014) studied the effect of spacing on growth and yield of turmeric under Madhya Pradesh conditions reported that maximum weight per

plant (92.39 g) was observed at a spacing of 60 cm X 20 cm and highest rhizome yield (11.20 t ha^{-1}) from 30 cm X 20 cm spacing.

2.2.3 Quality parameters

Shashidhar and Sulikeri (1996b) studied the effect of planting density on curcumin content of turmeric rhizomes and reported that plant spacing had no significant influence on curcumin content of turmeric cv. Amalapuram.

Valsala *et al.* (1998) in Kerala conditions conducted an experiment to study the influence of spacings on growth and yield of turmeric and reported that curcumin was not significantly affected by different spacings. Similarly Kaur (2001) also concluded non significant effect of different spacings on the curcumin content of turmeric rhizomes.

Neopaney (1988) studied the effect of different plant spacings on growth and yield of ginger and found that spacing does not exercise any significant effect on quality attributes *viz.,* oleoresin and crude fiber content. Similar results of non significant effects of different plant densities on essential oil and curcumin content was also reported by Kumar (2005) and Kandiannan and Chandaragiri (2006) in turmeric.

Similarly no significant effect of spacing was seen on crude fiber and oil content with different plant spacings. However the highest crude fiber (3.44%) and highest oil content (1.63%) were observed in 25 cm x 15 cm spacing compared to the other spacings (Yadav *et al.* 2014).

2.3 Interaction effect of rhizome size and plant spacing on growth, yield and quality of ginger under coconut and mango cropping systems.

Ahmed *et al.* (1988) studied the interaction effect of various plant material *viz.,* 10 g, 11-20g and 21-30 g in weight planted at 15 cm, 20 cm and 25 cm row spacing in rows 45 cm apart. The highest yield of 13.42 t ha^{-1} was obtained with the largest rhizomes planted at the closest spacing. The smallest rhizomes planted at 25 cm gave only 5.41 t ha^{-1}.

Blay *et al.* (1998) carried an experiment to study the influence of sett size and spacing on yield of ginger and reported that largest planting material (10 g) with closest spacing (12 cm X 12 cm) produced highest yield per plant (29.69 g) and combination of smaller sett size (1 g) with wider spacing (15 cm X 23 cm) produced the lowest yield per plant (3.37 g). However highest yield per hectare (52.49 t ha^{-1}) recorded from largest planting material (10 g) with wider spacing (15 cm x 23 cm).

Ghosh *et al.* (2007) conducted an experiment to study the effect of spacing and rhizome size on yield of turmeric grown as intercrops in coconut plantation and reported that a combination of 20 cm X 20 cm spacing with 30-35 g seed rhizome size recorded maximum yield per plot (18.39 kg/3m^2) against a combination of 30 cm X 25 cm spacing with 20-25 g seed rhizome size (12.34 kg/3m^2).

Pratap and singh (2007) conducted an experiment on influence of types of seed rhizome and plant geometry on growth and yield of turmeric and noticed that a combination of 30 cm X 30 cm with planting of mother rhizome recorded the highest weight per clump (269.13 g) followed by 30 X 30 cm with primary rhizome (259.66 g) and lowest weight per clump recorded from a spacing of 45 X 15 cm with primary rhizome. Similarly maximum number of tillers per plant at 90 days after germination was recorded from 45 X 30 cm spacing with mother rhizome and lowest was recorded from a combination of 30 X 15 cm with primary finger.

In another experiment by Ghosh and Hore (2011), the closest spacing (20 cm X 15 cm) in combination with bigger seed rhizome (25-30 g) produced highest plot yield (15.62 kg/3m^2 and projected yield 12.50 t ha^{-1}) as compared to widest spacing (30 cm X 25 cm) in combination with small seed rhizome (15-20 g) (10.49 kg/3m^2 and 8.39 t ha^{-1} respectively).

3 Economics of growing ginger

Ghos and Hore (2011) carried a field experiment to study the economics of coconut-based inter-cropping system as influenced by spacing and seed

rhizome of ginger and reported the maximum (Rs. 1,03,727/-) and minimum (Rs. 57,746/-) cost of cultivation with a combination of 20 cm X 15 cm spacing with 25-30 g rhizome size and 30 cm X 25 cm spacing with 15-20 g rhizome size, respectively. The maximum net return (Rs. 78,421/-) was realized from closest spacing with smaller seed rhizome.

Yadav *et al.* (2014) reported that the spacing of 25 cm X 15 cm gave highest net returns of RS. 392,893.40 with a B:C ratio of 2.27. Minimum net returns of Rs. 271,791.2 and B:C ratio of 2.19 was obtained from a spacing of 25 cm X 35 cm.

Kandiannan and Chandaragiri (2008) while studying the effect of seed rhizome size on the growth, yield and economic returns of ginger and reported closer spacing produced higher gross, net returns and B:C ratio than medium and wider spacings.

Chapter- III

Material and Methods

Chapter - III

MATERIAL AND METHODS

The present investigation on "Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems" was conducted from May to December-2014 at Horticultural college and Research Institute farm, Dr.Y.S.R. Horticultural University, Anantharajupet, YSR District, Andhra Pradesh. The details of material used and the methods adopted in the experiment are described here under following sub heads.

3.1 THE EXPERIMENTAL FIELD

3.1.1 Geographical location of the experimental site

The experiment was carried at Horticultural College and Research Institute, Anantharajupet which is located in Rayalaseema region of the Andhra Pradesh and situated at an altitude of 215 m above MSL and located at 13.98^0 North latitude and 79.40^0 East longitude.

3.1.2 Climate

The meteorological data pertaining to rainfall, mean minimum and maximum temperatures, humidity during the experimental period (May 2014 to December 2014) was recorded and presented in Appendix –1.

During the crop growth period, total rainfall received was 660.9 mm. The mean maximum and minimum temperatures during the crop growth period ranged from 40.14^0C to 25.42^0C and 28.42^0C to 17.71^0C respectively. The relative humidity during the period of crop growth ranged between from 82.42 to 89.57 percent.

3.1.3 Soil type

The soil type of experimental site is sandy loam with good drainage. The soil p^H is varying from 7.1 to 8.0 and EC 0.23 dSm^{-1}.

3.2 Experimental details

The present field experiment is a series of two experiment conducted simultaneously under coconut and mango cropping system.

Experiment-I: Standardization of seed rhizome size and plant spacing for ginger cv. Maran under coconut cropping system. (The existing coconut field (30 years old) is spaced at 7 m x 7 m). (Plate 3.1).

Treatment details

Crop	:	Ginger
Variety	:	Maran
Season and year	:	Early *kharif,* 2014 (May 2014 to December 2014)
Design	:	Factorial RBD
Replications	:	Three
Net plot size	:	1.2 m x1.2 m

Factor-1 : Seed rhizome size (3)

S_1: 20 g

S_2: 30 g

S_3: 40 g

Factor-2: Plant spacing (5)

D_1 : 25 cm x 15 cm

D_2 : 25 cm x 25 cm

D_3 : 30 cm x 20 cm

D_4 : 30 cm x 30 cm

D_5 : 40 cm x 20 cm

Plate 3.1: General view of experimental field-1

Plate 3.2. General view of experimental field-2

Experiment-II: Standardization of seed rhizome size and plant spacing for ginger cv. Maran under Mango cropping system. (The existing mango orchard (26 years old) is spaced at 9 m x 9 m). (Plate 3.2).

Treatment details

Crop	:	Ginger
Variety	:	Maran
Season and year	:	Early *kharif,* 2014 (May 2014 to December 2014)
Design	:	Factorial RBD
Replications	:	Three
Net plot size	:	1.2 m x1.2 m

Factor-1 : Seed rhizome size (3)

S_1: 20 g

S_2: 30 g

S_3: 40 g

Factor-2: Plant spacing (5)

D_1 : 25 cm x 15 cm

D_2 : 25 cm x 25 cm

D_3 : 30 cm x 20 cm

D_4 : 30 cm x 30 cm

D_5 : 40 cm x 20 cm

Treatments combinations for both experiments : 15

S_1D_1 : 20 g and 25 cm x 15 cm

S_1D_2 : 20 g and 25 cm x 25 cm

S_1D_3: 20 g and 30 cm x 20 cm

S_1D_4 : 20 g and 30 cm x 30 cm

S_1D_5: 20 g and 40 cm x 20 cm

S_2D_1 : 30 g and 25 cm x 15 cm

S_2D_2 : 30 g and 25 cm x 25 cm

S_2D_3 : 30 g and 30 cm x 20 cm

S_2D_4 : 30 g and 30 cm x 30 cm

S_2D_5 : 30 g and 40 cm x 20 cm

S_3D_1 : 40 g and 25 cm x 15 cm

S_3D_2 : 40 g and 25 cm x 25 cm

S_3D_3 : 40 g and 30 cm x 20 cm

S_3D_4 : 40 g and 30 cm x 30 cm

S_3D_5 : 40 g and 40 cm x 20 cm

R_1	R_2	R_3
S_1D_1	S_2D_3	S_3D_5
S_1D_2	S_2D_4	S_3D_3
S_1D_3	S_2D_1	S_3D_2
S_1D_4	S_2D_5	S_3D_1
S_1D_5	S_2D_2	S_3D_4
S_3D_5	S_1D_1	S_2D_3
S_3D_3	S_1D_2	S_2D_4
S_3D_2	S_1D_3	S_2D_1
S_3D_1	S_1D_4	S_2D_5
S_3D_4	S_1D_5	S_2D_2
S_2D_3	S_3D_5	S_1D_1
S_2D_4	S_3D_3	S_1D_2
S_2D_1	S_3D_2	S_1D_3
S_2D_5	S_3D_1	S_1D_4
S_2D_2	S_3D_4	S_1D_5

Fig. 3. 1. Layout of the experiment-I

R_1	R_2	R_3
S_1D_1	S_2D_3	S_3D_5
S_1D_2	S_2D_4	S_3D_3
S_1D_3	S_2D_1	S_3D_2
S_1D_4	S_2D_5	S_3D_1
S_1D_5	S_2D_2	S_3D_4
S_3D_5	S_1D_1	S_2D_3
S_3D_3	S_1D_2	S_2D_4
S_3D_2	S_1D_3	S_2D_1
S_3D_1	S_1D_4	S_2D_5
S_3D_4	S_1D_5	S_2D_2
S_2D_3	S_3D_5	S_1D_1
S_2D_4	S_3D_3	S_1D_2
S_2D_1	S_3D_2	S_1D_3
S_2D_5	S_3D_1	S_1D_4
S_2D_2	S_3D_4	S_1D_5

Fig. 3. 2. Layout of the experiment-II

3.3 Cultural operations

3.3.1 Land preparation

The land was prepared and brought to fine tilth by ploughing 2 times followed by two harrowing and plots were prepared for planting.

3.3.2 Plot size

Ginger rhizome pieces were planted a in raised bed of 1.2 m length, 1.2 m width and 15 cm height as per the treatment.

3.3.3 Seed rhizome source

Ginger cultivar used in the present experiment is Maran brought from Fruit Research Station, Sangareddy. Maran is improved high yielding indigenous variety of Assam and is characterized by plumpy and bold rhizome with high fibre content (6.10 %). Its mean fresh yield is 25.21 tonnes per hectare. It matures within 210 days. It has high dry rhizome recovery (20.0%), oleoresin (10.0 %) and essential oil (1.9 %) content.

3.3.4 Seed material and planting

Seed rhizomes of 20 g, 30 g and 40 g having 3 to 4 buds (Plate 3) were selected as per the treatment and treated with Mancozeb @ 3gm/lit and Quinolphos @ 2ml/lit for 30 minutes and shade dried. Treated rhizomes were planted in the raised beds at 4.0 cm depth.

3.3.5 Manures and fertilizers

A basal dose of FYM @ 25 t/ha was applied and mixed with soil at the time of land preparation. Recommended dose of NPK @ 75:50:50 kg/ha was applied along with neem cake @ 2 tonnes per hectare as per the fertilizer schedule.

Plate 3.3: Different seed rhizome size treatment used in a present experiment

3.3.6 Intercultural operations

The plots ware kept free from weeds. The crop was mulched immediately after sowing with green leaves. Earthing-up was done to cover exposed rhizomes as and when necessary. The crop was irrigated once in a week during rainless period.

3.3.7 Plant protection

The incidence of soft rot disease was noticed during August and September. Soft rot was controlled by drenching of Mancozeb 75% W.P @ 3 g/lit and leaf folder was controlled by Dimethoate @ 2 ml/lit. The spray was repeated depending upon the incidence. Totally three sprays were given during the crop growth.

3.3.8 Harvesting

The crop was harvested when the leaves started withering by digging out the rhizomes after complete maturity as indicated by the withering and drying up of leaves. Harvested rhizomes were cleaned to remove adhering soil and sticking roots.

3.4 Observations recorded.

Observations were recorded on different growth and yield parameters on five randomly selected plants in each replication of different treatments as detailed below.

3.4.1 Vegetative growth characters

Observations on vegetative growth parameters were recorded on five randomly selected plants in each replication of different treatments at 30 days after planting (DAP), 120 DAP and at harvest (210 DAP). Leaf parameters were recorded at 180 DAP.

3.4.1.1 Days to 1st sprouting

Days required for 1st sprouting from planting for each treatment was recorded. The 1st sprouting of planted rhizome pieces was recorded as and when emerged above ground.

3.4.1.2 Days to 50% sprouting

Days required for 50% sprouting from planting for each treatment was recorded. The 50% sprouting of planted rhizome pieces was recorded as and when emerged above ground.

3.4.1.3 Plant height (cm)

Plant height was measured from the ground level to the base of the fully opened youngest leaf of the tallest tiller and is expressed in centimetres.

3.4.1.4 Number of leaves per clump

Fully opened leaves were counted in the entire clump and expressed as total number of leaves per plant.

3.4.1.5 Length of leaf (cm)

The length of leaf was measured from the base of the leaf lamina to the tip of the fully opened third leaf from top in the tallest tiller of the plant and expressed in centimetres.

3.4.1.6 Breadth of leaf (cm)

The breadth of leaf was measured at the widest lamina of fully opened third leaf from the top in the tallest tiller of the plant and expressed in centimetres.

3.4.1.7 Leaf area (cm^2)

After separation of leaves from the plant, leaf area estimated using leaf area meter (Li-COR model LI 3000) and expressed as cm^2 per plant.

3.4.1.8 Leaf area index

Leaf area index was computed using the formula suggested by Sestak *et al.* (1971).

LAI= A/P

Where, A = Leaf area

P = Ground area covered by plant or spacing provided

3.4.1.9 Number of tillers per plant

The side shoots arising from the basal portion of the pseudostem were counted and expressed as total number of tillers per clump.

3.4.2 Yield and yield attributes

Observations on yield and yield attributes were recorded on five randomly selected plants from each replication when plants attained harvesting stage.

3.4.2.1 Fresh yield of rhizomes

The weight of individual rhizome per plant was recorded as green or fresh ginger and expressed in gm per plant, and kg per plot. The gross plot yield was computed per hectare and expressed in tones per hectare.

3.4.2.2 Length of rhizome (cm)

Five rhizomes were taken from randomly selected five plants for the purpose of measuring the length of rhizome by using thread and scale and expressed in centimetres.

3.4.2.3 Breadth of rhizome (cm)

Breadth of the rhizome was recorded with the help of thread and meter scale and expressed in centimetres.

3.5 Quality parameters

3.5.1 Oleoresin content (%)

Pre weighed finely ground ginger powder was extracted for 18 hours in soxhlets apparatus with anhydrous petroleum ether. The extract was transferred to a capsule and kept for evaporation at room temperature. Then it was dried in hot air oven at 110^0c till the loss in weight between successive weighing was less than 2 mg. The amount of non volatile ether extract was computed by using the formula given below (Anonymous, 1984).

$$\text{NVEE \% by weight on dry weight basis} = \frac{\text{Loss in wt. of sample (g)}}{\text{Weight of sample taken (g)}} \times 100$$

3.5.2 Crude fibre content (%)

Pre weighed ground ginger powder (2 g) was extracted in soxhlets apparatus for 18 hours with petroleum ether. The dried material was boiled with 200 ml of sulphuric acid (1.25%) for 30 minutes, then filtered through muslin cloth and washed with boiling water.

Then residue was boiled with 200 ml of sodium hydroxide (1.25%) for 30 minutes, filtered through muslin cloth and washed with 25 ml of boiling sulphuric acid (1.25%) and water. The residue was transferred to weighing (W_1) ashing dish. First, the residue was dried for two hours at 130 ± 2^0c and weight was taken (W_2). After that it was ignited for 30 minutes at 600 ± 15^0c and reweighed (W_3). The crude fibre content in ginger rhizome was estimated by using the formula suggested by Maynard (1970).

$$\text{Crude fibre (\%)} = \frac{(W_2 - W_1) - (W_3 - W_1)}{\text{Weight of the sample (g)}} \times 100$$

3.5.3 Essential Oil (%)

Essential oil content on fresh weight basis was obtained by steam distillation of freshly harvested rhizomes using Clevenger type apparatus (AOAC, 1975).

3.5.4 Starch (%)

Principle for estimation of starch by anthrone reagent.

The sample is treated with 80% alcohol to remove sugars and then starch is extracted with perchloric acid. In hot acidic medium starch is hydrolysed to glucose and dehydrated to hydroxymethyl furfural. This compound forms a green coloured product with anthrone.

Materials

- *Anthrone:* Dissolve 200 mg anthrone in 100 mℓ of ice-cold 95% sulphuric acid 80% ethanol .
- 52% perchloric acid.
- *Standard Glucose:* Stock – 100 mg in 100 mℓ water. Working Standard – 10 ml of stock diluted to 100 mℓ with water.

Procedure

1. Homogenize 0.1 to 0.5g of the sample in hot 80% ethanol to remove sugars. Centrifuge and retain the residue. Wash the residue repeatedly with hot 80% ethanol till the washing do not give color with anthrone reagent. Dry the well over a water bath.
2. To the residue add 5.0 mℓ of water and 6.5 mℓ of 52% perchloric acid.
3. Extract at 0°C for 20 min. Centrifuge and save the supernatant.
4. Repeat the extraction using fresh perchloric acid. Centrifuge and pool the supernatant and make up to 100 mℓ.
5. Pipette out 0.1 or 0.2 mℓ of the supernatant and make up the volume to 1mℓ with water.
6. Prepare the standards by taking 0.2, 0.4, 0.6, 0.8 and 1mℓ in each tube with water.

7. Add 4 ml of anthrone reagent to each tube.
8. Heat for eight minutes in a boiling water bath.
9. Cool rapidly and read the intensity of green to dark green color at 630 nm.

Calculation

Glucose content in the sample using the standard graph. Multiply the value by a factor 0.9 to arrive at the starch content.

3.6 Statistical analysis of data

The data obtained during investigation were statistically analysed as per the procedure and design given by Panse and Sukhatme (1985). The statistical significance was tested by applying 'F' test at 0.05 level of probability and critical differences were calculated for those parameters which turned significant ($P < 0.05$) to compare the effects of different treatments. The symbol 'NS' was indicated where ever the treatment differences were not-significant in the F-test.

3.7 Economics

3.7.1 Total cost of cultivation

Cost of fertilizers, manures, plant protection chemicals and labour wages for all the cultural practices *viz*. weeding, harvesting etc. were worked out as per the prevailing rates during the cropping season and total cost of cultivation was calculated and expressed as Rupees per hectare. The cost of cultivation is furnished in Appendix-IV.

3.7.2 Gross income

Total fresh weight of rhizome/ha was multiplied by average price prevailed in the market and expressed as total income (Rs/ha).

3.7.3 Net income

Net income is worked out by subtracting total cost of cultivation from total income.

3.7.4 Benefit : Cost ratio

It is computed by dividing the total income from the total cost of cultivation

i.e.

$$\text{Benefit cost ratio} = \frac{\text{Net returns (Rs.)}}{\text{Cost of cultivation (Rs.)}}$$

Chapter-IV

Results and Discussion

Chapter IV

RESULTS AND DISCUSSION

The present field experiment entitled "Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems" was conducted at Horticultural College and Research Institute, Dr.Y.S.R Horticultural University, Anantharajupet, Y.S.R. Dt., Andhra Pradesh from May to December-2014. The present field investigation is a series of two experiments conducted simultaneously under coconut and mango cropping system. The results obtained from both the experiments were presented with relevant discussion here under with the following sub heads.

Experiment-I: Standardization of seed rhizome size and plant spacing for ginger cv. Maran under coconut cropping system.

4.1 Vegetative growth parameters

While studying growth parameters, it was observed that the vegetative growth parameters *viz*., days to first sprouting, days to 50% sprouting, plant height, number of tillers per plant, number of leaves per plant, leaf length, leaf breadth, leaf area and leaf area index varies significantly with respect to different rhizome size and plant spacing treatments.

4.1.1 Days to first sprouting

The data pertaining to days to first sprouting of rhizomes as influenced by seed rhizome size, plant spacing and their interaction are presented in Table 4.1 and Fig. 4.1.

Seed rhizome size had significant effect on days to first sprouting. The rhizome size of 40 g (S_3) took least number of days to first sprouting of rhizome (12.73) followed by 30 g (S_2) and 20 g (S_1) rhizome sizes (13.47 and 13.93 respectively).

These findings are in accordance with the observations of Yothasiri *et al*. (1997) in turmeric. The whole mother rhizome resulted in more rapid growth resulting in quick germination and development of turmeric rhizome.

The effect of plant spacing on days to first sprouting was non-significant. However, spacing of 30 cm X 30 cm (D_4) took lowest number of days to first sprouting (12.78) while, the highest number of days to first sprouting was recorded by 25 cm X 25 cm (D_2). These results are in conformity with the findings of Kiran *et al.* (2013) in turmeric.

The interaction effect of seed rhizome size and plant spacing differed significantly. Significantly lowest number of days to first sprouting (11.33) was recorded from a combination of 40 g rhizome size with 30 cm X 30 cm (S_3D_4) spacing and the combination of 20 g seed rhizome size with 25 cm X 15 cm (S_1D_1) spacing took highest number of days to first sprouting (15.33).

4.1.2 Days to 50% sprouting

The data pertaining to days to 50% sprouting of rhizomes due to different seed rhizome sizes, plant spacing and their interactions are presented in Table 4.1 and Fig. 4.1.

Seed rhizome size had significant effect on days to 50% sprouting. The treatment S_3 (40 g rhizome size) recorded significantly the lowest number of days to 50% sprouting of rhizome (19.07) followed by the treatments S_2 (30 g rhizome size) and S_1 (20 g rhizome size).

These findings are in accordance with the observations recorded by Yothasiri *et al*. (1997). The whole mother rhizome resulted in more rapid growth resulting in quick germination and development of turmeric rhizome.

The effect of plant spacing on days to 50% sprouting was non-significant. However, the lowest number of days to 50% sprouting (20.67) was recorded from D_2 (25 cm X 25 cm), D_4 (30 cm X 30 cm) and highest number of days to 50% sprouting (21.44) was recorded by D_5 (40 cm X 20 cm).

These results are in conformity with findings of Kiran *et al.* (2013) in turmeric crop. Since the pre sprouted rhizomes were used for planting purpose plant spacing had little effect on days to first sprouting and days to 50% sprouting.

The interaction effect of rhizome size and plant spacing showed non-significant results. The combination of 40 g rhizome size with 30 cm X 30 cm spacing (18.33) recorded lowest number of days to 50% sprouting and a combination of 20 g rhizome size with 30 cm X 20 cm took maximum days to 50% sprouting (23.33).

4.1.3 Number of tillers per plant

The data pertaining to number of tillers per plant due to seed rhizome size, plant spacing and their interactions at 30 DAP, 120 DAP and at harvest are presented in Table 4.2 and Fig. 4.2.

Seed rhizome size had significant influence on number of tillers per plant at all the stages of crop growth i.e., 30 DAP, 120 DAP and at harvest.

Among the seed rhizome sizes, S_3 (40 g) has recorded significantly highest number of tillers per plant at 30 DAP, 120 DAP and at harvest (2.97, 10.55 and 11.51 respectively). However the treatment S_1 (20 g) recorded the lowest number of tillers plant (1.69, 7.84 and 8.72 respectively).

Results regarding variation in number of tillers per plant due to rhizome size might be due to the fact that the plants produced from the largest rhizome size emerged earlier and showed vigorous and rapid growth using the initial reserve food materials than the smallest rhizome size in ginger. These results are in conformity with the findings of Monnaf *et al*. (2010) and Sengupta and Dasgupta (2011) in ginger, Balashanmugam and Vanangamudi (1988), Meenakshi *et al*. (2001a), Kumar (2005), Pratap and Singh (2007) and Manhas and Gill. (2012)in turmeric crop.

Among the plant spacings, number of tillers per plant were significantly influenced at 120 DAP and at harvest. At 30DAP number of tillers per plant was non-significant.

Increase in plant spacing increases the number of tillers. Among different plant spacings, 30 cm X 30 cm (D_4) has recorded highest number of tillers per plant at 30DAP, 120 DAP and at harvest (2.64 at 10.93 and 11.64 respectively). However at harvest the spacing of 40 cm X 20 cm (D_5) showed significantly the lowest number of tillers per plant (9.84).

The plant density had marked influence on the capacity of plants to utilize environmental factors in building up the plant tissues through regulation of absorption capacity of plants due to better utilization of resources and lesser plant to plant competition. Hence, the widely spaced plants produced more number of tillers per plant. The reduced vegetative growth parameters under closer spacing may be owing to competition among the actively growing plants for space, light, soil moisture and nutrients. These results are in line with the earlier findings of Ramachandran and Muthuswami (1984), Bahadur *et al*. (2000), Islam *et al*. (2002), Kumar (2005), Kiran *et al*. (2013) and Bhadouria *et al*. (2014) in turmeric crop, Yadav *et al*. (2013) in ginger crop.

The interaction effect of seed rhizome size and plant spacing throughout the growth period showed significant difference among number *of* tillers per plant except at 30 DAP. However, combination of 40 g rhizome size with 30 cm X 30 cm spacing (S_3D_4) produced the highest number of tillers per plant at 30 DAP, 120 DAP and at harvest (3.60, 12.80 and 13.07 respectively). While, 20 g rhizome size with 25 cm X 25 cm spacing (S_1D_2) recorded the lowest number of tillers per plant.

Similar results of maximum number of tillers per plant were also reported in combination with wider spacing (45 cm X 30 cm) and planting of mother rhizome by Pratap and Singh (2007) in turmeric crop name.

4.1.4 Plant height (cm)

The data on plant height of ginger as influenced by rhizome size, plant spacing and their interactions is presented in Table 4.3 and Fig. 4.3. Plant height was significantly influenced by rhizome size and plant spacing at 30 DAP, 120 DAP and at harvest.

Seed rhizome size showed significant influence on plant height throughout the crop growth stages in ginger. Among different seed rhizome sizes, 40 g rhizome size (S_3) recorded significantly highest plant height at 30 DAP, 120 DAP and at harvest (16.68 cm, 43.25 cm and 67.87 cm respectively) followed by 30 g rhizome size (S_2) (15.36 cm, 41.99 cm and 63.76 cm respectively). While, 20 g seed rhizome size (S_1) recorded the lowest plant height at 30 DAP, 120 DAP and at harvest (14.91 cm 36.72 cm and 60.20 cm respectively).

The reason for highest plant height recorded from 40 g rhizome size could be explained in terms of availability of sufficient food reserves which probably encouraged vigorous plant growth. This is in agreement with the findings of Govinden *et al.* (1995), Maia *et al.* (1995), Rashid *et al*. (1996), Bahadur *et al*. (2000), Meenakshi *et al*. (2001a), Alam *et al.* (2003), Gill *et al*. (2004), Kumar (2005), Pratap and Singh (2007), Manhas and Gill (2012) and Padmadevi *et al*. (2012) in turmeric crop, Sengupta and Dasgupta (2011) in ginger crop.

Different spacing levels showed significant variation pertaining to plant height at all the crop growth stages observed. Closer spacing of 25 cm X 15 cm (D_1) recorded maximum plant height at 30 DAP, 120 DAP and at harvest (16.34 cm, 42.47 cm and 65.07 cm respectively) over other spacings. Plant height decreased with increased plant spacing.

Under closer spacing, plant might have adjusted its canopy in the vertical space by increasing inter nodal length as there was limited horizontal space. While, under wider spacing, there was less inter plant competition resulting in greater horizontal spread, less inter nodal length and shorter plants. These results are in accordance with the findings of Ramachandran and Muthuswamy (1984), Kandiannam and Chandaragiri (2008) and Pandey and Mishra (2009) in turmeric crop, Yadav *et al*. (2013) in ginger crop

Interaction effect of rhizome size and plant spacing on plant height was found to be non-significant at 30 DAP and 120 DAP. However at harvest it was found to be significant. Among the treatments, the combination of 40 g

rhizome size and 25 cm X 25 cm plant spacing recorded the highest plant height (69.67 cm) at harvest followed by 40 g rhizome size and 30 cm X 30 cm plant spacing (68.13 cm).

4.1.5 Number of leaves per plant

The data pertaining to number of leaves per plant due to rhizome size, plant spacings and their interactions is presented in Table 4.4 and Fig. 4.4.

Seed rhizome size showed significant effect on production of leaves per plant at 30 DAP, 120 DAP and at harvest. The rhizome size of 40 g (S_3) has recorded significantly more number of leaves per plant at 30 DAP, 120 DAP and at harvest (12.01, 104.52 and 115.36 respectively). Lowest number of leaves per plant recorded from 20 g rhizome size (7.56 at 30 DAP, 77.89 at 120 DAP and 82.39 at harvest).

The higher number of leaves per plant with 40 g rhizome size could be attributed to more reserve food material in bigger sized rhizomes which gave quick emergence and more vigorous growth of the plant leading to the production of more number of leaves per plant than the smaller seed rhizome size. Increase in growth parameters with the increase in seed rhizome size could be due to larger buds and large amount of food reserves in the larger seed rhizomes which enhanced the plant growth. These results are in accordance with the findings of Singh *et al.* (1988a), Govind et al. (1993), Rashid *et al.* (1996), Meenakshi *et al*. (2001a), Kumar (2005), Pratap and Singh (2007), Manhas and Gill (2012) and Padmadevi *et al*. (2012) in turmeric crop, Sengupta and Dasgupta (2011) in ginger crop.

With regard to plant spacing, different plant spacings showed significant effect on production of leaves per plant throughout the crop growth stages except at 30 DAP.

Among the spacings, 30 cm X 30 cm (D_4) recorded the maximum number of leaves per plant at 30 DAP, 120 DAP and at harvest (10.69, 104.47

and 106.09 respectively).

The increase in total number of leaves per plant at wider spacing might be due to the less competition because of less population and this might have resulted in more horizontal growth at lower plant population and has contributed to more number of leaves per plant. The results are in accordance with the findings of Ramachandran and Muthuswami (1984), Philip (1985), Shashidhar and Sulikeri (1996a), Bahadur *et al*. (2000), Islam *et al*. (2002), Pandey and Mishra (2009), Kiran *et al*. (2013), Bhadouria *et al*. (2014) and Mohamed *et al*. (2014) in turmeric crop.

The interaction effect of seed rhizome size and plant spacing showed significant effect on number of leaves per plant at all the growth stages except at 30 DAP under study. The combination of 40 g seed rhizome size with 30 cm X 30 cm spacing (S_3D_4) has recorded highest number of leaves per plant at 30 DAP (13.20). While, 40 g rhizome size with 40 cm X 20 cm spacing (S_3D_5) has recorded the highest number of leaves per plant at harvest (120.20).

4.1.6 Leaf length (cm), breadth (cm) and area (cm^2)

The data pertaining to various leaf characters like leaf length, leaf breadth and leaf area as influenced by seed rhizome size, plant spacing and their interactions are presented in Table 4.5, 4.6 and Fig. 4.5.

Seed rhizome size showed significant effect on various leaf characters under study. Among different seed rhizome sizes, rhizome size of 40 g (S_3) recorded significantly highest leaf length (18.94 cm), leaf breadth (2.07 cm) and leaf area (21.70 cm^2). While, the seed rhizome size of 20 g (S_1) produced the lowest leaf length (17.56 cm), leaf breadth (1.91 cm) and leaf area (19.29 cm^2).

These results of higher leaf length, breadth and area with higher rhizome size are in conformity with the research findings of Korla *et al.* (1989) and Blay *et al.* (1998) in ginger crop, Meenakshi *et al*. (2001a) and Padmadevi *et al.* (2012) in turmeric crop.

Different plant spacing showed significant variation regarding leaf length, breadth and area. The spacing treatment of 30 cm X 30 cm (D_4)

produced highest leaf length (18.96 cm), leaf breadth (2.09 cm) and leaf area (22.13 cm^2).

Shading with neighboring plant is the principal and significant factor of competition among the plants because it had greatly affected the leaf development. Similar observations were recorded by Philip (1985) in Turmeric, who observed maximum leaf breadth with wider spacing of 30 cm X 30 cm. Yadav *et al.* (2013) also observed longest leaf (19.15 cm), broadest leaf (2.16 cm) and highest leaf area (35.37 cm^2) at wider spacing of 25 cm X 35 cm.

Interaction effect of seed rhizome size and plant spacings on leaf length, leaf breadth and leaf was found to be significant. The treatment S_3D_4 (40 g rhizome size and 30 cm X 30 cm) recorded significantly longest leaf (20.82 cm), broadest leaf (2.21 cm) and highest leaf area (23.87 cm^2) over rest of the treatments.

4.1.7 Leaf area index

The data pertaining to leaf area index due to rhizome size, plant spacings and their interactions were significant and are presented in Table 4.6.

Seed rhizome size had significant influence on harvest index of ginger under coconut cropping system. The treatment of 40 g rhizome size (S_3) recorded significantly highest leaf area index (3.59), while lowest harvest index (3.18) was observed in the 20 g rhizome size (S_1). The results are in accordance with the findings of Blay *et al.* (1998) in ginger crop.

Different plant spacing showed significant variation regarding leaf area index. The spacing treatment of 25 cm X 15 cm (D_1) produced highest leaf area index (5.25) and lowest (2.45) recorded from spacing of 30 cm X 30 cm. At closer spacing, more plants per unit area can be achieved compared to medium and wider spacings as a result more leaf area per unit area of land. These findings are in accordance and in conformity with the findings of Kandiannan and Chandaragiri (2006) in turmeric crop.

The interaction between seed rhizome size and spacing showed significant effect leaf area index of ginger. Significantly highest leaf area index

(5.88) was observed from a combination of 40 g rhizome size with 25 cm X 15 cm (S_3D_1). The lowest leaf area index (2.12) was recorded from a combination of 20 g rhizome size with 30 cm X 30 cm (S_1D_4).

4.2 Yield and yield attributes

4.2.1 Rhizome length (cm) and breadth (cm)

The data pertaining to various rhizome characters like rhizome length and rhizome breadth as influenced by rhizome size, plant spacing and their interactions are presented in Table 4.7 and Fig. 4.6 (Plate 4.1(a,b)).

Different seed rhizome sizes showed significant variation for rhizomes characters. Among the rhizome sizes, 40 g seed rhizome size (S_3) followed by 30 g rhizome size (S_2) recorded the longest (15.82 cm and 14.55 cm) and broadest rhizome (15.89 cm and 14.79 cm).

Highest length and width of fresh rhizome might be due to increase in seed rhizome size used for planting. These findings are in accordance and in conformity with the findings of Korla *et al*. (1989) and Hailemichael and Tesfaye (2008) in ginger, Govind *et al*. (1993) and Singh *et al*. (2014) in turmeric crop.

Different plant spacings showed non-significant variation with regard to rhizome characters. Among the spacing treatments, 30 cm X 30 cm plant spacing (D_4) produced longest rhizome (14.90 cm) and broadest rhizome (14.67 cm).

The reason for longest and broadest rhizome with wider spacing might be due to better availability of plant nutrients, moisture and light in wider spaced plants. Under closer spacing rhizome could not expose properly, which ultimately resulted in smaller rhizome compared with that of wider spacing. Similar results were reported by Modupeola *et al*. (2013) and Yadav *et al*. (2013) in ginger, Kiran *et al*. (2013) in turmeric crop.

Plate 4.1(a): Green ginger rhizome length at best seed rhizome size, plant spacing and interaction effect under coconut cropping system.

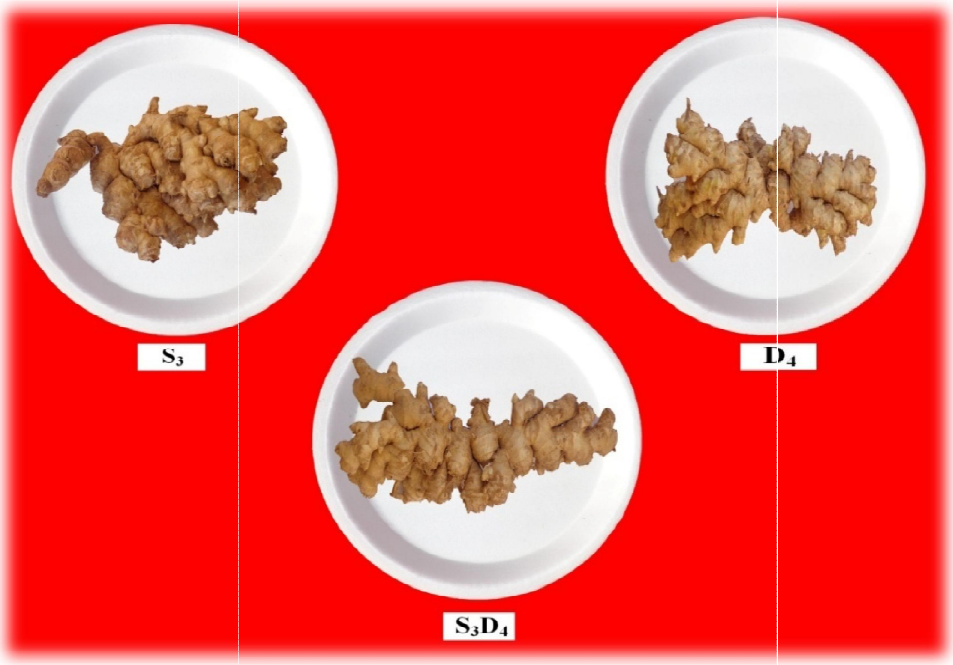

Plate 4.1(b): Green ginger rhizome breadth at best seed rhizome size, plant spacing and interaction effect under coconut cropping system.

The interaction effect of rhizome size and plant spacing on rhizome length and breadth was found to be significant. Among the interactions, a combination of 40 g rhizome size with 25 cm X 25 cm spacing (S_3D_2) recorded maximum rhizome length (17.20 cm) and combination of 40 g rhizome size with 30 cm X 30 cm spacing (S_3D_4) recorded maximum rhizome breadth (17.07 cm).

4.2.2 Rhizome yield per plant (g), plot (kg) and hectare (t)

Yield and yield attributing characters of ginger **viz.,** fresh rhizome yield per plant, rhizome yield per plot and per hectare as influenced by seed rhizome size, plant spacings and their interactions are presented in Table 4.8 and Fig. 4.7a and 4.7b.

Seed rhizome size showed significant effect on yield and yield attributing characters in ginger. Among the different seed rhizome sizes, rhizome size of 40 g (S_3) produced significantly highest rhizome yield per plant (204.01 g), per plot (3.29 kg) and rhizome yield per hectare (27.41 t) followed by 30 g rhizome size(193.55 g, 2.59 kg and 21.56 t respectively). Lowest rhizome yield per plant (165.51 g), per plot (2.30 kg) and per hectare (19.13 t) was recorded from 20 g (S_1) rhizome size.

Results regarding variation in yield due to seed rhizome size might be due to the fact that the plants produced from the largest rhizome size emerged earlier and showed vigorous and rapid growth using the initial reserve food materials and producing maximum yield and yield attributes than the smaller rhizome size in ginger. Therefore highest rhizome yield in the largest seed rhizome size is due to taller plants that have higher number of leaves per tiller, longer and thickest rhizomes. These results are in conformity with the findings of Korla *et al*. (1989), Blay *et al*. (1998), Monnaf *et al*. (2010), Sengupta and Dasgupta (2011) and Sharma *et al*. (2012) in ginger crop, Tayde and Deshmukh (1986), Singh and Kar (1989), Chattopadhyay *et al*. (1990), Barholia *et al*. (1992), George (1993), Yothasiri *et al*. (1997), Alam *et al*. (2003), Hossain *et al*. (2005a), Pratap and Singh (2007), Ghosh and hore (2011), Manhas and Gill

(2012), Padmadevi *et al*. (2012) and Singh *et al*. (2014) in turmeric crop.

Plant spacings showed significant effect on yield and yield attributing characters of ginger. Among the plant spacings, 30 cm X 30 cm spacing (D_4) produced highest rhizome yield per plant (203.02 g) and it was significantly superior over rest of the treatments. The lowest rhizome yield per plant (179.33 g) was observed with 40 cm X 20 cm spacing.

The increase in yield under higher plant population was attributed due to more plant population per hectare. The higher rhizome weight in wider spacing may be due to better availability of nutrients, moisture and adequate space available for the enlargement of rhizomes under wider spacing. These results are in line with the earlier findings of Shashidhar and Sulikeri (1996a), Bahadur *et al*. (2000), Pratap and Singh (2007), Pandey and Mishra (2009), Kumar and Gill (2010) and Bhadouria *et al*. (2014) in turmeric crop, Yadav *et al*. (2013) in ginger crop.

However, green ginger yield per plot and per hectare was significantly highest under 25 cm X 15 cm (3.17 kg and 26.40 t respectively), while the lowest green ginger yield per plot (2.39 kg) and per hectare (19.92 t) was recorded from 30 cm X 30 cm spacing. However, D_4 (30 cm X 30 cm) and D_5 (40 cm X 20 cm) are at par with each other.

The significant increase in yield per plot and yield per hectare under closer spacing may solely be ascribed on the function of higher plant density per unit area of land together with efficient availability and utilization of nutrients by the growing plants. Similar results were reported by of Bahadur *et al*. (2000), Hore and Chattopadhyay (2003), Pratap and Singh (2007), Pandey and Mishra (2009), Kumar and Gill (2010) and Bhadouria *et al*. (2014) in turmeric crop, Ghosh and Hore (2011), Modupeola *et al*. (2013) and Yadav *et al*. (2013) in ginger crop.

The interaction between seed rhizome size and spacing showed significant effect on yield and yield attributing characters of ginger. Significantly highest green ginger yield per plant (215.40 g) was observed from a combination

of 40 g rhizome size with 30 cm X 30 cm (S_3D_4). The lowest rhizome yield (147.20 g) was recorded from a combination of 20 g rhizome size with 40 cm X 20 cm (S_1D_5).

The yield of green ginger yield per plot and per hectare varied significantly with seed rhizome size and plant spacings. The highest green ginger yield per plot (4.57 kg) and per hectare (38.06 t) was recorded by a combination of 40 g rhizome size with 25 cm X 15 cm spacing (S_3D_1). The lowest yield of green ginger per plot (2.17 kg) and per hectare (18.06 t) was produced by a combination of 20 g rhizome size with 25 cm X 25 cm spacing (S_1D_2).

Similar observation of highest weight per clump with 30 cm X 30 cm spacing was recorded by Pratap and Singh (2007) in turmeric crop and Ghosh and Hore (2011) in ginger crop, who observed that closest spacing (20 cm X15 cm) in combination with bigger seed rhizome (25-30 g) produce highest plot yield (15.62 kg/3m^2 and projected yield 12.50 t ha^{-1}).

4.2.3 Harvest index (%)

The data pertaining to harvest index of ginger due to different seed rhizome sizes and plant spacings is presented in Table 4.9.

Seed rhizome size had significant influence on harvest index of ginger under coconut cropping system. The treatment of 40 g rhizome size (S_3) recorded significantly highest harvest index (61.53%), while lowest harvest index (57.97%) was observed in the 20 g rhizome size (S_1).

Plant spacing had non-significant influence on harvest index of ginger. Among different spacing levels, 25 cm X 15 cm spacing (D_1) had produced highest harvest index (60.37%) followed by 25 cm X 25 cm spacing (D_2). These results are in line with the earlier findings of Yadav *et al*. (2014) in ginger crop.

The interaction effect between seed rhizome size and plant spacing pertaining to harvest index was insignificant.

4.3 Quality attributes

4.3.1 Essential oil content (%)

The essential oil content of ginger under coconut cropping system as influenced by seed rhizome size and plant spacing and their interactions is presented in Table 4.10 and Fig. 4.8.

Rhizome size showed significant effect on essential oil content of ginger. Among the treatments, 40 g rhizome size (S_3) recorded significantly higher essential oil content (1.83%) followed by 30 g rhizome (1.81%). It was observed that essential oil content increased with the increase in seed rhizome size in ginger.

These results are analogous with the findings reported by Kumar and Gill (2010) in turmeric.

The essential oil content differed non-significantly among different treatments of spacing. However, highest oil content (1.81%) was observed in 30 cm X 30 cm spacing and the lowest (1.78%) was observed in 25 cm X 25 cm.

Similar observations of non significant influence of spacing on essential oil content was reported by Kumar and Gill (2010) in turmeric, who observed highest oil content (7.14%) with lower plant density.

Interaction effect of rhizome size and plant spacing was seen significant. Significantly the highest essential oil content (1.85%) was observed from a combination of 40 g rhizome size with 30 cm X 30 cm spacing (S_3D_4).

4.3.2 Oleoresin content (%)

The oleoresin content of ginger as affected by rhizome size, spacing and their interaction is presented in Table 4.10 and Fig. 4.8.

Seed rhizome size was found to be significant pertaining to oleoresin content in ginger. Among the different seed rhizome sizes, the oleoresin content

was highest under 40 g rhizome (7.87%). The lowest oleoresin content was observed in 20 g rhizome (7.62%). Similar observation was recorded by Philip (1983), Maia *et al*. (1995) and Kumar and Gill (2010) in turmeric crop.

Plant spacing had no significant effect on the oleoresin content. However, the highest oleoresin content was observed in 30 cm X 30 cm (7.80%) and the lowest was observed in closest spacing of 25 cm X 15 cm (7.75%). Neopaney (1998) also mentioned similar results in ginger. He found that spacing does not exercise any significant effect on oleoresin content.

Similarly the interaction effect of rhizome size and plant spacing on oleoresin content of ginger was non-significant under coconut cropping system.

4.3.3 Starch content (%)

The starch content of ginger as affected by rhizome size, spacing and their interaction is presented in Table 4.11 and Fig. 4.9.

Seed rhizome size showed significant influence on starch content of ginger. Among various rhizome sizes, 40 g rhizome size (S_3) showed significantly superior starch content (30.36%). The lowest starch content was observed in 20 g rhizome size (30.27%).

It was observed from the data that the plant spacing had no significant effect on the starch content. However, the highest starch content was observed in 30 cm X 30 cm (30.33%) and the lowest was observed in 25 cm X 25 cm (30.29%). These results are in accordance with findings of Modupeola *et al.* (2013) who observed highest total starch content with wider spacing.

The interaction effect of seed rhizome size and spacing was significant. The highest starch content (30.48%) was observed from a combination of 40 g rhizome size with 30 cm X 20 cm spacing (S_3D_3) and the lowest was observed from a combination of 20 g rhizome size with 30 cm X 20 cm spacing (30.20%).

4.3.4 Crude fibre content (%)

The crude fibre content of ginger under coconut cropping system as affected by seed rhizome size, spacings and their interaction is presented in Table 4.11 and Fig. 4.9.

The crude fibre content was non-significantly highest under 40 g rhizome size and 30 cm X 30 cm plant spacing (4.90% and 4.89% respectively). While, the lowest crude fibre content was observed in 20 g rhizome size and 25 cm X 15 cm spacing (4.84% and 4.85% respectively). Similar results were observed by Nizam and Jayachandran (1997) in turmeric crop.

Similarly the interaction effect of rhizome size and plant spacing on crude fibre content of ginger was non-significant under coconut cropping system.

4.4 ECONOMICS OF GROWING GINGER UNDER COCONUT CROPPING SYSTEM

The details of cost of cultivation of ginger and value of the produce have been worked out on the basis of prevailing market rates during the year of experiments (Appendix-II, III and IV).

Cost of cultivation

The total cost of production varied from Rs.1,77,981 ha^{-1} to 6,00,203 ha^{-1}. The 20 g seed rhizome size with a combination of wider plant spacing (30 cm X 30 cm) recorded minimum cost of cultivation (1,77,981 ha^{-1}). Whereas, the 40 g seed rhizome size with a combination of closer spacing (25 cm X 15 cm) recorded maximum cost of cultivation (Rs. 6,00,203 ha^{-1}) (Table 4.12).

Gross returns

Among the different treatmental combinations, 40 g rhizome size with 25 cm X 15 cm plant spacing recorded highest gross returns (19,03,000 ha^{-1}). The 20 g seed rhizome size with 25 cm X 25 cm plant spacing recorded the lowest gross returns (Rs.9,03,000 ha^{-1}) (Table 4.12).

Net returns

The maximum net returns were realized in 40 g seed rhizome size with 25 cm X 15 cm plant spacing (13,02,797 ha^{-1}) followed by 40 g seed rhizome size with 25 cm X 25 cm plant spacing (12,32,630 ha^{-1}) (Table 4.12). The minimum net returns were obtained with 20 g seed rhizome size with 25 cm X 15 cm plant spacing (6,16,463 ha^{-1}).

Benefit cost ratio

The economic analysis indicated higher B:C ratio with 20 g seed rhizome size with 40 cm X 20 cm plant spacing (4.68) followed by 20 g rhizome size with 30 cm X 30 cm plant spacing (4.16) (table 4.12). The lower B:C ratio was obtained with 30 g seed rhizome size with 25 cm X 15 cm plant spacing.

Table: 4.1 Sprouting of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing											
	Days to first sprouting						Days to 50 % sprouting					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	15.33	15.00	13.67	12.67	13.00	13.93	23.00	22.67	23.33	22.00	22.33	22.67
S_2	12.67	13.33	13.33	14.33	13.67	13.47	21.00	20.33	20.67	21.67	22.67	21.27
S_3	13.00	13.33	11.67	11.33	14.33	12.73	19.33	19.00	19.33	18.33	19.33	19.07
Mean	13.67	13.89	12.89	12.78	13.67		21.11	20.67	21.11	20.67	21.44	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.26	0.76	0.21	0.61
D	0.34	NS	0.27	NS
SXD	0.59	1.71	0.47	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table : 4.2 Number of tillers per plant in ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing																	
	No. of tillers per plant at 30 DAP						No. of tillers per plant at 120 DAP						No. of tillers per plant at harvest					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	1.73	1.40	1.73	1.73	1.87	1.69	6.87	6.67	7.87	9.73	8.07	7.84	8.93	7.53	8.47	9.53	9.13	8.72
S_2	2.33	2.27	2.60	2.60	3.13	2.59	11.00	9.93	8.40	10.27	10.33	9.99	10.20	9.53	10.67	12.33	9.80	10.51
S_3	3.20	2.67	2.73	3.60	2.67	2.97	11.40	10.40	8.13	12.80	10.00	10.55	12.47	10.53	10.87	13.07	10.60	11.51
Mean	2.42	2.11	2.36	2.64	2.56		9.76	9.00	8.13	10.93	9.47		10.53	9.20	10.00	11.64	9.84	

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.11	0.32	0.23	0.67	0.13	0.36
D	0.14	NS	0.30	0.86	0.16	0.47
SXD	0.25	NS	0.52	1.50	0.28	0.82

S-Rhizome size	D-Spacing
S_1-20 g	D_1-25 cm X 15 cm
S_2-30 g	D_2-25 cm X 25 cm
S_3-40 g	D_3-30 cm X 20 cm
	D_4-30 cm X 30 cm
	D_5-40 cm X 20 cm

Table: 4.3 Plant height of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing																	
	Plant height (cm) at 30 DAP						Plant height (cm) at 120 DAP						Plant height (cm) at harvest					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	15.00	15.13	14.83	14.87	14.70	14.91	38.40	33.33	35.73	38.13	38.00	36.72	61.53	60.40	62.33	55.27	61.47	60.20
S_2	16.69	16.03	14.33	16.27	13.50	15.36	43.60	43.60	41.13	43.93	37.67	41.99	66.33	64.20	62.00	63.73	62.53	63.76
S_3	17.33	17.10	16.13	16.03	16.80	16.68	45.40	43.07	43.00	44.27	40.53	43.25	67.33	69.67	66.40	68.13	67.80	67.87
Mean	16.34	16.09	15.10	15.72	15.00		42.47	40.00	39.96	42.11	38.73		65.07	64.76	63.58	62.38	63.93	

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.27	0.78	0.66	1.92	0.40	1.17
D	0.35	1.01	0.86	2.48	0.52	1.51
SXD	0.61	NS	1.48	NS	0.90	2.62

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.4 Number of leaves per plant in ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing																	
	No. of leaves per plant at 30 DAP						No. of leaves per plant at 120 DAP						No. of leaves per plant at harvest					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	8.07	7.33	6.60	7.20	8.60	7.56	75.60	60.73	74.80	91.40	86.93	77.89	92.80	71.33	76.33	93.20	78.27	82.39
S_2	11.27	10.93	11.27	11.67	11.33	11.29	94.47	102.07	83.20	113.27	107.20	100.04	100.07	108.27	88.60	105.53	101.07	100.71
S_3	11.53	12.13	12.80	13.20	10.40	12.01	115.53	103.13	88.00	108.73	107.20	104.52	116.07	113.13	107.87	119.53	120.20	115.36
Mean	10.29	10.13	10.22	10.69	10.11		95.20	88.64	82.00	104.47	100.44		102.98	97.58	90.93	106.09	99.84	

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.34	0.98	1.06	3.08	0.99	2.87
D	0.44	NS	1.37	3.98	1.28	3.70
SXD	0.76	NS	2.38	6.89	2.21	6.42

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.5 Leaf characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing											
	Leaf length (cm)						Leaf breadth (cm)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	16.66	17.27	17.51	18.41	17.93	17.56	1.94	2.02	1.89	1.87	1.85	1.91
S_2	18.77	18.20	17.00	17.63	17.31	17.78	2.08	2.11	1.96	2.20	1.96	2.06
S_3	17.87	19.55	18.21	20.82	18.26	18.94	1.99	2.11	2.09	2.21	1.94	2.07
Mean	17.77	18.34	17.57	18.96	17.84		2.00	2.08	1.98	2.09	1.92	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.21	0.62	0.02	0.05
D	0.28	0.80	0.02	0.07
SXD	0.48	1.39	0.04	0.11

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.6 Leaf characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing											
	Leaf area (cm^2)						Leaf area index					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	18.78	19.60	18.57	19.10	20.40	19.29	5.00	3.13	3.09	2.12	2.56	3.18
S_2	18.31	21.96	20.20	23.40	22.38	21.25	4.88	3.51	3.36	2.60	2.79	3.43
S_3	22.06	20.99	19.10	23.87	22.49	21.70	5.88	3.35	3.18	2.65	2.89	3.59
Mean	19.71	20.85	19.29	22.13	21.76		5.25	3.33	3.21	2.45	2.75	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.32	0.93	0.06	0.17
D	0.41	1.20	0.07	0.21
SXD	0.72	2.08	0.13	0.37

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.7 Rhizome characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing											
	Rhizome length (cm)						Rhizome breadth (cm)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	13.20	12.87	12.60	13.00	13.80	13.09	11.73	11.47	13.13	11.53	13.13	12.20
S_2	13.53	14.53	14.80	14.87	15.00	14.55	13.93	15.07	14.60	15.40	14.93	14.79
S_3	15.20	17.20	15.07	16.82	14.80	15.82	15.93	15.93	15.47	17.07	15.07	15.89
Mean	13.98	14.87	14.16	14.90	14.53		13.87	14.16	14.40	14.67	14.38	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.22	0.63	0.17	0.49
D	0.28	NS	0.22	NS
SXD	0.49	1.41	0.38	1.10

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.8 Effect of seed rhizome size and plant spacing on ginger yield under coconut cropping system.

Rhizome size	Plant spacing																	
	Yield per plant (g)						Yield per plot (kg)						Yield per hectare (t)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	169.07	165.87	160.47	184.93	147.20	165.51	2.28	2.17	2.21	2.20	2.62	2.30	19.00	18.06	18.42	18.36	21.81	19.13
S_2	173.47	196.80	199.53	208.73	189.20	193.55	2.66	3.43	2.36	2.30	2.19	2.59	22.14	28.58	19.69	19.17	18.22	21.56
S_3	201.13	206.80	195.13	215.40	201.60	204.01	4.57	3.89	2.87	2.67	2.46	3.29	38.06	32.39	23.89	22.22	20.47	27.41
Mean	181.22	189.82	185.04	203.02	179.33		3.17	3.16	2.48	2.39	2.42		26.40	26.34	20.67	19.92	20.17	

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	1.79	5.19	0.16	0.46	1.34	3.87
D	2.31	6.70	0.21	0.60	1.72	5.00
SXD	4.01	11.61	0.36	1.04	2.99	8.65

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.9 Harvest index of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing					
	Harvest index (%)					
	D_1	D_2	D_3	D_4	D_5	Mean
S_1	59.33	58.38	57.48	56.62	58.03	57.97
S_2	59.90	60.00	58.42	59.63	59.90	59.57
S_3	61.87	62.50	62.33	60.40	60.57	61.53
Mean	60.37	60.29	59.41	58.88	59.50	

	S.Em±	CD at 5%
S	0.37	1.06
D	0.47	NS
SXD	0.82	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.10 Quality characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing											
	Essential oil (%)						Oleoresin (%)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	1.78	1.78	1.76	1.74	1.73	1.76	7.68	7.66	7.46	7.70	7.62	7.62
S_2	1.80	1.77	1.82	1.82	1.83	1.81	7.73	7.76	7.77	7.79	7.86	7.78
S_3	1.83	1.80	1.83	1.85	1.82	1.83	7.84	7.88	7.87	7.89	7.87	7.87
Mean	1.80	1.78	1.80	1.81	1.79		7.75	7.76	7.70	7.80	7.78	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.01	0.02	0.03	0.08
D	0.01	NS	0.03	NS
SXD	0.01	0.04	0.06	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.11 Quality characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Rhizome size	Plant spacing											
	Starch content (%)						Crude fibre content (%)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	30.30	30.25	30.20	30.31	30.31	30.27	4.83	4.75	4.83	4.88	4.89	4.84
S_2	30.31	30.31	30.29	30.33	30.33	30.31	4.88	4.90	4.90	4.85	4.85	4.88
S_3	30.30	30.32	30.48	30.36	30.33	30.36	4.85	4.92	4.88	4.95	4.88	4.90
Mean	30.31	30.29	30.32	30.33	30.32		4.85	4.86	4.87	4.89	4.88	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.01	0.03	0.02	NS
D	0.01	NS	0.02	NS
SXD	0.02	0.07	0.04	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.12 Gross returns, net returns and benefit cost ratio as influenced by seed rhizome size and plant spacing in ginger under coconut cropping system.

Treatments	Fresh rhizome yield (t ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Selling price (Rs. t^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
S_1D_1 : 20 g and 25 cm x 15 cm	19.00	333537	50000	950000	616463	1.85
S_1D_2 : 20 g and 25 cm x 25 cm	18.06	226870	50000	903000	676130	2.98
S_1D_3: 20 g and 30 cm x 20 cm	18.42	233537	50000	921000	687463	2.94
S_1D_4 :20 g and 30 cm x 30 cm	18.36	177981	50000	918000	740019	4.16
S_1D_5: 20 g and 40 cm x 20 cm	21.81	191870	50000	1090500	898630	4.68
S_2D_1 : 30 g and 25 cm x 15 cm	22.14	466870	50000	1107000	640130	1.37
S_2D_2 : 30 g and 25 cm x 25 cm	28.58	306870	50000	1429000	1122130	3.66
S_2D_3 : 30 g and 30 cm x 20 cm	19.69	316870	50000	984500	667630	2.11
S_2D_4 : 30 g and 30 cm x 30 cm	19.17	233570	50000	958500	724963	3.10
S_2D_5 : 30 g and 40 cm x 20 cm	18.22	254370	50000	911000	656630	2.58
S_3D_1 : 40 g and 25 cm x 15 cm	38.06	600203	50000	1903000	1302797	2.17
S_3D_2 : 40 g and 25 cm x 25 cm	32.39	386870	50000	1619500	1232630	3.19
S_3D_3 : 40 g and 30 cm x 20 cm	23.89	400203	50000	1194500	794297	1.98
S_3D_4 : 40 g and 30 cm x 30 cm	22.22	289092	50000	1111000	821909	2.84
S_3D_5 : 40 g and 40 cm x 20 cm	20.47	316870	50000	1023500	706630	2.23

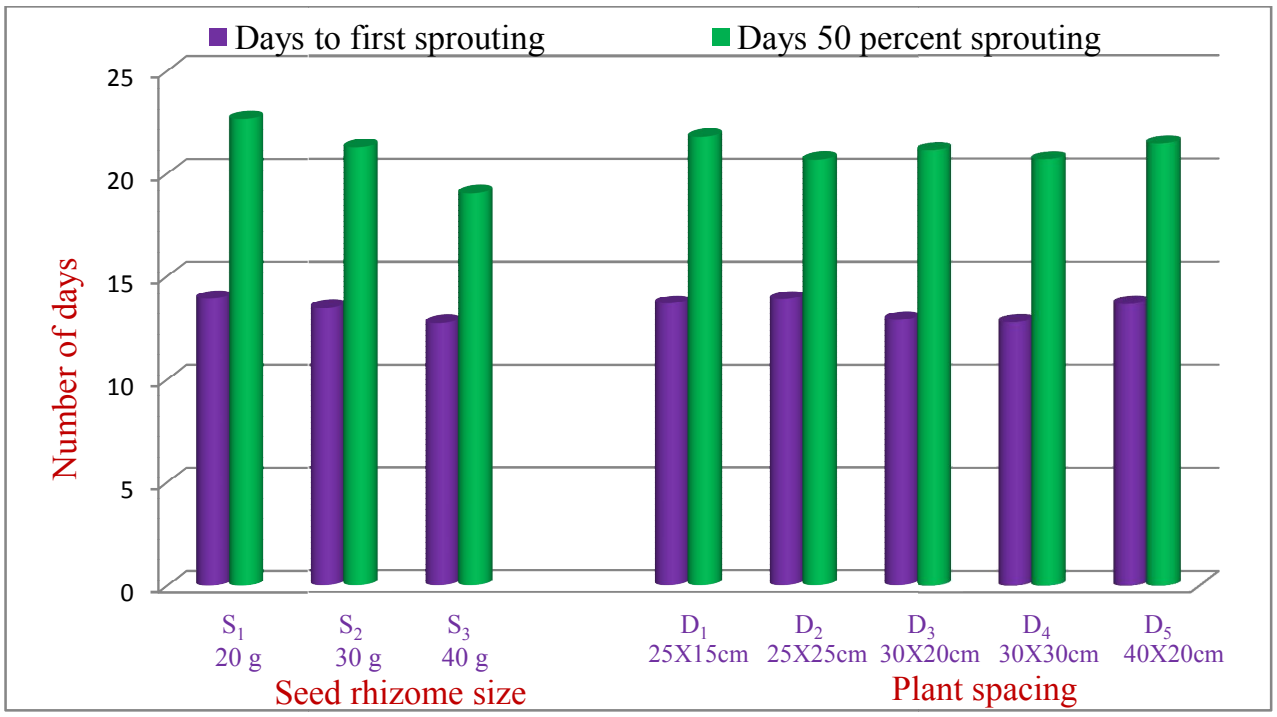

Fig. 4.1 Sprouting of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

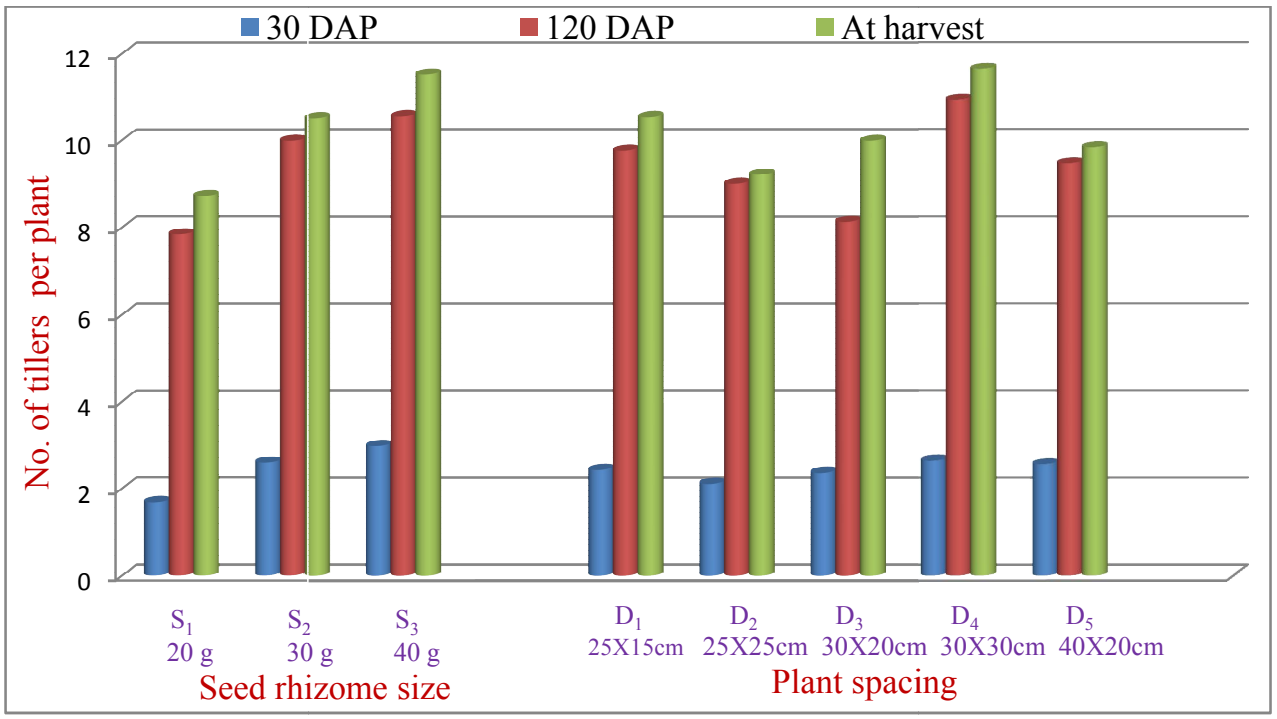

Fig. 4.2 Number of tillers per plant in ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

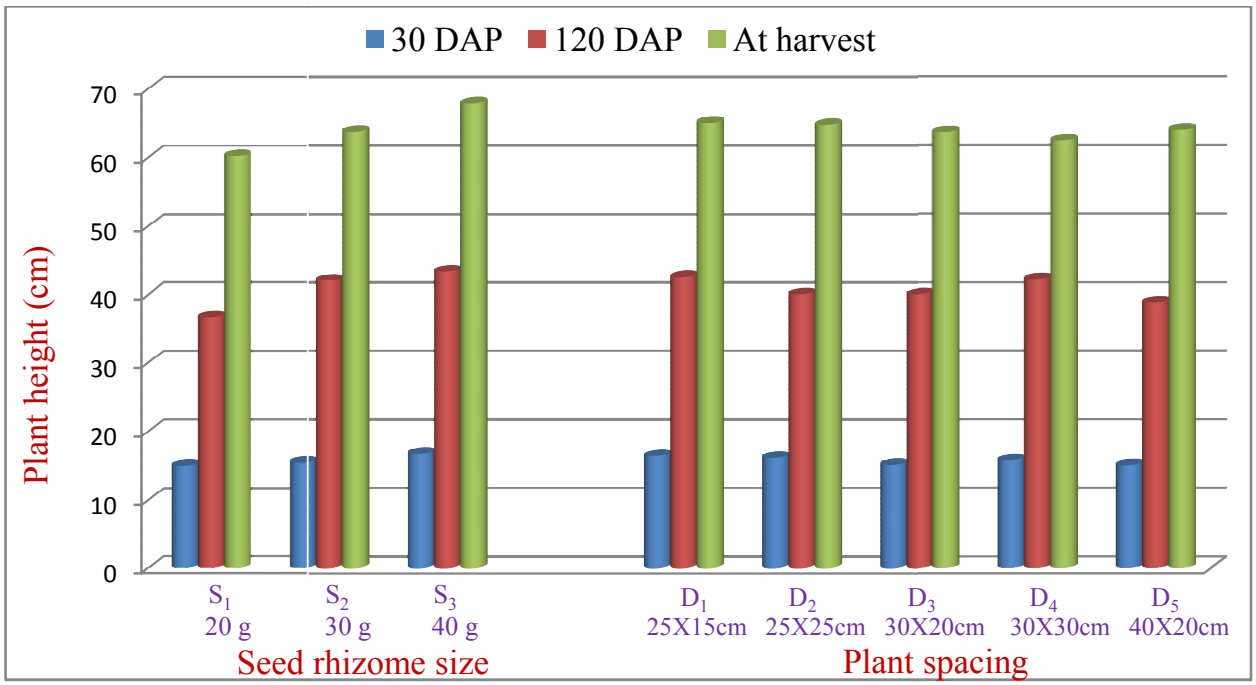

Fig. 4.3 Plant height of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

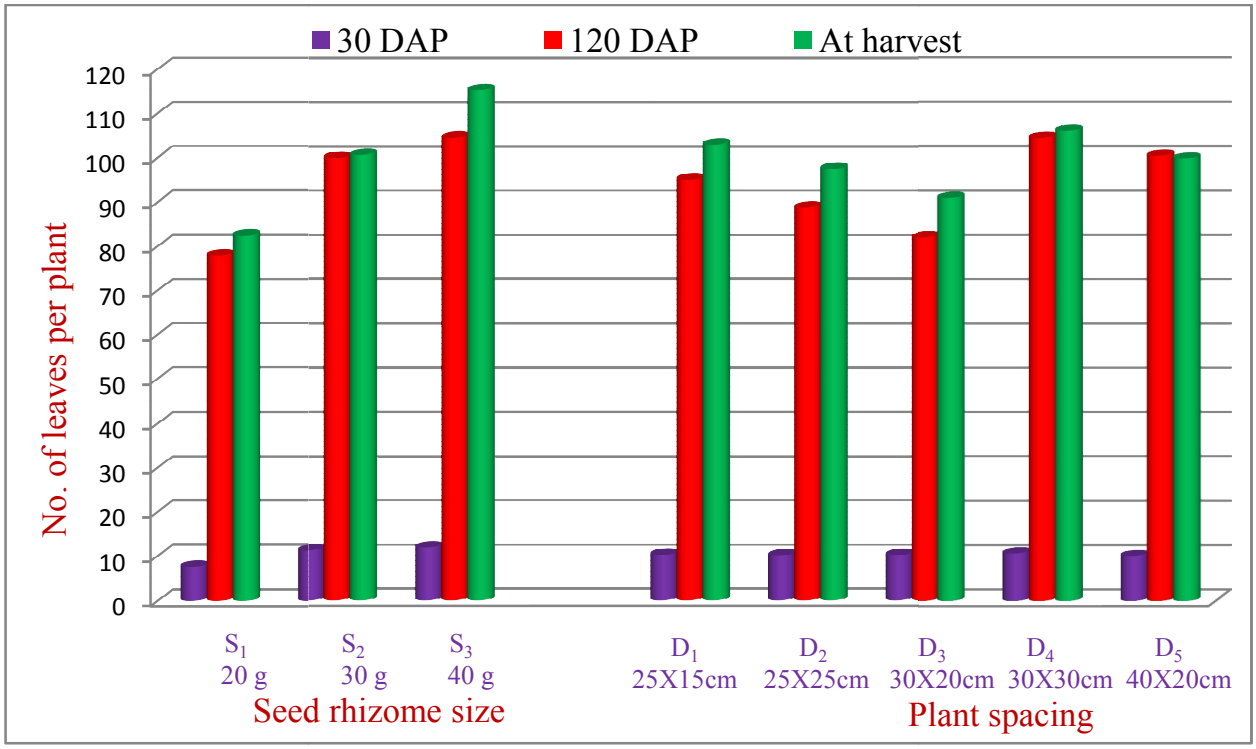

Fig. 4.4 Number of leaves per plant in ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

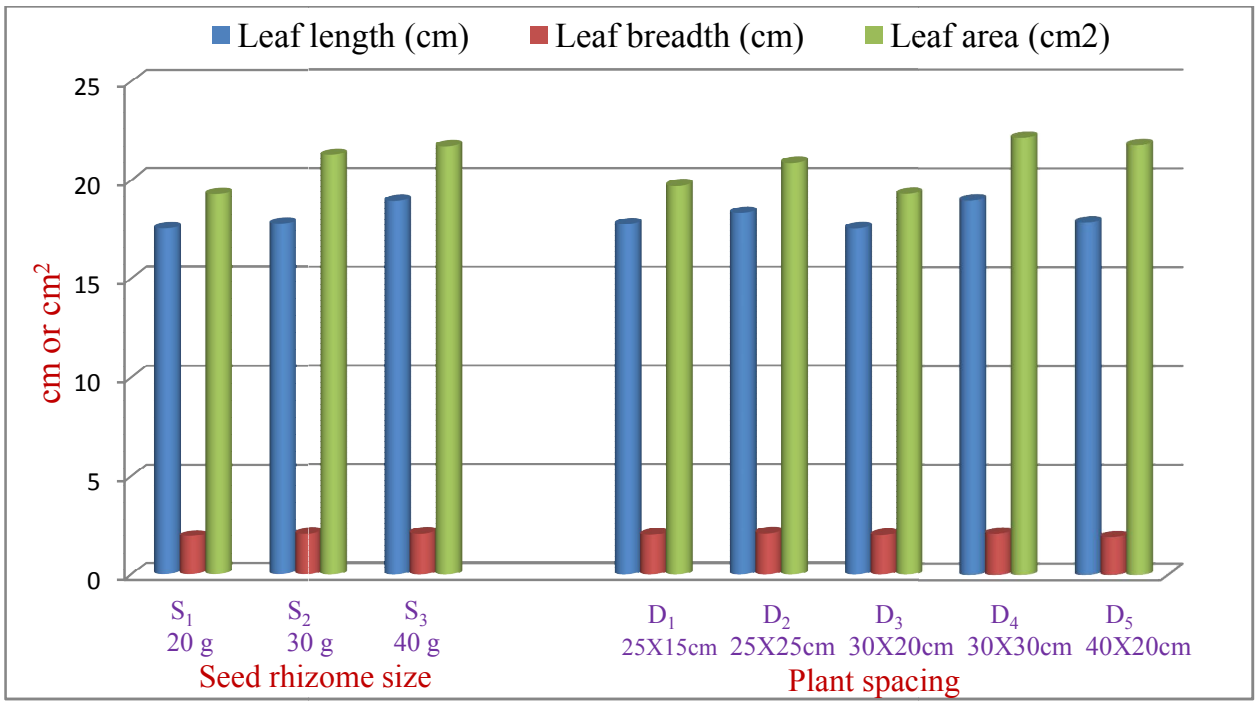

Fig. 4.5 Leaf characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

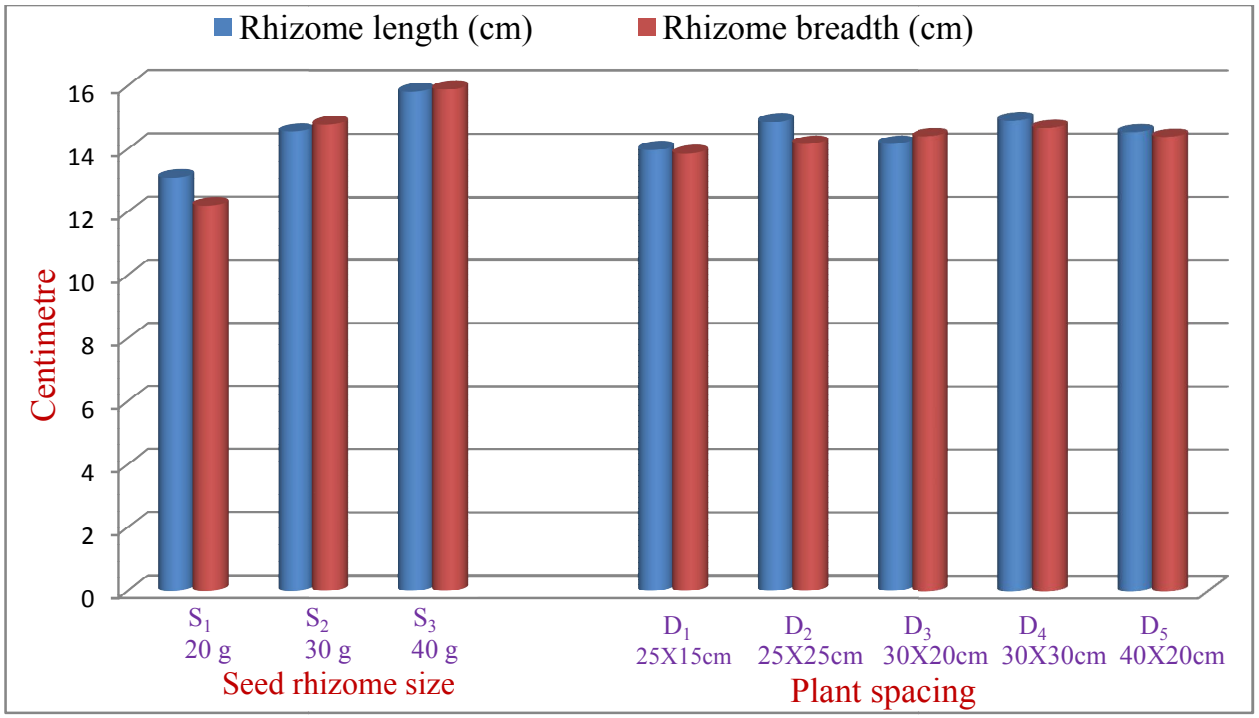

Fig. 4.6 Rhizome characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

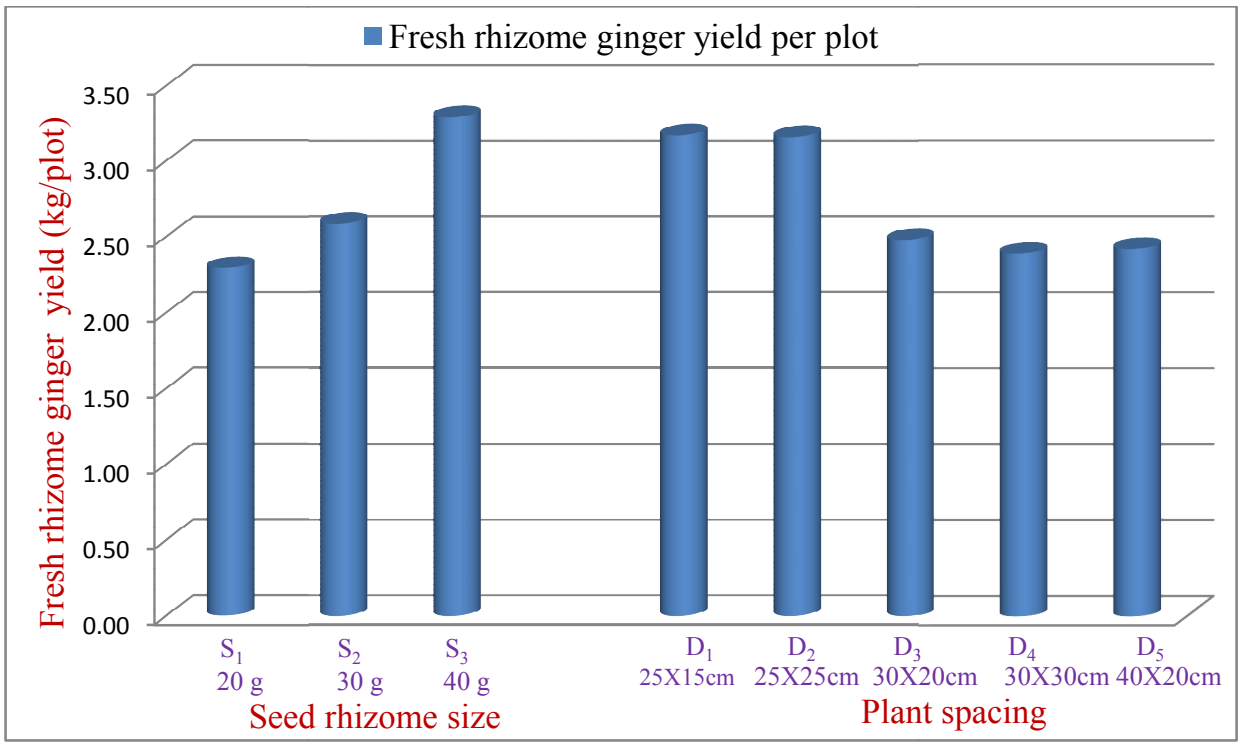

Fig. 4.7a Yield per plot in ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

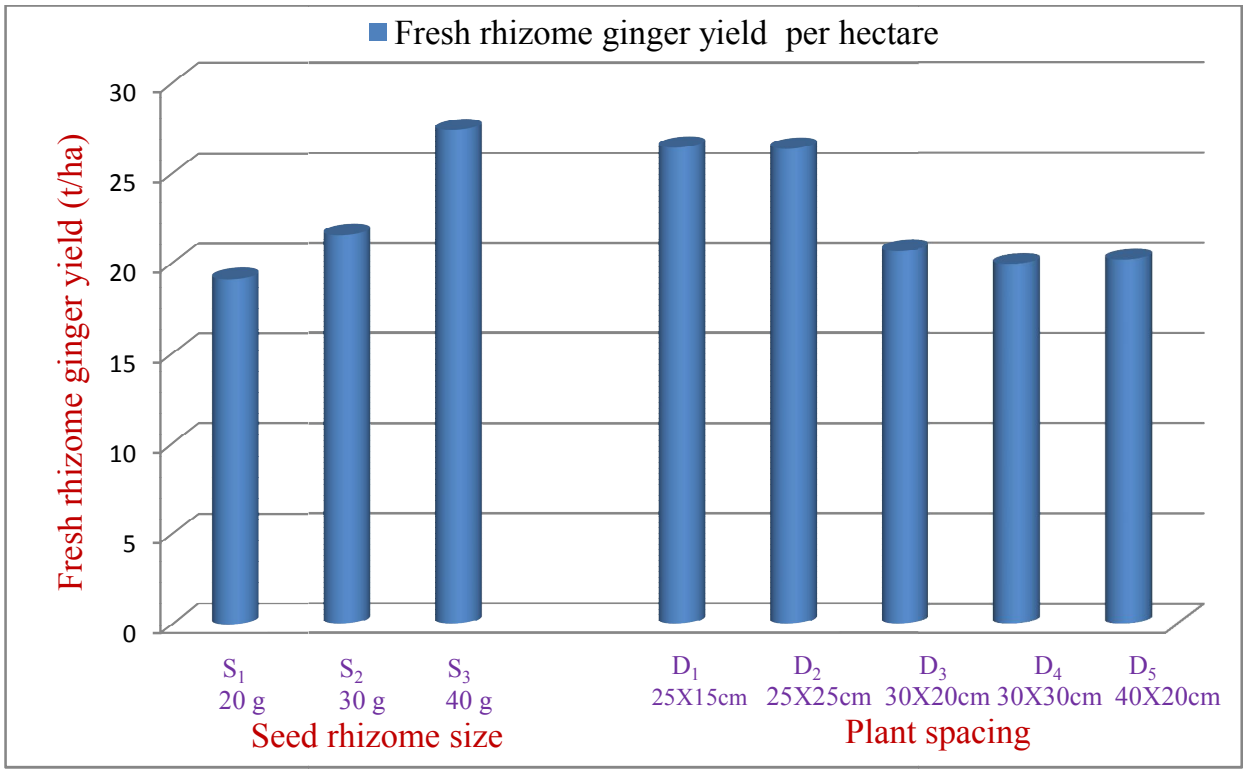

Fig. 4.7b Yield per hectare in ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

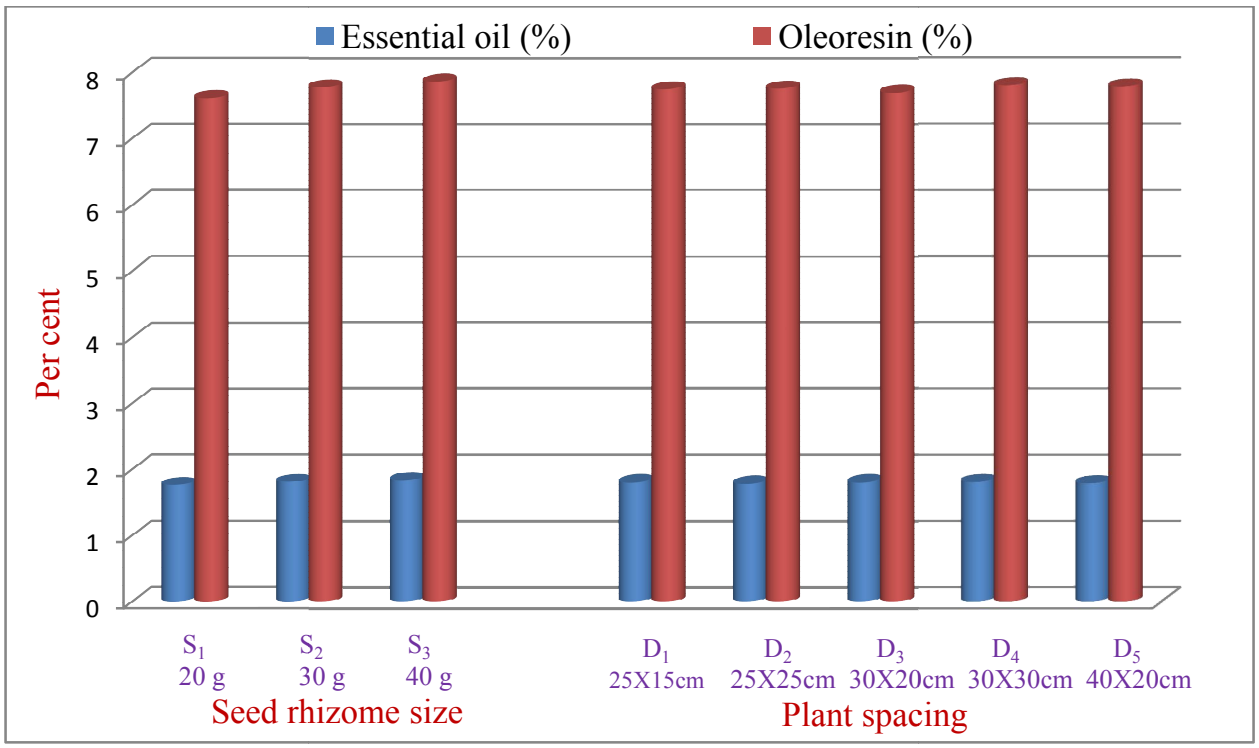

Fig. 4.8 Quality characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

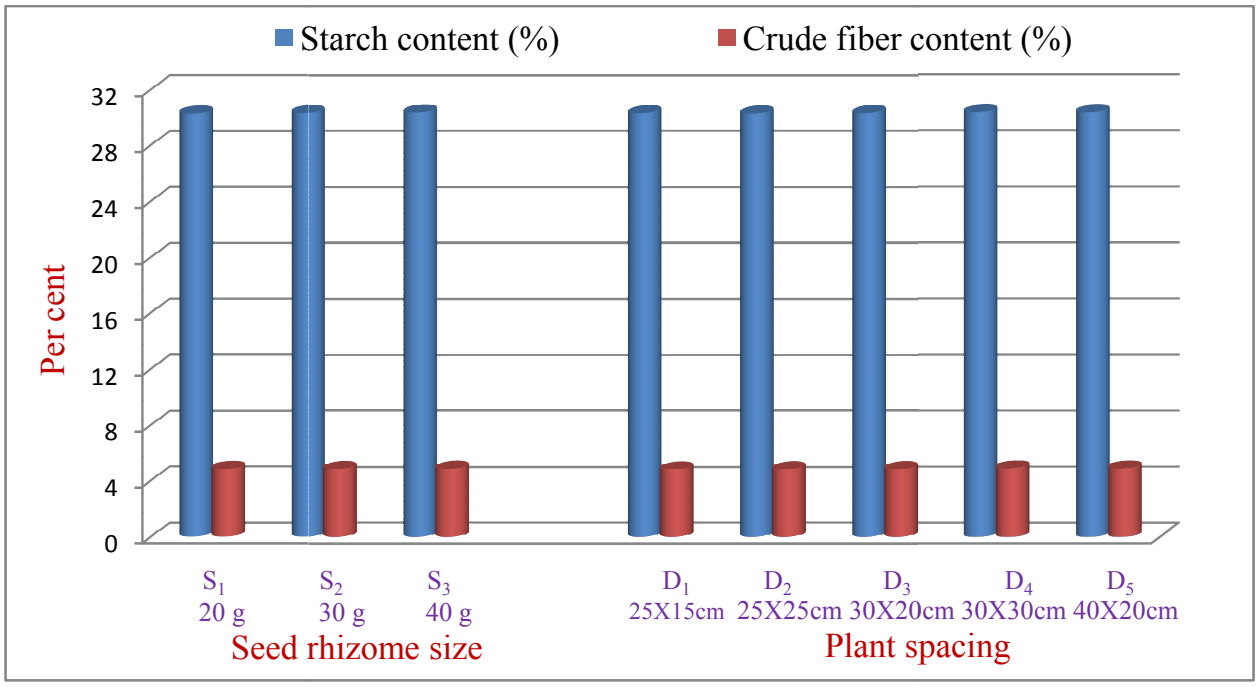

Fig. 4.9 Quality characters of ginger as influenced by seed rhizome size and plant spacing under coconut cropping system.

Experiment-II: Standardization of seed rhizome size and plant spacing for ginger cv. Maran under mango cropping system.

4.5 Vegetative growth parameters

Vegetative growth parameters *viz*., days to first sprouting, days to 50% sprouting, plant height, number of tillers per plant, number of leaves per plant, leaf length, leaf breadth, leaf area and leaf area index were observed to be significantly influenced by seed rhizome size and plant spacing in ginger.

4.5.1 Days to first sprouting

The data pertaining to days to first sprouting of rhizomes as influenced by seed rhizome size, plant spacing and their interaction is presented in Table 4.13 and Fig. 4.10.

Seed rhizome size had significant effect on days to first sprouting. The rhizome size of 40 g (S_3) took least number of days to first sprouting of rhizome (9.67) followed by 30 g (S_2) and 20 g (S_1) rhizome sizes (10.80 and 11.33 respectively).

These findings are in accordance with the observations of Yothasiri *et al*. (1997) in turmeric. The whole mother rhizome resulted in more rapid growth resulting in quick germination and development of rhizome.

The effect of plant spacing on days to first sprouting was non-significant. However, a spacing of 30 cm X 30 cm (D_4) recorded earlier sprouting (10.11) followed by 30 cm X 20 cm (D_3) spacing (10.67). While, 25 cm X 15 cm (D_1) took maximum number of days to first sprouting (11.00). These results are in conformity with the findings of Kiran *et al.* (2013) in turmeric.

The interaction effect of rhizome size and plant spacing on days to first sprouting was found to be non-significant.

4.5.2 Days to 50% sprouting

The data pertaining to days to 50% sprouting due to different seed rhizome sizes, plant spacing and their interaction is presented in Table 4.13 and Fig. 4.10.

Seed rhizome size had significant effect on days to 50% sprouting. The treatment S_3 (40 g rhizome size) took significantly the lowest number of days to 50% sprouting of rhizome (17.20) followed by S_2 (30 g rhizome size) and S_1 (20 g rhizome size).

These findings are in accordance with the observations recorded by Yothasiri *et al*. (1997) in turmeric crop. The whole mother rhizome resulted in more rapid growth resulting in quick germination and development of rhizome.

The effect of plant spacing on days to 50% sprouting was significant. The lowest number of days to 50% sprouting (19.11) was recorded from D_4 (30 cm X 30 cm) and highest number of days to 50% sprouting (20.33) was recorded by D_2 (25 cm X 25 cm).

These results are in conformity with findings of Kiran *et al.* (2013) in turmeric crop.

The interaction effect between rhizome size and plant spacing on days to 50% sprouting was found to be non-significant.

4.5.3 Number of tillers per plant

The data pertaining to number of tillers per plant due to seed rhizome size, plant spacing and their interactions at 30 DAP, 120 DAP and at harvest are presented in Table 4.14 and Fig. 4.11.

Seed rhizome size had significant influence on number of tillers per plant at all the stages of crop growth i.e., 30 DAP, 120 DAP and at harvest.

Among the seed rhizome sizes, 40 g rhizome (S_3) has recorded significantly the highest number of tillers per plant at 30 DAP, 120 DAP and at harvest (3.24, 8.57 and 12.25 respectively). While the treatment 20 g rhizome (S_1) has the lowest number of tillers plant (2.21, 6.43 and 8.24 respectively).

Results regarding variation in number of tillers per plant due to rhizome size might be due to the fact that the plants produced from the largest rhizome size emerged earlier and showed vigorous and rapid growth using the initial reserve food materials than the smallest rhizome size in ginger. These results are in conformity with the findings of Monnaf *et al*. (2010) and Sengupta and Dasgupta (2011) in ginger, Balashanmugam and Vanangamudi (1988), Meenakshi *et al*. (2001a), Kumar (2005), Pratap and Singh (2007) and Manhas and Gill. (2012) in turmeric crop.

Plant spacing had significant influence on number of tillers per plant at 30 DAP, 120 DAP and at harvest.

Increase in plant spacing increases the number of tillers. Among different plant spacings, 30 cm X 30 cm (D_4) has recorded significantly highest number of tillers per plant at 30 DAP, 120 DAP and at harvest (3.00 at 8.36 and 12.36 respectively). While the spacing of 25 cm X 25 cm (D_2) showed significantly the lowest number of tillers per plant (9.02) at harvest.

The plant density had marked influence on the capacity of plants to utilize environmental factors in building up the plant tissues through regulation of absorption capacity of plants due to better utilization of resources and lesser plant to plant competition. Hence, the widely spaced plants produced more number of tillers per plant. The reduced vegetative growth parameters under closer spacing may be owing to competition among the actively growing plants for space, light, soil moisture and nutrients. These results are in line with the earlier findings of Ramachandran and Muthuswami (1984), Bahadur *et al*. (2000), Islam *et al*. (2002), Kumar (2005), Kiran *et al*. (2013) and Bhadouria *et al*. (2014) in turmeric crop, Yadav *et al*. (2013) in ginger crop.

The interaction effect of seed rhizome size and plant spacing showed significant influence on number of tillers per plant at all the growth stages under study. The combination of 40 g rhizome size with 30 cm X 30 cm spacing (S_3D_4) produced the highest number of tillers per plant at 30 DAP, 120 DAP and at harvest (3.60, 10 and 14.87 respectively). While, 20 g rhizome size with 25 cm X 25 cm spacing (S_1D_2) recorded the lowest number of tillers per plant at harvest.

Similar results of maximum number of tillers per plant were also reported in with wider spacing (45 cm X 30 cm) in combination with planting of mother rhizomes in turmeric crop (Pratap and Singh, 2007).

4.5.4 Plant height (cm)

The data pertaining to plant height of ginger as influenced by rhizome size, plant spacing and their interactions is presented in Table 4.15 and Fig. 4.12.

Seed rhizome size showed significant influence on plant height throughout the growth stages in ginger. Among different seed rhizome sizes, 40 g rhizome size (S_3) recorded significantly highest plant height at 30 DAP, 120 DAP and at harvest (22.17 cm, 63.33 cm and 97.93 cm respectively) followed by 30 g rhizome size (S_2) (19.47 cm, 61.88 cm and 95.47 cm respectively). While, 20 g seed rhizome size (S_1) recorded the lowest plant height at 30 DAP, 120 DAP and at harvest (18.54 cm 58.25 cm and 91.20 cm respectively).

The reason for highest plant height recorded from 40 g rhizome size could be explained in terms of availability of sufficient food reserves which probably encouraged vigorous plant growth. This is in agreement with the findings of Govinden *et al.* (1995), Maia *et al.* (1995), Rashid *et al*. (1996), Bahadur *et al*. (2000), Meenakshi *et al*. (2001a), Alam *et al.* (2003), Gill *et al*. (2004), Kumar (2005), Pratap and Singh (2007), Manhas and Gill (2012) and Padmadevi *et al*. (2012) in turmeric crop, Sengupta and Dasgupta (2011) in ginger crop.

Different levels of plant spacing showed significant variation with plant height at 120 DAP and at harvest. Closer spacing of 25 cm X 15 cm (D_1) recorded maximum plant height at 30 DAP, 120 DAP and at harvest (21.20 cm, 63.40 cm and 98.20 cm respectively) over other spacings. Plant height decreased with increased plant spacing.

Under closer spacing, plant might have adjusted its canopy in the vertical space by increasing inter nodal length as there was limited horizontal space. While, under wider spacing, there was less inter plant competition resulting in greater horizontal spread, less inter nodal length and shorter plants.

These results are in accordance with the findings of Ramachandran and Muthuswamy (1984), Kandiannam and Chandaragiri (2008) and Pandey and Mishra (2009) in turmeric crop, Yadav *et al*. (2013) in ginger crop

Interaction effect of rhizome size and plant spacing on plant height was found to be non-significant at 30 DAP. However at 120 DAP and at harvest it was found to be significant. Among the treatments, the combination of 40 g rhizome size with 25 cm X 15 cm plant spacing (S_3D_1) recorded the highest plant height at 30 DAP, 120 DAP and at harvest (23.93 cm, 63.40 cm and 102.87 cm respectively).

4.5.5 Number of leaves per plant

The data pertaining to number of leaves per plant due to rhizome size, plant spacing and their interactions is presented in Table 4.16 and Fig. 4.13.

Seed rhizome size showed significant effect on production of leaves per plant at 30 DAP, 120 DAP and at harvest. The rhizome size of 40 g (S_3) recorded significantly more number of leaves per plant at 30 DAP, 120 DAP and at harvest (16.24, 93.61 and 137.47 respectively). Lowest number of leaves per plant recorded from 20 g rhizome size (10.64 78.83 117.87 respectively).

The higher number of leaves per plant with 40 g rhizome size could be attributed to more reserve food material in bigger sized rhizomes which gave quick emergence and more vigorous growth of the plant leading to the production of more number of leaves per plant than the smaller seed rhizome size. Increase in growth parameters with the increase in seed rhizome size could be due to larger buds and large amount of food reserves in the larger seed rhizomes which enhanced the plant growth. These results are in accordance with the findings of Singh *et al.* (1988a), Govind *et al.* (1993), Rashid *et al.* (1996), Meenakshi *et al*. (2001a), Kumar (2005), Pratap and Singh (2007), Manhas and Gill (2012) and Padmadevi *et al*. (2012) in turmeric crop, Sengupta and Dasgupta (2011) in ginger crop.

With regard to plant spacing, different plant spacings showed significant effect on production of leaves per plant throughout the crop growth stages.

Among the plant spacings, 30 cm X 30 cm (D_4) recorded the maximum number of leaves per plant at 30 DAP, 120 DAP and at harvest (14.64, 97.02 and 135.20 respectively) followed by 40 cm X 20 cm. Lowest number of leaves per plant was recorded with 30 cm X 20 cm spacing at 30 DAP and at harvest (12.31 and 123.76).

The increase in total number of leaves per plant at wider spacing might be due to the less competition because of less population and this might have resulted in more horizontal growth at lower plant population and has contributed to more number of leaves per plant. The results are in accordance with the findings of Ramachandran and Muthuswami (1984), Philip (1985), Shashidhar and Sulikeri (1996a), Bahadur *et al*. (2000), Islam *et al*. (2002), Pandey and Mishra (2009), Kiran *et al*. (2013), Bhadouria *et al*. (2014) and Mohamed *et al*. (2014) in turmeric crop.

The interaction effect of seed rhizome size and plant spacing showed significant effect on number of leaves per plant at 30 DAP and 120 DAP. While it was non-significant at harvest. However, the combination of 40 g seed rhizome size with 30 cm X 30 cm spacing (S_3D_4) has recorded the highest number of leaves per plant at all the crop growth stages.

4.5.6 Leaf length (cm), breadth (cm) and area (cm^2)

The data pertaining to various leaf characters like leaf length, leaf breadth and leaf area as influenced by seed rhizome size, plant spacing and their interactions is presented in Table 4.17, 4.18 and Fig. 4.14.

Seed rhizome size showed significant effect on various leaf characters under study. Among seed rhizome sizes, rhizome size of 40 g (S_3) has recorded significantly the highest leaf length (23.71 cm), leaf breadth (2.46 cm) and leaf area (28.14 cm^2). While, the seed rhizome size of 20 g (S_1) produced the lowest leaf length (21.49 cm), leaf breadth (2.06 cm) and leaf area (25.19 cm^2).

These results of higher leaf length, leaf breadth and leaf area with higher rhizome size are in conformity with the research findings of Korla *et al.* (1989) and Blay *et al.* (1998) in ginger crop, Meenakshi *et al*. (2001a) and

Padmadevi *et al.* (2012) in turmeric crop.

Plant spacing showed significant variation regarding leaf breadth, area and non-significant variation regarding leaf length. The 30 cm X 30 cm (D_4) spacing produced the highest leaf length (23.24 cm), leaf breadth (2.46 cm) and leaf area (28.61 cm^2).

Shading with neighboring plant is the principal and significant factor of competition among the plants because it had greatly affected the leaf development. Similar observations were recorded by Philip (1985) in Turmeric, who observed maximum leaf breadth with wider spacing of 30 cm X 30 cm. Yadav *et al.* (2013) also observed longest leaf (19.15 cm), broadest leaf (2.16 cm) and highest leaf area (35.37 cm^2) at wider spacing of 25 cm X 35 cm.

Interaction effect of seed rhizome size and plant spacing on leaf length was found to be significant and it was non-significant with leaf breadth and leaf area. The treatmental combination of S_3D_4 (40 g rhizome size and 30 cm X 30 cm) recorded the longest leaf (24.77 cm), broadest leaf (2.63 cm) and highest leaf area (31.17 cm^2) over rest of the treatments.

4.5.7 Leaf area index

The data pertaining to leaf area index as influenced by seed rhizome size, plant spacing and their interactions is presented in Table 4.18.

Seed rhizome size had significant influence on leaf area index of ginger under mango cropping system. The treatment of 40 g rhizome size (S_3) recorded significantly the highest leaf area index (4.57), while lowest harvest index (4.13) was observed with 20 g rhizome size (S_1). The results are in conformity with the findings of Blay *et al.* (1998) in ginger crop.

Different plant spacings showed significant variation regarding leaf area index. The closest spacing treatment of 25 cm X 15 cm (D_1) produced the highest leaf area index (6.61) and lowest (3.18) recorded from 30 cm X 30 cm spacing. At closer spacing, more plants per unit area can be achieved compared to medium and wider spacings as a result more leaf area per unit area of land. These findings are in accordance with the findings of Kandiannan and Chandaragiri (2006) in turmeric crop.

The interaction effect of seed rhizome size and plant spacings on leaf area index was found to be non-significant under mango cropping system.

4.6 Yield and yield attributes

4.6.1 Rhizome length (cm) and breadth (cm)

The data pertaining to yield attributing characters like rhizome length and rhizome breadth as influenced by rhizome size, plant spacing and their interactions in ginger is presented in Table 4.19 and Fig. 4.15 (Plate 4.2).

Seed rhizome size showed significant variation for rhizomes characters. Among the rhizome sizes, 40 g seed rhizome size (S_3) followed by 30 g rhizome size (S_2) recorded the longest (17.03 cm and 16.46 cm) and broadest rhizome (17.16 cm and 16.31 cm).

Highest length and width of fresh rhizome in 40 g rhizome size might be due to increase in seed rhizome size used for planting. These findings are in accordance and in conformity with the findings of Korla *et al*. (1989) and Hailemichael and Tesfaye (2008) in ginger, Govind *et al*. (1993) and Singh *et al*. (2014) in turmeric crop.

Different plant spacings showed non-significant variation with regard to rhizome length. Among the spacing treatments, 30 cm X 30 cm plant spacing (D_4) produced longest rhizome (16.54 cm) and significantly produced broadest rhizome (17.12 cm).

The reason for longest and broadest rhizome with wider spacing might be due to better availability of plant nutrients, moisture and light in wider spaced plants. Under closer spacing rhizome could not expose properly, which ultimately resulted in smaller rhizome compared with that of wider spacing. Similar results were reported by Modupeola *et al*. (2013) and Yadav *et al*. (2013) in ginger, Kiran *et al*. (2013) in turmeric crop.

The interaction effect of rhizome size and plant spacing on rhizome length was found to be significant. Among the interactions, a combination of 40 g rhizome size with 30 cm X 30 cm spacing (S_3D_4) recorded maximum rhizome length (18.59 cm) and the interaction effect on rhizome breadth was found to be non-significant under mango cropping system.

Plate 4.2: Green ginger rhizome length and breadth at best seed rhizome size, plant spacing and interaction effect under mango cropping system.

4.6.2 Rhizome yield per plant (g), per plot (kg) and per hectare (t)

Yield attributing characters of ginger *viz.,* fresh rhizome yield per plant, rhizome yield per plot and per hectare as influenced by seed rhizome size, plant spacings and their interactions are presented in Table 4.20 and Fig. 4.16a and 4.16b.

Seed rhizome size showed significant effect on yield and yield attributing characters in ginger under mango cropping system. Among the different seed rhizome sizes, rhizome size of 40 g (S_3) produced significantly the highest rhizome yield per plant (206.88 g), per plot (3.08 kg) and rhizome yield per hectare (25.69 t) followed by 30 g rhizome size (197.93 g, 2.76 kg and 23.03 t respectively). Lowest rhizome yield per plant (173.95 g), per plot (2.46 kg) and per hectare (20.52 t) was recorded from 20 g (S_1) rhizome size.

Results regarding variation in yield due to seed rhizome size might be due to the fact that the plants produced from the largest rhizome size emerged earlier and showed vigorous and rapid growth using the initial reserve food materials and producing maximum yield and yield attributes than the smaller rhizome size in ginger. Therefore highest rhizome yield in the largest seed rhizome size is due to taller plants that have higher number of leaves per tiller, longer and thickest rhizomes. These results are in conformity with the findings of Korla *et al*. (1989), Blay *et al*. (1998), Monnaf *et al*. (2010), Sengupta and Dasgupta (2011) and Sharma *et al*. (2012) in ginger crop, Tayde and Deshmukh (1986), Singh and Kar (1989), Chattopadhyay *et al*. (1990), Borholia *et al*. (1992), George (1993), Yothasiri *et al*. (1997), Alam *et al*. (2003), Hossain *et al*. (2005a), Pratap and Singh (2007), Ghosh and hore (2011), Manhas and Gill (2012), Padmadevi *et al*. (2012) and Singh *et al*. (2014) in turmeric crop.

Plant spacings showed significant effect on yield and yield attributing characters of ginger. Among the plant spacings, 30 cm X 30 cm spacing (D_4) produced highest rhizome yield per plant (200.93 g) and it was significantly superior over rest of the treatments. The lowest rhizome yield per plant (187.94 g) was observed with 25 cm X 15 cm spacing.

The increase in yield under higher plant population was attributed due to more plant population per hectare. The higher rhizome weight in wider spacing

may be due to better availability of nutrients, moisture and adequate space available for the enlargement of rhizomes under wider spacing. These results are in line with the earlier findings of Shashidhar and Sulikeri (1996a), Bahadur *et al*. (2000), Pratap and Singh (2007), Pandey and Mishra (2009), Kumar and Gill (2010) and Bhadouria *et al*. (2014) in turmeric crop, Yadav *et al*. (2013) in ginger crop.

However, green ginger yield per plot and per hectare yield was significantly highest with 25 cm X 15 cm spacing (3.09 kg and 25.77 t respectively), while the lowest green ginger yield per plot (2.41 kg) and per hectare (20.04 t) was recorded from 40 cm X 20 cm spacing.

The significant increase in yield per plot and yield per hectare under closer spacing may solely be ascribed on the function of higher plant density per unit area of land together with efficient availability and utilization of nutrients by the growing plants. Similar results were reported by of Bahadur *et al*. (2000), Hore and Chattopadhyay (2003), Pratap and Singh (2007), Pandey and Mishra (2009), Kumar and Gill (2010) and Bhadouria *et al*. (2014) in turmeric crop, Ghosh and Hore (2011), Madupeola *et al*. (2013) and Yadav *et al*. (2013) in ginger crop.

The interaction between seed rhizome size and spacing showed significant effect on yield and yield attributing characters of ginger. Significantly highest green ginger yield per plant (220.80 g) was observed from a combination of 40 g rhizome size with 30 cm X 30 cm (S_3D_4). The lowest rhizome yield (152.00 g) was recorded from a combination of 20 g rhizome size with 25 cm X 15 cm (S_1D_1).

The yield of green ginger per plot and per hectare varied significantly with seed rhizome size and plant spacing. The highest green ginger yield per plot (3.67 kg) and per hectare (30.56 t) was recorded by a combination of 40 g rhizome size with 25 cm X 15 cm spacing (S_3D_1).

Similar observation of highest weight per clump with 30 cm X 30 cm spacing was recorded by Pratap and Singh (2007) in turmeric and Ghosh and Hore (2011) in ginger, who observed that closest spacing (20 cm X15 cm) in combination with bigger seed rhizome (25-30 g) produce highest plot yield

(15.62 kg/3m^2 and projected yield 12.50 t ha^{-1}).

4.6.3 Harvest index (%)

The data pertaining to harvest index of ginger due to seed rhizome size, plant spacing and their interactions is presented in Table 4.21.

Seed rhizome size had significant influence on harvest index of ginger under mango cropping system. The treatment of 40 g rhizome size (S_3) recorded significantly highest harvest index (60.35%), while lowest harvest index (56.81%) was observed in the 20 g rhizome size (S_1).

Plant spacing had non-significant influence on harvest index of ginger. However, 30 cm X 30 cm spacing (D_4) had produced highest harvest index (59.02%). This might be due to more favorable environmental conditions resulting in higher growth and higher yield.

The interaction effect of seed rhizome size and plant spacing on harvest index of ginger was found to be significant. The combination of 40 g rhizome size with 30 cm X 30 cm (S_3D_4) recorded highest harvest index (61.67%).

4.7 Quality attributes

4.7.1 Essential oil content (%)

The essential oil content of ginger under mango cropping system as influenced by seed rhizome size and plant spacing and their interactions is presented in Table 4.22 and Fig. 4.17.

Rhizome size showed significant effect on essential oil content of ginger. Among the treatments, 40 g rhizome size (S_3) recorded significantly higher essential oil content (1.68%) followed by 30 g rhizome (1.62%). It was observed that essential oil content increased with the increase in seed rhizome size in ginger.

These results are analogous with the findings of Kumar and Gill (2010) in turmeric.

The essential oil content differed non-significantly among different treatments of plant spacing. However, highest oil content (1.66%) was observed

in 25 cm X 15 cm spacing and the lowest (1.63%) was observed in 25 cm X 25 cm. These results were also line with the earlier findings of Kumar (2005).

Interaction effect of rhizome size and plant spacing was found to be non-significant on essential content of ginger under mango cropping system.

4.7.2 Oleoresin content (%)

The oleoresin content of ginger under mango cropping system as affected by rhizome size, spacing and their interaction is presented in Table 4.22 and Fig. 4.17.

Seed rhizome size showed significant influence on oleoresin content in ginger. Among the different seed rhizome sizes, the oleoresin content was highest under 40 g rhizome (7.28%). The lowest oleoresin content was observed in 20 g rhizome (7.18%). Similar observation was recorded by Philip (1983), Maia *et al*. (1995) and Kumar and Gill (2010) in turmeric crop.

Plant spacing had no significant effect on the oleoresin content. However, the highest oleoresin content was observed from 30 cm X 30 cm (7.26%) followed by 40 cm X 20 cm (7.25%) and the lowest (7.20%) was observed in 25 cm X 15 cm and 25 cm X 25 cm spacings. Neopaney (1998) also mentioned similar results in ginger. He found that spacing does not exercise any significant effect on oleoresin content.

Similarly the interaction effect of rhizome size and plant spacing on oleoresin content of ginger was observed to be non-significant under mango cropping system.

4.7.3 Starch content (%)

The starch content of ginger as affected by rhizome size, spacing and their interaction is presented in Table 4.23 and Fig. 4.18.

Seed rhizome size showed non-significant influence on starch content of ginger. Among the treatments, 40 g rhizome size (S_3) showed non-significantly superior starch content (30.22%). The lowest starch content was observed in 20 g rhizome size (30.19%).

Similarly plant spacing had no significant effect on the starch content. The highest starch content was observed from 40 cm X 20 cm and 30 cm X 20 cm spacing (30.23%) and the lowest was observed in 25 cm X 15 cm (30.06%).

These results are in accordance with findings of Nizam and Jayachandran (1997) in turmeric crop.

Similarly the interaction effect of rhizome size and plant spacing on starch content of ginger was non-significant under mango cropping system.

4.7.4 Crude fibre content (%)

The crude fibre content of ginger under mango cropping system as affected by seed rhizome size, spacing and their interaction is presented in Table 4.23 and Fig. 4.18.

The crude fibre content was significantly highest under 40 g rhizome size and non-significantly higher under 30 cm X 30 cm plant spacing (4.88% and 4.86% respectively). Similar results were observed by Nizam and Jayachandran (1997) in turmeric crop and Yadav *et al.* (2014) in ginger crop.

The interaction effect of seed rhizome size and plant spacing on crude fibre content of ginger was significant under mango cropping system. The highest crude fibre content (4.95%) was observed from a combination of 40 g rhizome size with 30 cm X 30 cm spacing (S_3D_4).

4.8 ECONOMICS OF GROWING GINGER UNDER MANGO CROPPING SYSTEM

The details of cost of cultivation of ginger and value of the produce have been worked out on the basis of prevailing market rates during the year of experiments (Appendix-II, III and IV).

Cost of cultivation

The total cost of production varied from Rs.1,77,981 ha^{-1} to 6,00,203 ha^{-1}. The 20 g seed rhizome size with a combination of wider plant spacing (30 cm X 30 cm) recorded minimum cost of cultivation (1,77,981 ha^{-1}). Whereas, the 40 g seed rhizome size with a combination of closer spacing (25 cm X 15 cm) recorded maximum cost of cultivation (Rs. 6,00,203 ha^{-1}) (Table 4.24).

Gross returns

Among the different treatmental combinations, 40 g rhizome size with 25 cm X 15 cm plant spacing recorded highest gross returns (15,28,000 ha^{-1}). The 30 g seed rhizome size with 30 cm X 20 cm plant spacing recorded the lowest gross returns (Rs.8,51,500 ha^{-1}) (Table 4.24).

Net returns

The maximum net returns were realized in 20 g seed rhizome size with 30 cm X 20 cm plant spacing (10,04,463 ha^{-1}) followed by 40 g seed rhizome size with 30 cm X 30 cm plant spacing (10,02,408 ha^{-1}) (Table 4.24). The minimum net returns were obtained with 20 g seed rhizome size with 25 cm X 15 cm plant spacing (6,14,963 ha^{-1}).

Benefit cost ratio

The economic analysis indicated higher B:C ratio with 20 g seed rhizome size with 30 cm X 20 cm plant spacing (4.30) followed by 20 g rhizome size with 30 cm X 30 cm plant spacing (4.14) (table 4.24). The lower B:C ratio was obtained with 40 g seed rhizome size with 25 cm X 15 cm plant spacing.

Table: 4.13 Sprouting of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing											
	Days to first sprouting						Days to 50 % sprouting					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	11.67	11.33	11.67	10.67	11.33	11.33	21.67	21.67	22.33	21.00	21.67	21.67
S_2	11.00	11.00	10.67	10.33	11.00	10.80	20.33	20.67	20.00	20.00	19.67	20.13
S_3	10.33	10.00	9.67	9.33	9.00	9.67	17.00	18.67	17.67	16.33	16.33	17.20
Mean	11.00	10.78	10.67	10.11	10.44		19.67	20.33	20.00	19.11	19.22	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.19	0.55	0.22	0.63
D	0.24	NS	0.28	0.81
SXD	0.42	NS	0.48	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table : 4.14 Number of tillers per plant in ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing																	
	No. of tillers per plant at 30 DAP						No. of tillers per plant at 120 DAP						No. of tillers per plant at harvest					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	2.67	2.13	1.67	2.27	2.33	2.21	6.47	5.13	7.47	7.40	5.67	6.43	6.80	6.33	8.92	9.60	9.53	8.24
S_2	2.33	2.73	2.60	3.13	2.73	2.71	6.27	7.67	6.07	7.67	7.60	7.05	10.73	10.27	11.00	12.60	11.50	11.22
S_3	3.27	3.13	2.87	3.60	3.33	3.24	8.67	6.93	8.07	10.00	9.20	8.57	11.27	10.47	12.13	14.87	12.50	12.25
Mean	2.76	2.67	2.38	3.00	2.80		7.13	6.58	7.20	8.36	7.49		9.60	9.02	10.68	12.36	11.18	

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.07	0.21	0.23	0.66	0.19	0.54
D	0.09	0.27	0.29	0.85	0.24	0.70
SXD	0.16	0.47	0.51	1.48	0.42	1.21

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.15 Plant height of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing																	
	Plant height (cm) at 30 DAP						Plant height (cm) at 120 DAP						Plant height (cm) at harvest					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	19.93	19.43	16.90	16.50	19.93	18.54	59.07	59.20	59.80	54.73	58.47	58.25	93.07	91.13	89.67	88.73	93.40	91.20
S_2	19.73	21.17	20.40	18.07	17.97	19.47	65.27	61.93	62.60	60.67	58.93	61.88	98.67	96.47	93.20	97.80	91.20	95.47
S_3	23.93	19.47	21.27	23.47	22.73	22.17	65.87	58.67	64.80	65.33	62.00	63.33	102.87	98.60	97.87	98.27	92.07	97.93
Mean	21.20	20.02	19.52	19.34	20.21		63.40	59.93	62.40	60.24	59.80		98.20	95.40	93.58	94.93	92.22	

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.58	1.69	0.53	1.54	0.72	2.08
D	0.75	NS	0.68	1.98	0.93	2.69
SXD	1.30	NS	1.19	3.43	1.61	4.66

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.16 Number of leaves per plant in ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing																	
	No. of leaves per plant at 30 DAP						No. of leaves per plant at 120 DAP						No. of leaves per plant at harvest					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	11.20	10.73	9.33	11.73	10.20	10.64	83.67	62.53	72.67	87.87	87.40	78.83	121.67	114.67	113.07	122.47	117.47	117.87
S_2	13.20	14.27	12.87	13.53	13.40	13.45	87.80	87.07	73.87	93.27	95.67	87.53	127.20	119.87	121.27	139.13	129.20	127.33
S_3	14.87	15.40	14.73	18.67	17.53	16.24	95.67	81.93	94.47	109.93	86.07	93.61	132.00	137.73	136.93	144.00	136.67	137.47
Mean	13.09	13.47	12.31	14.64	13.71		89.04	77.18	80.33	97.02	89.71		126.96	124.09	123.76	135.20	127.78	

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	0.21	0.62	0.62	1.79	1.48	4.28
D	0.28	0.80	0.80	2.31	1.91	5.52
SXD	0.48	1.39	1.38	4.00	3.30	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.17 Leaf characters of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing											
	Leaf length (cm)						Leaf breadth (cm)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	21.07	21.53	21.59	21.00	22.25	21.49	2.12	2.21	1.79	2.14	2.03	2.06
S_2	23.71	20.73	23.53	23.95	22.93	22.97	2.26	2.19	2.24	2.60	2.45	2.35
S_3	22.97	24.47	22.76	24.77	23.58	23.71	2.45	2.47	2.29	2.63	2.47	2.46
Mean	22.58	22.24	22.63	23.24	22.92		2.28	2.29	2.11	2.46	2.32	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.26	0.76	0.05	0.15
D	0.34	NS	0.07	0.19
SXD	0.59	1.71	0.11	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.18 Leaf characters of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing											
	Leaf area (cm^2)						Leaf area index					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	24.43	23.79	23.79	26.13	27.81	25.19	6.51	3.81	3.97	2.90	3.48	4.13
S_2	24.75	27.80	26.63	28.53	28.10	27.16	6.60	4.45	4.44	3.17	3.51	4.43
S_3	25.20	28.13	27.27	31.17	28.91	28.14	6.72	4.50	4.54	3.46	3.61	4.57
Mean	24.79	26.57	25.90	28.61	28.27		6.61	4.25	4.32	3.18	3.53	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.43	1.26	0.08	0.22
D	0.56	1.63	0.10	0.28
SXD	0.97	NS	0.17	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.19 Rhizome characters of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing											
	Rhizome length (cm)						Rhizome breadth (cm)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	12.80	13.67	14.93	15.35	14.83	14.32	13.73	13.51	14.63	17.37	14.87	14.82
S_2	17.93	16.63	14.77	15.67	17.30	16.46	15.73	16.00	16.70	15.58	17.53	16.31
S_3	17.37	16.09	17.18	18.59	15.91	17.03	16.57	16.83	17.43	18.43	16.57	17.16
Mean	16.03	15.46	15.63	16.54	16.01		15.35	15.44	16.25	17.12	16.32	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.26	0.76	0.31	0.91
D	0.34	NS	0.41	1.18
SXD	0.58	1.69	0.70	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.20 Effect of seed rhizome size and plant spacing on ginger yield under mango cropping system.

Rhizome size	Plant spacing																	
	Yield per plant (g)						Yield per plot (kg)						Yield per hectare (t)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	152.00	162.93	181.13	192.73	180.97	173.95	2.28	2.73	2.97	2.19	2.14	2.46	18.97	22.78	24.76	18.28	17.83	20.52
S_2	213.00	206.73	183.27	189.27	197.40	197.93	3.33	3.09	2.04	2.58	2.78	2.76	27.78	25.73	17.03	21.49	23.13	23.03
S_3	198.83	208.67	200.93	220.80	205.17	206.88	3.67	3.10	3.24	3.10	2.30	3.08	30.56	25.85	27.03	25.83	19.18	25.69
Mean	187.94	192.78	188.44	200.93	194.51		3.09	2.97	2.75	2.62	2.41		25.77	24.79	22.94	21.87	20.04	

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
S	1.68	4.86	0.13	0.37	1.07	3.09
D	2.17	6.28	0.17	0.48	1.38	3.99
SXD	3.75	10.87	0.29	0.83	2.39	6.91

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.21 Harvest index of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing					
	Harvest index (%)					
	D_1	D_2	D_3	D_4	D_5	Mean
S_1	56.27	57.03	57.87	57.27	55.60	56.81
S_2	60.13	58.50	57.60	58.13	59.40	58.75
S_3	60.40	61.13	60.30	61.67	58.27	60.35
Mean	58.93	58.89	58.59	59.02	57.76	

	S.Em±	CD at 5%
S	0.27	0.77
D	0.34	NS
SXD	0.59	1.72

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.22 Quality characters of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing											
	Essential oil (%)						Oleoresin (%)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	1.62	1.60	1.62	1.63	1.65	1.62	7.22	7.10	7.15	7.20	7.21	7.18
S_2	1.65	1.64	1.66	1.65	1.59	1.64	7.20	7.24	7.23	7.18	7.23	7.21
S_3	1.72	1.65	1.68	1.66	1.69	1.68	7.19	7.25	7.24	7.40	7.31	7.28
Mean	1.66	1.63	1.65	1.65	1.64		7.20	7.20	7.21	7.26	7.25	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.01	0.03	0.02	0.06
D	0.01	NS	0.03	NS
SXD	0.02	NS	0.04	NS

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table: 4.23 Quality characters of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Rhizome size	Plant spacing											
	Starch content (%)						Crude fibre content (%)					
	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
S_1	30.12	30.20	30.32	30.10	30.20	30.19	4.78	4.81	4.85	4.79	4.75	4.80
S_2	29.90	30.13	30.15	30.18	30.22	30.12	4.85	4.83	4.83	4.84	4.92	4.86
S_3	30.16	30.22	30.22	30.24	30.26	30.22	4.87	4.85	4.85	4.95	4.88	4.88
Mean	30.06	30.18	30.23	30.17	30.23		4.83	4.83	4.85	4.86	4.85	

	S. Em ±	CD at 5%	S. Em ±	CD at 5%
S	0.04	NS	0.01	0.03
D	0.05	NS	0.01	NS
SXD	0.09	NS	0.02	0.06

S-Rhizome size
S_1-20 g
S_2-30 g
S_3-40 g

D-Spacing
D_1-25 cm X 15 cm
D_2-25 cm X 25 cm
D_3-30 cm X 20 cm
D_4-30 cm X 30 cm
D_5-40 cm X 20 cm

Table:4.24 Gross returns, net returns and benefit cost ratio of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Treatments	Fresh rhizome yield (t ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Selling price (Rs. t^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
S_1D_1 : 20 g and 25 cm x 15 cm	18.97	333537	50000	948500	614963	1.84
S_1D_2 : 20 g and 25 cm x 25 cm	22.78	226870	50000	1139000	912130	4.02
S_1D_3: 20 g and 30 cm x 20 cm	24.76	233537	50000	1238000	1004463	4.30
S_1D_4 : 20 g and 30 cm x 30 cm	18.28	177981	50000	914000	736019	4.14
S_1D_5: 20 g and 40 cm x 20 cm	17.83	191870	50000	891667	699797	3.65
S_2D_1 : 30 g and 25 cm x 15 cm	27.78	466870	50000	1389000	922130	1.98
S_2D_2 : 30 g and 25 cm x 25 cm	25.73	306870	50000	1286500	979630	3.19
S_2D_3 : 30 g and 30 cm x 20 cm	17.03	316870	50000	851500	534630	1.69
S_2D_4 : 30 g and 30 cm x 30 cm	21.49	233537	50000	1074500	840963	3.60
S_2D_5 : 30 g and 40 cm x 20 cm	23.13	254370	50000	1156500	902130	3.55
S_3D_1 : 40 g and 25 cm x 15 cm	30.56	600203	50000	1528000	927797	1.55
S_3D_2 : 40 g and 25 cm x 25 cm	25.85	386870	50000	1292500	905630	2.34
S_3D_3 : 40 g and 30 cm x 20 cm	27.03	400203	50000	1351500	951297	2.38
S_3D_4 : 40 g and 30 cm x 30 cm	25.83	289092	50000	1291500	1002408	3.47
S_3D_5 : 40 g and 40 cm x 20 cm	19.18	316870	50000	959000	642130	2.03

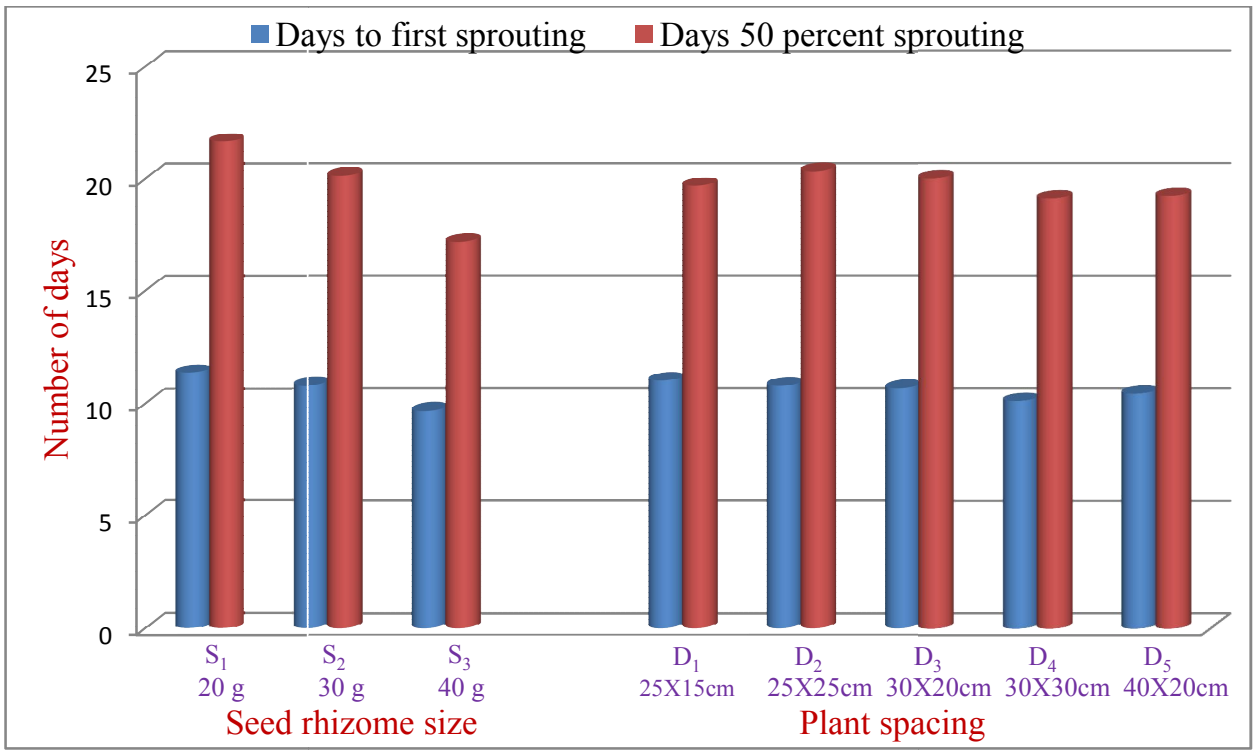

Fig. 4.10 Sprouting of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

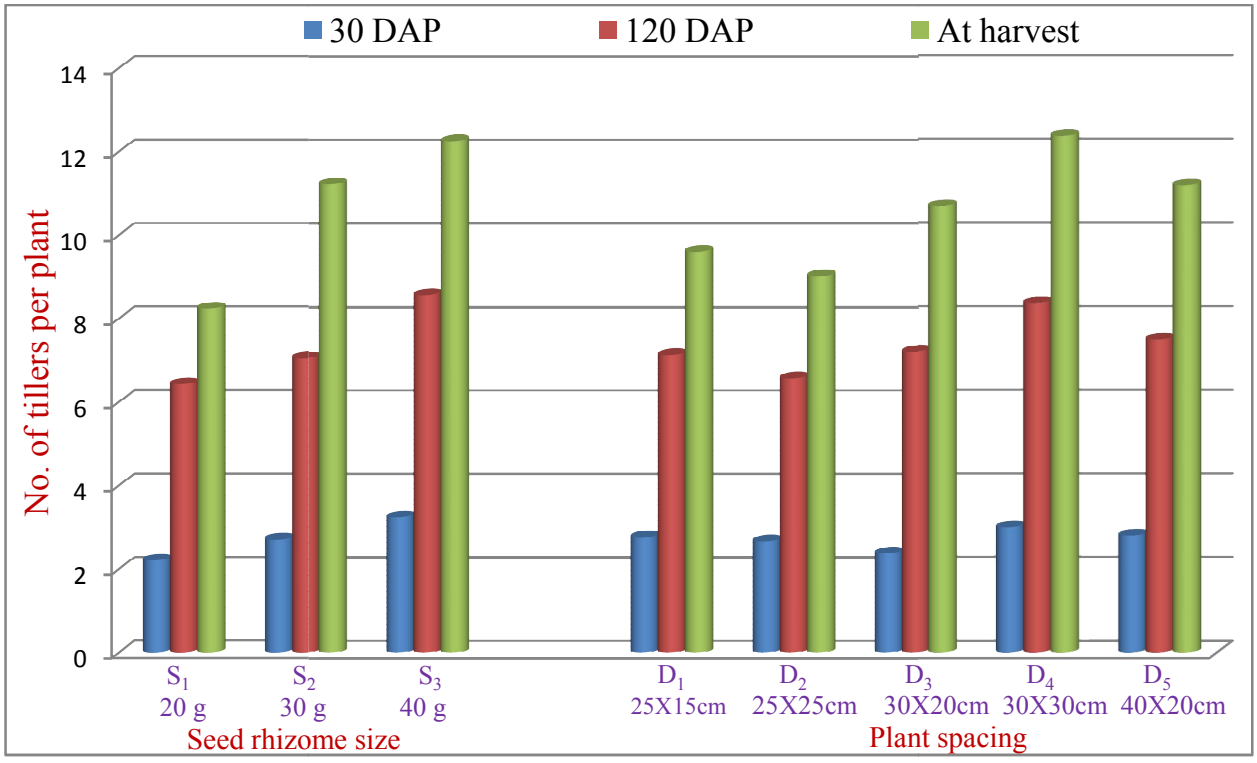

Fig. 4.11 Number of tillers per plant in ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

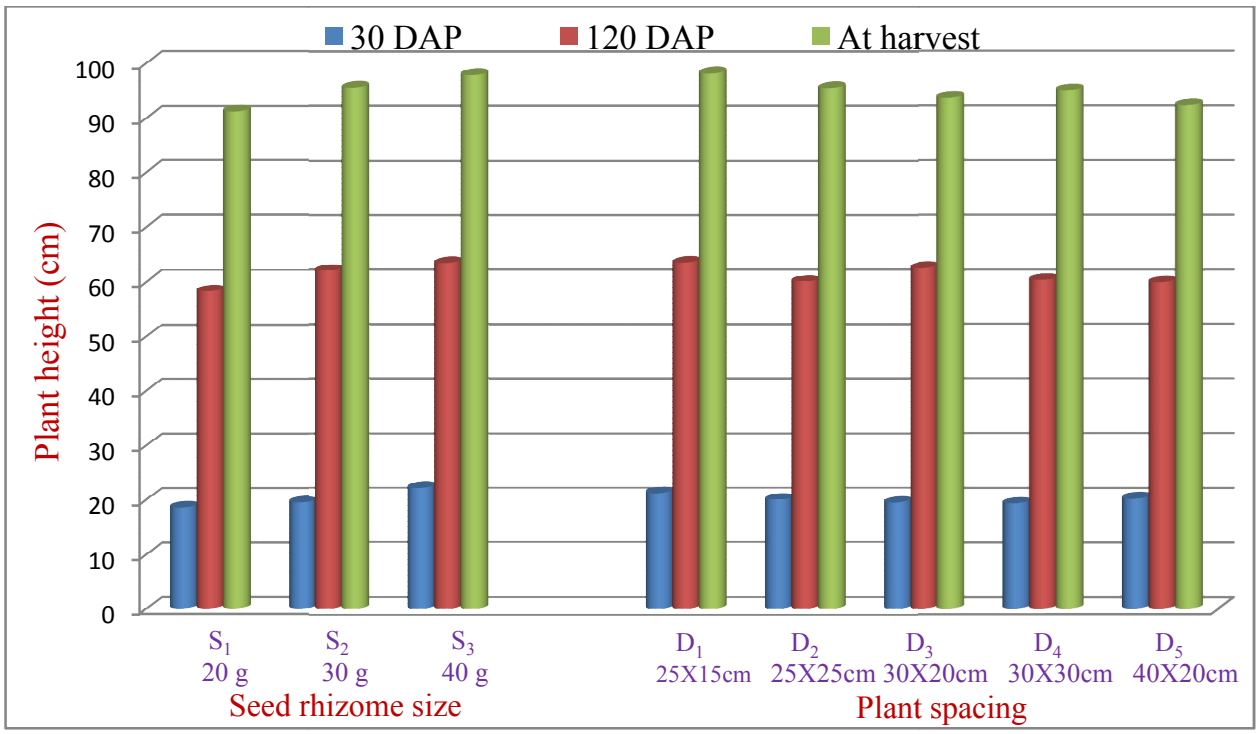

Fig. 4.12 Plant height of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

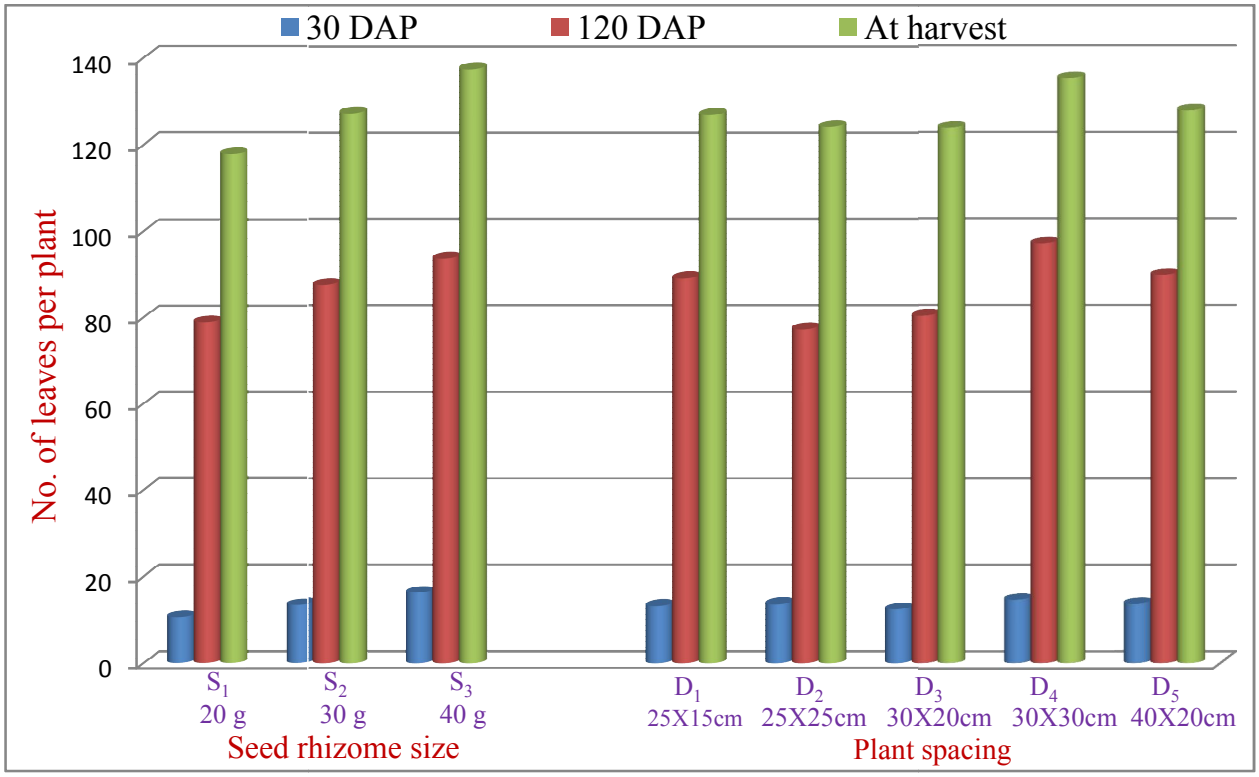

Fig. 4.13 Number of leaves per plant in ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

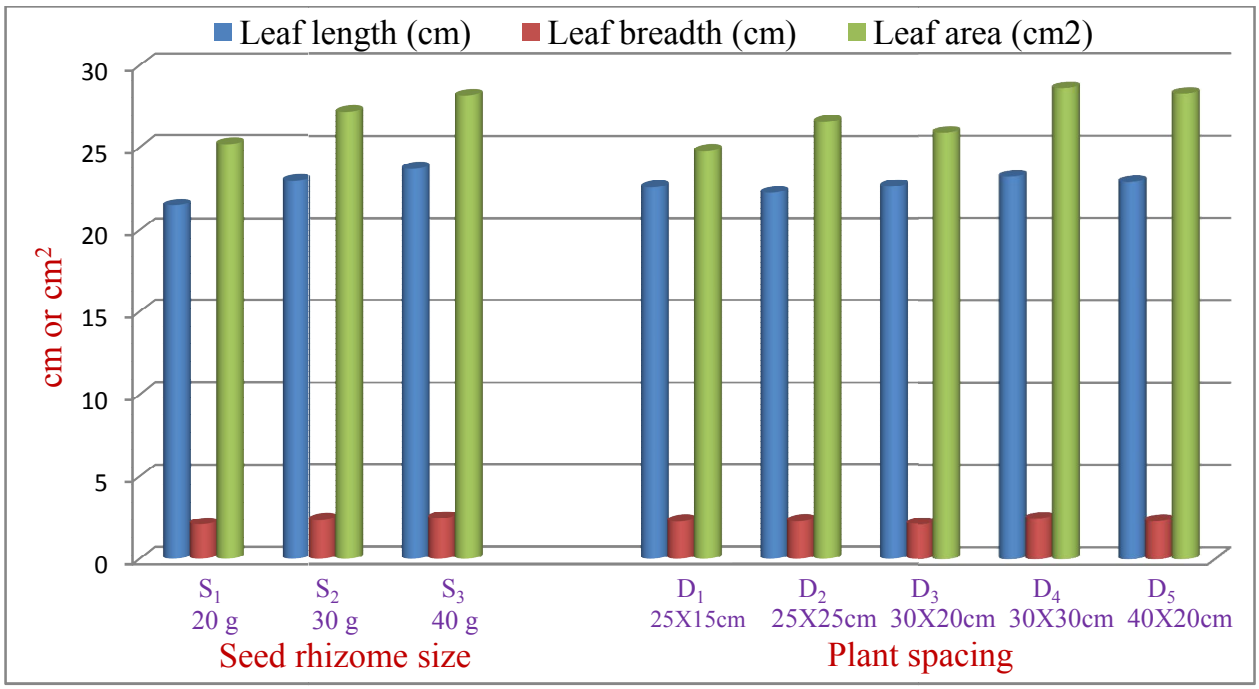

Fig. 4.14 Leaf characters of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

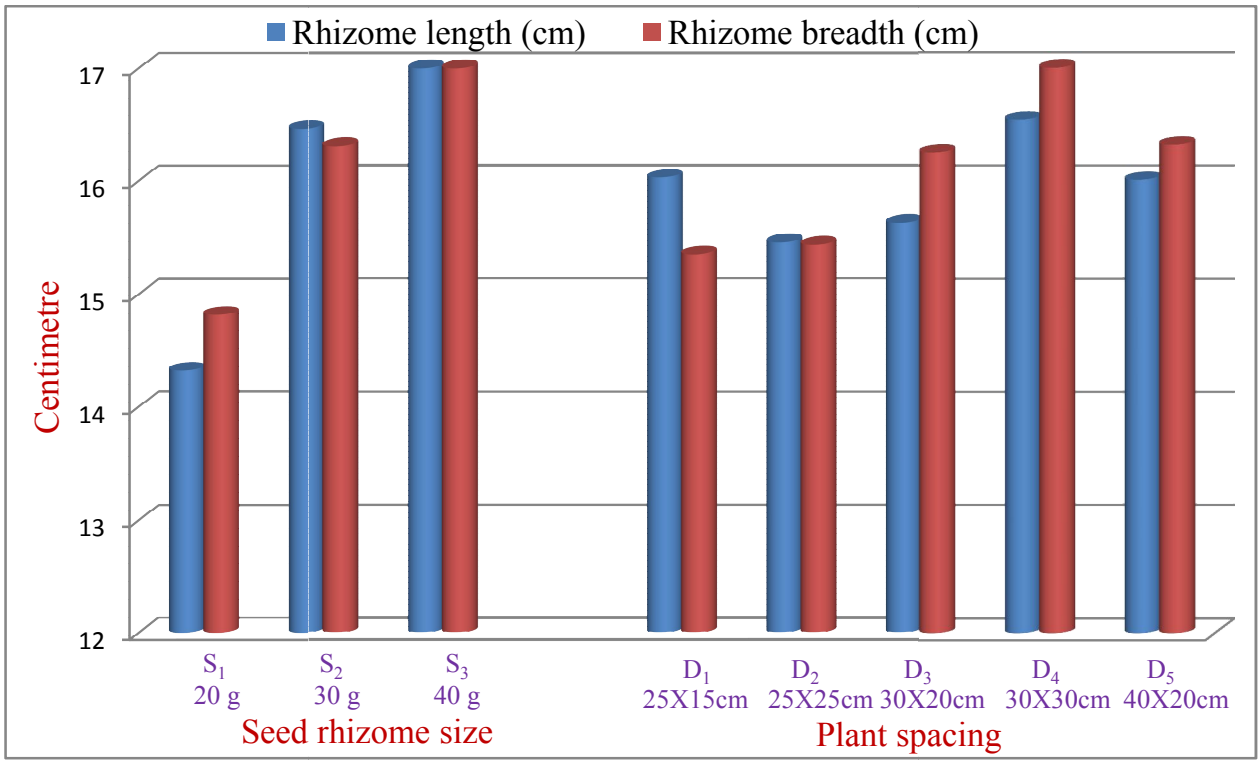

Fig. 4.15 Rhizome characters of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

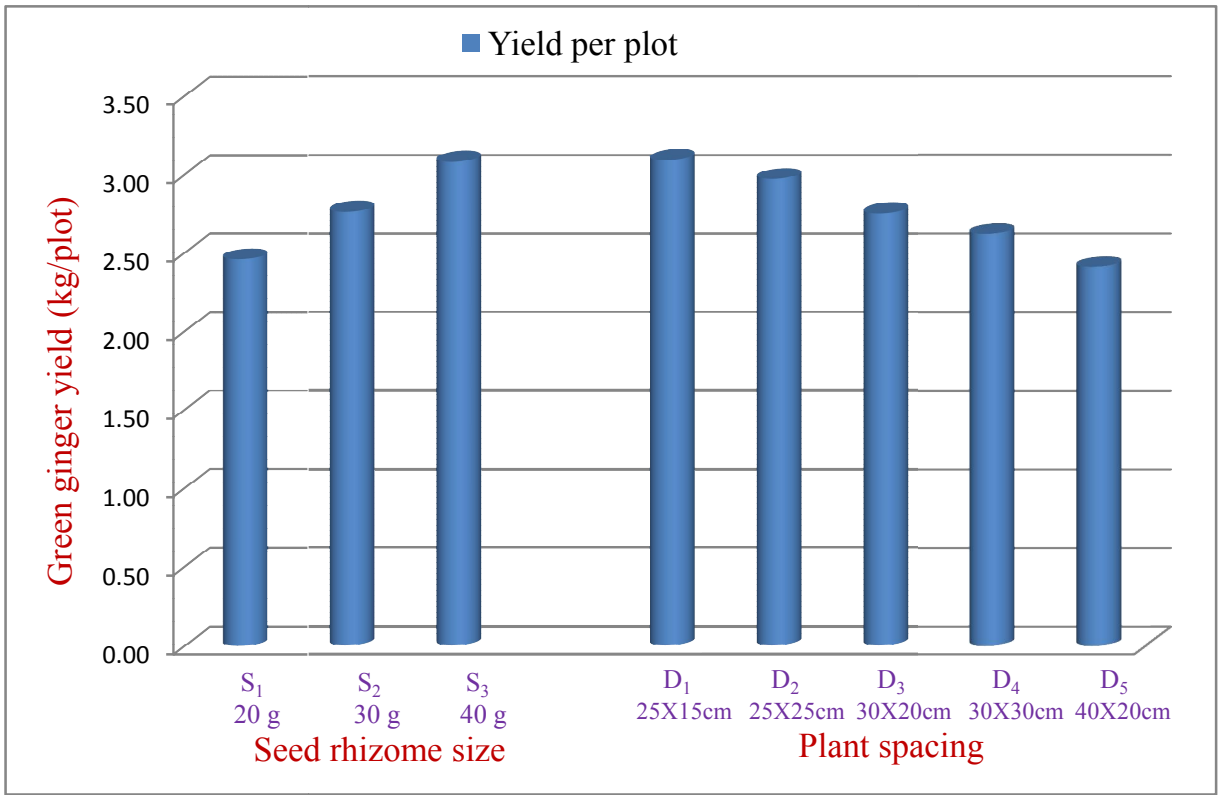

Fig. 4.16a Yield per plot in ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

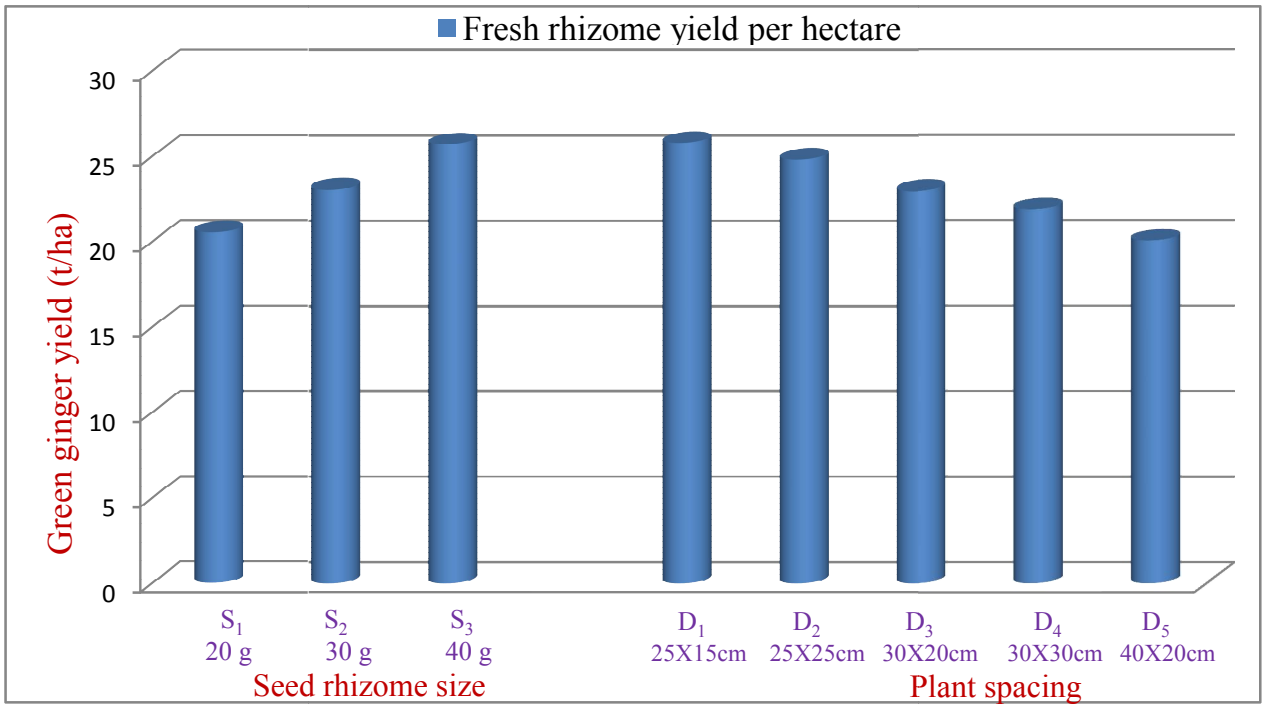

Fig. 4.16b Yield per hectare in ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

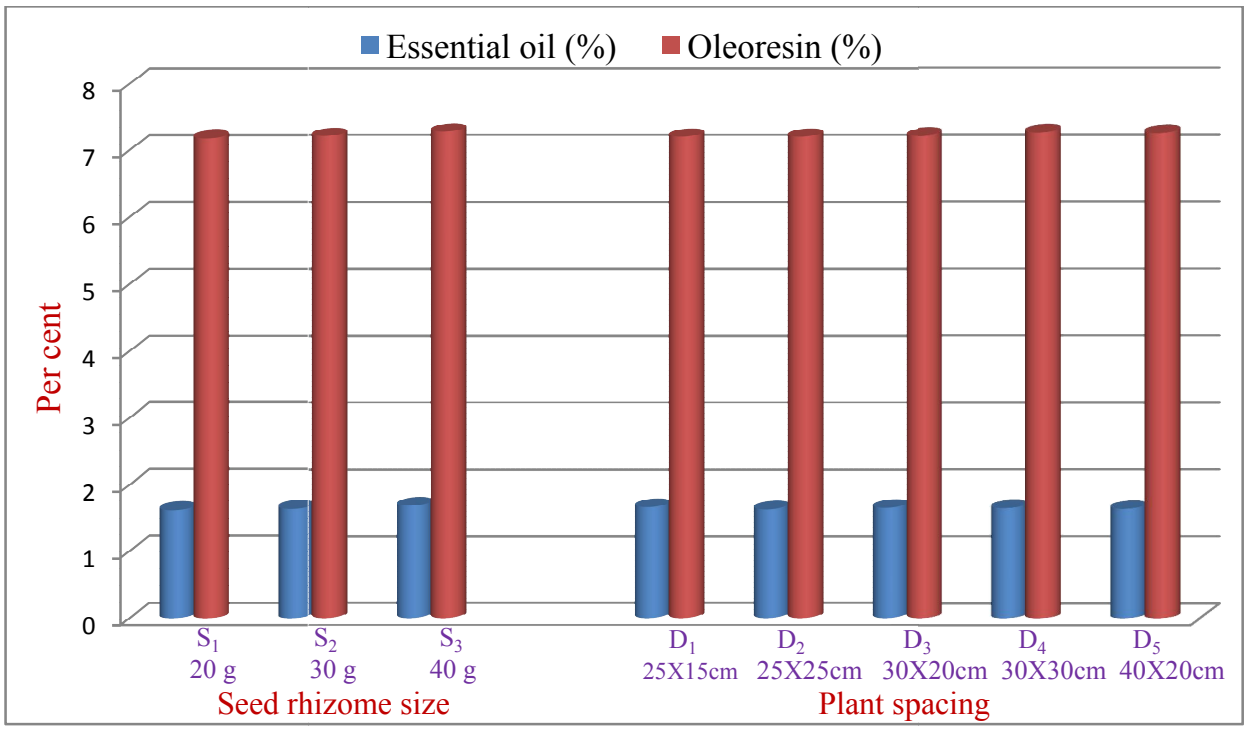

Fig. 4.17 Quality characters of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

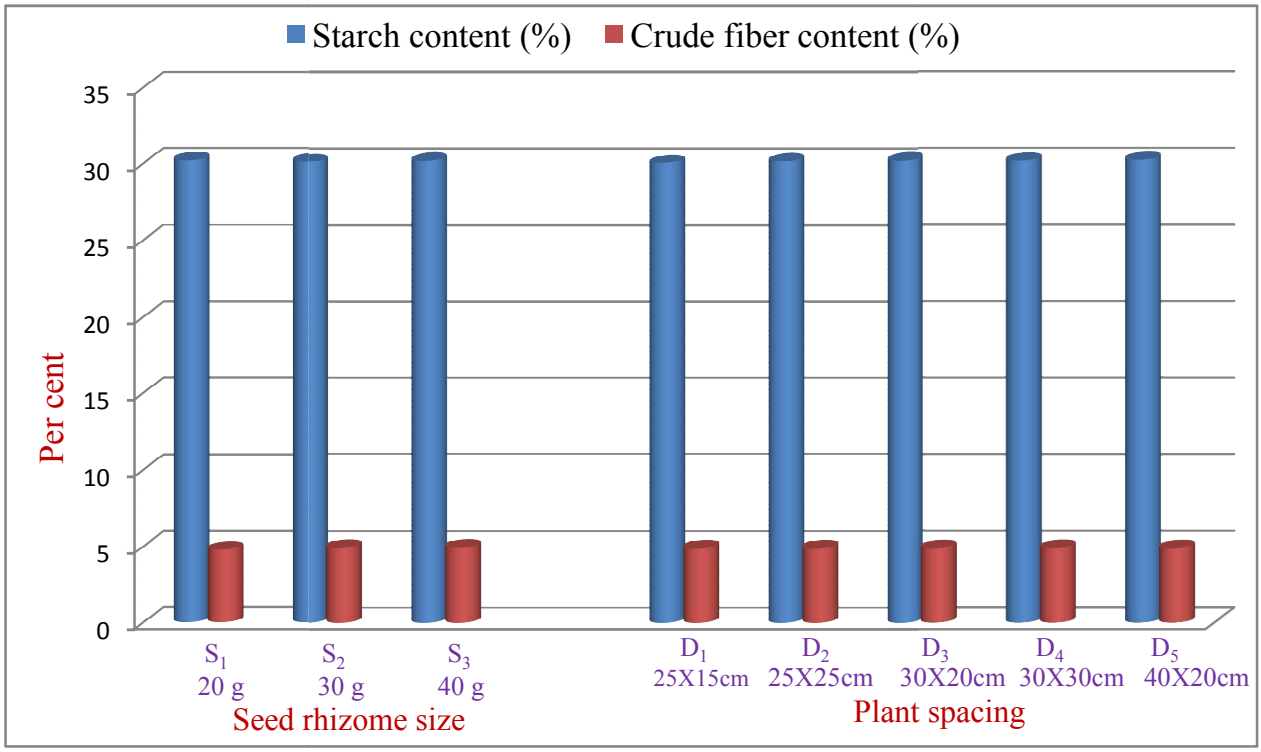

Fig. 4.18 Quality characters of ginger as influenced by seed rhizome size and plant spacing under mango cropping system.

Chapter-V

Summary and Conclusions

Chapter-V

SUMMARY AND CONCLUSIONS

The present field investigation entitled "Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems" was carried out during May to December-2014 at Horticultural College and Research Institute farm, Dr.Y.S.R. Horticultural University, Anantharajupet, Y.S.R. Dist., Andhra Pradesh. The present experiment is a series of two separate experiments conducted simultaneously under coconut and mango cropping system. Each experiment was laid out in a randomized block design with factorial concept with three seed rhizome sizes of ginger *viz.,* 20 g, 30 g and 40 g and five plant spacings *viz.,* 25 cm X 15 cm, 25 cm X 25 cm, 30 cm X 20 cm, 30 cm X 30 cm and 40 cm X 20 cm. Fifteen treatment combinations were replicated thrice. Observations on vegetative, yield and quality parameters were recorded. The salient findings of the investigation are summarized experiment wise below.

Experiment-I: Standardization of seed rhizome size and plant spacing for ginger cv. Maran under coconut cropping system.

A. Effect of Seed rhizome size:

1. Among the seed rhizome sizes, rhizome size of 40 g recorded maximum number of tillers per plant (2.97, 10.55 and 11.51), plant height (16.68 cm, 43.25cm and 67.87 cm) and number of leaves per plant (12.01, 104.52 and 115.36) at 30, 120 DAP and at harvest. Leaf length, leaf breadth, leaf area and leaf area index were found to be significantly maximum with 40 g seed rhizome size (18.94 cm, 2.07 cm, 21.70 cm^2 and 3.59 respectively). Similarly days to first sprouting and days to 50 percent sprouting was lowest from 40 g rhizome size.
2. With regard to yield and yield attributing parameters, rhizome length (15.82 cm), rhizome breadth (15.89 cm), yield per plant (204.01 g), yield per plot (3.29 kg),

yield per hectare (27.41 t) and harvest index (61.53%) were found to be maximum with 40 g rhizome size. Whereas, 20 g seed rhizome size produced lower values for yield and yield attributes.

3. Quality parameters *viz.,* essential oil content (1.83%), oleoresin content (7.87%), starch content (30.36%) and crude fibre content (4.90%) were also observed to be maximum from 40 g seed rhizome size.

B. Effect of plant spacing

Spacing significantly influencing the growth, yield and quality parameters of ginger except, days to first sprouting , days to 50% sprouting, number of tillers per plant (30 DAP), number of leaves per plant (30 DAP), rhizome length, breadth, harvest index and quality parameters.

1. Among the different plant spacings, 30 cm X 30 cm spacing showed maximum values for number of tillers per plant (2.64, 10.93 and 11.64) and number of leaves per plant (10.69, 104.47 and 106.09) at 30, 120 DAP and at harvest. Leaf length, leaf breadth and leaf area (18.96 cm, 2.09 cm and 22.13 cm^2) were highest with 30 cm X 30 cm spacing. However, highest leaf area index (5.25) was recorded from spacing of 25 cm X 15 cm. Minimum days to first sprouting (12.78) and days to 50% sprouting (20.67) were reported from 30 cm X 30 cm spacing. However, the plant height was highest (16.34 cm, 42.47 cm, and 65.07 cm) from a closer spacing of 25 cm X 15 cm at 30, 120 DAP and at harvest.
2. With regard to yield and yield attributing parameters, maximum rhizome length (14.90 cm), rhizome breadth (14.67 cm) and yield per plant (203.02 g) were observed from a wider spacing of 30 cm X 30 cm. Whereas, yield per plot (3.17 kg), yield per hectare (26.40 t) and harvest index (60.37%) were recorded from closest spacing of 25 cm X 15 cm.
3. The data on quality parameters indicated that highest values of essential oil content (1.81%), oleoresin content (7.80%), starch content (30.33%) and crude fibre content (4.89%) were observed from 30 cm X 30 cm plant spacing.

C. Interaction effect of seed rhizome size and plant spacing in ginger

The interaction effect between seed rhizome size and plant spacing was found to be significant for certain growth, yield and quality parameters except days to 50% sprouting, number of tillers per plant at 30 DAP, plant height at 30 DAP and 120 DAP, number of leaves at 30 DAP, harvest index, oleoresin and crude fibre content.

1. The highest yield per plant (215.40 g) was obtained from a combination of 40 g rhizome size with 30 cm X 30 cm spacing. However, yield per plot (4.57) and yield per hectare (38.06 t) were found to be maximum with 40 g rhizome size and 25 cm X 15 cm spacing.
2. The highest benefit cost ratio (4.68) was obtained with the 20 g rhizome size with 40 cm X 20 cm spacing followed by 30 cm X 30 cm spacing (4.16).

Experiment-II: Standardization of seed rhizome size and plant spacing for ginger cv. Maran under mango cropping system.

A. Effect of Seed rhizome size:

Seed rhizome size significantly influencing the vegetative growth parameters, yield and yield attributes and quality parameters.

1. Among the seed rhizome sizes, rhizome size of 40 g recorded maximum number of tillers per plant (3.24, 8.57 and 12.25), plant height (22.17 cm, 63.33 cm and 97.93 cm) and number of leaves per plant (16.24, 93.61 and 137.47) at 30, 120 DAP and at harvest. Leaf length, leaf breadth, leaf area and leaf area index were found to be significantly maximum from 40 g seed rhizome size (23.71 cm, 2.46 cm, 28.18 cm^2 and 4.57 respectively). Similarly days to first sprouting and days to 50 percent sprouting was lowest from 40 g rhizome size.
2. With regard to yield and yield attributing parameters, maximum rhizome length (17.03 cm), rhizome breadth (17.16 cm), yield per plant (206.88 g), yield per plot (3.08 kg), yield per hectare (25.69 t) and harvest index (60.35%) were recorded with 40 g rhizome size. Whereas, 20 g seed rhizome size produced lower values of yield attributes.

3. Quality parameters *viz.,* essential oil content (1.68%), oleoresin content (7.28%), starch content (30.22%) and crude fibre content (4.88%) were also observed to be maximum from 40 g seed rhizome size.

B. Effect of plant spacing

Spacing significantly influencing the growth, yield and quality parameters of ginger except, days to first sprouting , days to 50% sprouting, number of tillers per plant (30 DAP), number of leaves per plant (30 DAP), rhizome length, breadth, harvest index and quality parameters.

1. Among the different plant spacings, 30 cm X 30 cm spacing showed maximum values for number of tillers per plant (3.00, 8.36 and 12.36) and number of leaves per plant (14.64, 97.02 and 135.20) at 30, 120 DAP and at harvest. Leaf length, leaf breadth and leaf area (23.24 cm, 2.11 cm and 28.61 cm^2) were highest with 30 cm X 30 cm spacing. However, highest leaf area index (6.61) was recorded from spacing of 25 cm X 15 cm. Minimum days to first sprouting (10.11) and days to 50% sprouting (19.11) were reported from 30 cm X 30 cm spacing. However, the plant height was highest (21.20 cm, 63.40 cm, and 98.20 cm) from a closer spacing of 25 cm X 15 cm at 30, 120 DAP and at harvest.
2. With regard to yield and yield attributing parameters, maximum rhizome length (16.54 cm), rhizome breadth (17.12 cm) and yield per plant (200.93 g) were observed from a wider spacing of 30 cm X 30 cm. Whereas, yield per plot (3.09 kg), yield per hectare (25.77 t) and harvest index (58.93%) were recorded from closest spacing of 25 cm X 15 cm.
3. The data on quality parameters indicated that highest values of crude fibre content (4.86%), oleoresin content (7.26%) were recorded from 30 cm X 30 cm. Essenrial oil content (1.81) was recorded from closer spacing of 25 cm X 15 cm. However, starch content (30.33%) was recorded from 25 cm X 25 cm plant spacing.

C. Interaction effect of seed rhizome size and plant spacing in ginger

The interaction effect between seed rhizome size and plant spacing was found to be significant for certain growth, yield and quality parameters except, days to first sprouting, days to 50% sprouting, plant height at 30 DAP, number of leaves at harvest, leaf area, leaf area index, rhizome breadth, essential oil content, oleoresin content and starch content.

1. The highest yield per plant (220.80 g) was obtained from a combination of 40 g rhizome size with 30 cm X 30 cm spacing. However, yield per plot (3.67 kg) and yield per hectare (30.56 t) were found to be maximum with 40 g rhizome size and 25 cm X 15 cm spacing.
2. The highest benefit cost ratio (4.30) was obtained with the 20 g rhizome size with 30 cm X 20 cm spacing followed by 30 cm X 30 cm spacing (4.14).

Conclusion

From the investigation entitled, "Standardization of seed rhizome size and plant spacing for ginger (*Zingiber officinale* Rosc.) cv. Maran under coconut and mango cropping systems", it could be concluded that an increase in seed rhizome size of ginger significantly improved the growth and yield components of ginger both under coconut and mango cropping systems. However increse in seed rhizome size incresing the cost of cultivation and decreasing the benefit cost ratio.

Regarding plant spacing, it could be concluded that closer spacing was found to increase the yield per hectare. However, wider spacing improving the yield per plant and other rhizome attributing characters *viz.,* rhizome length and breadth

Interaction effect of rhizome size and plant spacing exhibited significant variation on the yield of ginger. The yield per plot and hectare showed highest value under the treatment combination of largest rhizome size (40 g) with closer plant spacing (25 cm X 15 cm) and on the other hand, lowest yield was reported from the treatment combination of smallest rhizome size with wider plant spacing. However benefit cost ratio was observed from a 20 g rhizome size with 40 cm X 20 cm spacing under coconut cropping

system while it was highest with 20g rhizome size with 30 cm X 20 cm plant spacing under mango cropping system.

It is also observed that most of the vegetative growth parameters were found to be higher under mango cropping system over coconut cropping system. In contrast rhizome characters and fresh rhizome yield was found to be higher under coconut cropping system. This might be due to less shade effect under tall growing coconut plantation compared to bushy and more shading under 26 years old mango cropping system. It could be concluded that mango inter spaces can be better utilized in the initial stages of mango upto 10-15 years of age before its full canopy spread. The effect of light intensity in relation to day temperature and allopathic effect of inter crop during ginger crop growth period is further needs to be studied under dense mango cropping system. Futher it may also required to study the impact of ginger inter crop on mango flowering and yield.

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Appendices

Appendix-I

Weekly meteorological data during the period from 01-01-2014 to 31-12-2014 at Horticultural College and Research Institute, Anantharajupet, Rly. Kodur, Andhra Pradesh.

Standard week	Date	Month	Temperature (^{0}C)		Relative Humidity (%)		Rain fall (mm)	No. of rainy days
			Max	Min	Morning	Evening		
1	1-7	January	25	18	89.57	43.28	--	--
2	8-14	January	26.28	18.28	86.57	42.42	--	--
3	15-21	January	27.28	18.57	86.71	35.57	--	--
4	22-28	January	25.28	20.28	86.28	35.57	--	--
5	29-4	February	25.71	17.71	86.14	36.14	--	--
6	5-11	February	28.28	17.57	85.57	31.42	--	--
7	12-18	February	30.42	19.85	86.42	34.85	--	--
8	19-25	February	29	22.42	86.57	40.00	--	--
9	26-4	March	29.14	22.85	87.57	35.85	--	--
10	5-11	March	29.57	22.28	83.57	35.85	--	--
11	12-18	March	35.71	26.14	85.57	35.71	--	--
12	19-25	March	39.71	27.14	84.14	35.28	--	--
13	26-1	March	40.28	27.42	85.57	35.85	--	--
14	2-8	April	40.14	26.28	84.28	35.14	--	--
15	9-15	April	38.71	25.85	86.42	36	--	--
16	16-22	April	39.42	28	86.57	35.85	--	--
17	23-29	April	39.85	26.14	85.28	36.85	--	--
18	30-6	May	39.57	28	85.85	36.28	--	--
19	7-13	May	41	25.71	85.28	33.85	--	--
20	14-20	May	39.85	22.28	85	35.14	--	--
21	21-27	May	39.57	26.71	85.00	34.28	--	--
22	28-3	May	40.14	28.42	85.71	35.71	80	3

23	4-10	June	38.14	26.57	85.14	35.42	66	1
24	11-17	June	35.85	25.85	85.14	35.28	--	--
25	18-24	June	35.28	24.42	83.42	35.00	--	--
26	25-1	June	35.57	25.71	84.71	34.71	5	1
27	2-8	July	34.42	25.14	85.42	34.85	46.6	2
28	9-15	July	35.00	25.28	84.28	34.28	--	--
29	16-22	July	34	25.28	84.42	33.71	--	-
30	23-29	July	28.85	25.57	85.00	35.28	--	-
31	30-5	July	29.42	27.00	85.14	34.70	--	-
32	6-12	August	33.85	25.85	84.71	34.71	28.40	1
33	13-19	August	33.71	23.85	85.42	35.28	48.00	2
34	20-26	August	31.28	22.57	84.28	35.71	86.00	3
35	27-2	August	28.57	22.85	80.85	38.71	4.00	2
36	3-9	September	29.57	25.00	82.14	34.50	34.00	2
37	10-16	September	29.42	25.00	85.20	33.00	19.50	2
38	17-23	September	29.28	25.14	84.71	32.42	6.40	4
39	24-30	September	29.57	24.28	83.00	33.42	37.00	1
40	1-7	October	25.42	20.85	83.57	33.28	--	-
41	8-14	October	28.71	22.14	83.71	33.71	--	-
42	15-21	October	28.57	25.71	82.42	32.25	22.60	3
43	22-28	October	29	25	84.42	34.71	53.00	3
44	29-4	October	27.57	21.57	87	37.57	12.00	2
45	5-11	November	26.85	19.71	83.85	40.85	--	-
46	12-18	November	27.57	22.14	83.85	35.85	55.2	3
47	19-25	November	27.42	21.14	85.85	35.85	--	--
48	26-2	November	25.71	18.42	89.42	44.14	--	--
49	3-9	December	29.71	17.71	89.42	41.57	--	--
50	10-16	December	25.71	20	89.57	37.42	50.9	5

51	17-23	December	25.57	18.28	86.14	35.57	--	--
52	24-30	December	25.57	17.85	88.57	37.71	--	--

Appendix-II

Input costs

S. No.	Item	Unit	Price (Rs.)
1.	Land preparation		
	Ploughing with tractor	hr	400
	Harrowing with tractor	hr	600
2.	Cost of planting material	kg	50
3.	Cost of manures and fertilizers		
	FYM	t	800
	Urea	50 kg	284
	SSP	50 kg	380
	MOP	50 kg	840
4	Cost of plant protection chemicals		
	Dimethoate	ℓ	376
	Phorate 10 G	5 kg	369
	Chlorpyrifos	ℓ	420
	Mancozeb	1 kg	450
5	Labour wages		
	Men for eight hours	MD	130
	Women for eight hours	MD	130

Appendix-III

Requirement of inputs (per ha)

S. No.	Particulars	Quantity	Labour	
			Men	Women
1.	Land preparation			
	Ploughing with tractor (once)	3 hr		
	Harrowing with tractor (twice)	4 hr		
2.	Cost of planting material	As per seed rate		
3.	Cost of manures and fertilizers			
	FYM	30 t		
	Urea	163.04		
	SSP	312.5		
	MOP	83.33		
4.	Seed treatment			
	mancozeb	3.25 kg		
	Chlorpyrifos	2 ℓ		
5.	Cost of plant protection chemicals			
	Dimethoate	2 ℓ		
	Phorate 10 G	5.0 kg		
	Mancozeb	10 kg		
6.	Labour			
	Seed beds formation		15 MD	
	Planting			30MD
	Manures and fertilizer application		10 MD	
	Spraying of chemicals		8 MD	
	Irrigation		15 MD	
	Thinning, hand weeding and earthing up (twice)			60 MD
	Harvesting			40 MD

Appendix-IV

Details of cost of cultivation in different treatments (Rs. ha^{-1})

S.No	Particulars	S_1D_1	S_1D_2	S_1D_3	S_1D_4	S_1D_5	S_2D_1	S_2D_2
1	Land preparation							
	A. Ploughing & harrowing	3600	3600	3600	3600	3600	3600	3600
	B. Raised beds formation	1950	1950	1950	1950	1950	1950	1950
2	Sowing							
	A.Cost of planting material	266666.66	160000.00	166666.66	111111.11	125000.00	399999.99	240000.00
	B.Planting cost	3900	3900	3900	3900	3900	3900	3900
	C.Seed treatment	2302.5	2302.5	2302.5	2302.5	2302.5	2302.5	2302.5
3	Manure and fertilizers							
	A.Cost of manures and fertilizes	28706.46	28706.46	28706.46	28706.46	28706.46	28706.46	28706.46
	B.Application charges	1300	1300	1300	1300	1300	1300	1300
4	Intercultural operations	7800	7800	7800	7800	7800	7800	7800
5	Irrigation	1950	1950	1950	1950	1950	1950	1950
6	Plant protection							
	A.Cost of plant protection chemicals	5621	5621	5621	5621	5621	5621	5621
	B.Spraying charges	1040	1040	1040	1040	1040	1040	1040
7	Harvesting	5200	5200	5200	5200	5200	5200	5200
8	Packing , Transport and miscellaneous items	3500	3500	3500	3500	3500	3500	3500
Total cost of cultivation		333536.62	226869.96	233536.62	177981.07	191869.96	466869.95	306869.96

Table Cont.

S.No	Particulars	S_2D_3	S_2D_4	S_2D_5	S_3D_1	S_3D_2	S_3D_3	S_3D_4	S_3D_5
1	Land preparation								
	A.Ploughing & harrowing	3600	3600	3600	3600	3600	3600	3600	3600
	B.Raised beds formation	1950	1950	1950	1950	1950	1950	1950	1950
2	Sowing								
	A.Cost of planting material	249999.99	166666.67	187500.00	533333.32	320000.00	333333.32	222222.22	250000.00
	B.Planting cost	3900	3900	3900	3900	3900	3900	3900	3900
	C.Seed treatment	2302.5	2302.5	2302.5	2302.5	2302.5	2302.5	2302.5	2302.5
3	Manure and fertilizers								
	A.Cost of manures and fertilizes	28706.46	28706.46	28706.46	28706.46	28706.46	28706.46	28706.46	28706.46
	B.Application charges	1300	1300	1300	1300	1300	1300	1300	1300
4	Intercultural operations	7800	7800	7800	7800	7800	7800	7800	7800
5	Irrigation	1950	1950	1950	1950	1950	1950	1950	1950
6	Plant protection								
	A.Cost of plant protection chemicals	5621	5621	5621	5621	5621	5621	5621	5621
	B.Spraying charges	1040	1040	1040	1040	1040	1040	1040	1040
7	Harvesting	5200	5200	5200	5200	5200	5200	5200	5200
8	Packing , Transport and miscellaneous items	3500	3500	3500	3500	3500	3500	3500	3500
Total cost of cultivation		316869.95	233536.63	254369.96	600203.28	386869.96	400203.28	289092.18	316869.96