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Growth regulators in increasing pedicel thickness and shelf-life in 'Tas-A-Ganesh' grapes (*Vitis vinifera*) grafted on '1613 C' rootstock

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ABSTRACT

A field experiment was conducted during 1997–99 to study the effect of growth regulators to increase pedicel thickness and shelf-life in 'Tas-A-Ganesh' grapes (*Vitis vinifera* L.) grafted on '1613 C' rootstock. Treatments with growth regulators like 4-CPA, 6-BA and CPPU increased the pedicel thickness by 19.4% and enhanced the shelf-life (PLW) by 2 days compared with the 2 applications of GA₃ alone. Berry drop and berry rot were reduced to 32.25% and 35.96%, respectively, with the delay in pedicel browning by 32.5% at day 5 in shelf after removal of samples from the cold storage at day 30. Among the growth regulators, CPPU along with GA₃ was more effective in increasing the shelf-life when the clusters were applied twice in 2 ppm aqueous solution, once at 6 mm berry size stage and again at veraison stage with 25 ppm GA₃ at 3 mm berry size and 6 mm berry size stage. Among the different treatments, dipping bunches first with GA₃ @ 25 ppm at 3 mm berry size, followed by combination of GA₃ @ 25 ppm and CPPU @ 2 ppm at 6 mm berry size and final dipping of bunches with CPPU @ 2 ppm during veraison was found effective compared with other treatments like GA₃ in combination either with 4-CPA or 6-BA.

Key words: Growth regulators, Pedicel thickness, Shelf-life, 'Tas-A-Ganesh' grape, *Vitis vinifera*

Increasing the shelf-life is of prime importance in any export-oriented fruits. Grape being non-climacteric fruit has to be harvested after ripening and because of improper management practices, harvesting and handling procedures, desiccation and decay are the major aspects reducing the shelf-life. Detachment of berries from the bunches leads to reduced exportable quality and thus the market price. Pedicel thickness plays an important role in increasing the shelf-life of harvested grape (*Vitis vinifera* L.). Weak pedicel results in pedicel browning, increasing physiological loss in weight, berry drop and shrivelling of berries. 'Thompson Seedless' and its clones are leading commercial varieties exported to European market. Brittle and weak pedicel is typical characteristic of 'Thompson Seedless' and its clones (Chadha and Shikhamany 1999). Therefore, it is essential to increase the pedicel thickness to increase its shelf-life. Various cultural practices like girdling or the pre-harvest treatments of plant growth regulators help in overcoming many of the post harvest losses (Sharma and Jindal 1981). Retamales *et al.* (1995) reported that the application of CPPU results in increasing rachis length, pedicel thickness and bunch weight. Keeping these views in mind, an experiment was conducted to study the effect of growth regulators on pedicel thickness and shelf-life of 'Tas-A-Ganesh' grapes grafted on 1613 C rootstock.

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MATERIALS AND METHODS

A field experiment was carried out with 'Tas-A-Ganesh' grafted on '1613 C' grape rootstock at Research and Development farm of Maharashtra State Grape Grower's Association during 1997–98 and 1998–99 under uniform cultural operations. The experiment was laid out in randomized block design with 10 treatments and 3 replications. The growth regulators, viz 6-BA (benzyl adenine), 4-CPA (4-chlorophenoxy acetic acid) and CPPU [N-(2-chloro-4-pyridinyl)-N'-phenyl urea] were used for experimentation. The bunches were dipped with growth regulators at different stages of 3 mm, 6 mm berry size and at veraison stage. The details of different growth regulators applied are: T₁, GA₃ @ 25 ppm at 3 mm berry size and GA₃ @ 25 ppm + 4-CPA @ 10 ppm at 6 mm berry size; T₂, GA₃ @ 25 ppm each at 3 mm and 6 mm berry size + 4-CPA @ 10 ppm at veraison stage; T₃, GA₃ @ 25 ppm at 3 mm berry size, GA₃ @ 25 ppm + 4-CPA @ 10 ppm at 6 mm berry size and 4-CPA @ 10 ppm at veraison stage; T₄, GA₃ @ 25 ppm at 3 mm berry size and GA₃ @ 25 ppm + 6-BA @ 10 ppm at 6 mm berry size; T₅, GA₃ @ 25 ppm at 3 and 6 mm berry size and 6-BA @ 10 ppm at veraison stage; T₆, GA₃ @ 25 ppm at 3 mm berry size, GA₃ @ 25 ppm + 6-BA @ 10 ppm at 6 mm berry size and 6-BA @ 10 ppm at veraison stage; T₇, GA₃ @ 25 ppm at 3 mm berry size and GA₃ @ 25 ppm + CPPU @ 2 ppm at 6 mm berry size;

T₈, GA₃ @ 25 ppm at 3 and 6 mm berry size and CPPU @ 2 ppm at veraison stage; T₉, GA₃ @ 25 ppm at 3 mm, GA₃ @ 25 ppm + CPPU @ 2 ppm at 6 mm berry size and CPPU @ 2 ppm at veraison stage; and T₁₀, GA₃ @ 25 ppm at 3 and 6 mm berry size (control).

Uniformly ripened grape bunches were harvested and the pedicel thickness was measured with the help of Vernier calipers. The harvested bunches in replicated samples were placed in polyethylene bags, later packed in corrugated or cardboard boxes and finally kept in cold storage for 30 days. Under each treatment, 5 kg grapes were maintained. Packing procedure was followed as per the guidelines of international standard. After removing the bunches from the cold storage, observations were recorded daily up to 5 days for pedicel browning, per cent fallen, rotten berries and physiological loss in weight (PLW%). Visual scoring method was used to grade pedicel browning based on the intensity of brown colour. The data were analysed statistically by following Gomez and Gomez (1984) method. The angular transformed values were used for per cent fallen and rotten berries and physiological loss in weight (%). Thirty units in each parameter were taken to study correlation among the parameters studied.

RESULTS AND DISCUSSION

In general growth regulators increased the pedicel thickness by 19.4% over the control (T₁₀). Among the different growth regulator treatments, 4-CPA applied at 6 mm berry size and at veraison stage along with GA₃ applied at 3 and 6 mm berry size (T₃) increased pedicel thickness significantly (1.82 mm), followed by CPPU applied in combination with GA₃ at different stages (1.80 mm) compared with that of the control. This might be due to the reduction in peroxidase activity in

increase in enzyme activity which contributed the thickness. These results confirm the findings of Abdul *et al.* (1998) on 'Fujiminari' grapes. Retamales *et al.* (1993) also reported the increase in pedicel thickness with increased concentration of CPPU. Significant correlation could not be observed between pedicel thickness and other parameters studied.

Per cent fallen berries were minimum (6.41%) under the CPPU applied at veraison stage (T₈) compared with 11.33% of the control. The reduction in berry fall might be due to delay in formation of abscissic acid (ABA) in peduncle. The CPPU might play a role in controlling the formation of ABA in pedicel through delusion of pedicel senescence. Abdul *et al.* (1998) also reported the increase in activity of auxins known to reduce berry drop with the application of CPPU.

The significant differences were recorded for per cent rotten berries. There was 35.96% reduction in berry rot compared with the control. The CPPU-applied bunches at 6 mm and veraison stage (T₈) showed the lowest berry rot on day 5 under shelf. This can be attributed to delay in senescence which leads to reduction in cell-wall turgidity and thus reduction in berry rot. This is in confirmation with the results of Retamales *et al.* (1998), who also reported reduction in berry drop with additional application of CPPU with GA₃.

Pedicel browning was reduced significantly in all the treatments under shelf compared with the control (Table 1). In general, application of either 4-CPA @ 10 ppm (T₃), 6BA @ 10 ppm (T₇) or CPPU 2 ppm (T₈) twice was found to be effective in reducing the pedicel browning. This is attributed to the role of CPPU in mobilization of amino acids in treated parts (pedicel and berries) and their accumulation. This might be due to the sustaining the nucleic acid and protein which delayed the senescence. Positive and significant correlation was observed

Table 1 Effect of growth-regulator treatments on pedicel thickness, quality and storage life on day 5 after 30 days of cold storage in 'Tas-A-Ganesh' grape (means data of 1997-98 and 1998-99 seasons)

Treatment	Pedicel thickness (mm)	Pedicel browning (visual score 0-10)	Fallen berries (%)	Rotten berries (%)	Physiological loss in weight (%)
T ₁	1.49	9.66	11.76 (20.01)	10.01 (18.34)	15.39 (23.05)
T ₂	1.54	9.17	9.75 (18.18)	9.70 (18.20)	13.19 (21.24)
T ₃	1.82	8.50	12.41 (20.60)	9.77 (18.05)	13.63 (21.59)
T ₄	1.52	9.67	11.33 (19.65)	10.10 (18.43)	15.62 (23.22)
T ₅	1.70	9.00	10.95 (19.31)	8.55 (16.85)	14.17 (22.08)
T ₆	1.53	8.00	9.85 (18.25)	8.53 (16.87)	13.29 (21.34)
T ₇	1.78	10.00	16.38 (23.81)	9.22 (17.63)	14.71 (22.53)
T ₈	1.63	9.33	6.41 (14.66)	10.03 (18.27)	15.98 (23.54)
T ₉	1.80	8.17	7.87 (16.18)	6.25 (14.43)	12.71 (20.87)
T ₁₀ (control)	1.33	10.00	14.35 (22.24)	12.40 (20.40)	17.53 (24.73)
SEm±	0.057	0.265	0.805	0.74	0.580
CD (P=0.05)	0.170	0.790	2.392	2.20	1.730

* Details of treatments are given under Materials and Methods

** The figures in parentheses are angular transformed values

between pedicel browning and fallen berries and also between pedicel browning and physiological loss in weight (Table 2). This indicates that browning favours the detachment of berries from the peduncle leading to increased fallen berries.

Significant differences were also observed for physiological loss in weight (%) in all the treatments. The least physiological loss in weight was recorded when the CPPU was applied twice at 6 mm berry size stage and at veraison stage along with GA₃ at 3 mm and 6 mm berry size stage. The CPPU might have played a role in maintaining the turgidity of cell-wall and its firmness which resulted in less loss of water

Table 2 Correlation between pedicel thickness, pedicel browning, fallen and rotten berries and physiological loss in weight

Character	Pedicel thickness	Pedicel browning	Fallen berries	Rotten berries	Physiological loss in weight
Pedicel thickness	0	-0.301	0.005	-0.144	-0.266
Pedicel browning		0	0.434*	0.184	0.570*
Fallen berries			0	0.260	0.190
Rotten berries				0	0.296
Physiological loss in weight					0

* $P = 0.05$

from the berries.

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Induction and analysis of gamma ray-induced flower head shape mutation in 'Lalima' chrysanthemum (*Chrysanthemum morifolium*)

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ABSTRACT

An experiment was conducted during the rainy season of 1998 to study the effects of gamma irradiation in 'Lalima' Chrysanthemum (*Chrysanthemum morifolium* L.) with particular reference to induction of somatic mutation. The rooted cuttings were irradiated with 0, 15, 20 and 25 Gy of gamma rays. Reduction in survival, growth, plant height, number of branches and leaves/plant and leaf and flower size and increased morphological, floral and chromosomal abnormalities were recorded after irradiation. Mutation in flower head shape were detected from 25 Gy treatment in M_1V_1 and M_1V_2 generation and established in pure form. Comparative cytomorphological and anatomical analysis of original and mutant was carried out to understand the nature of mutation. Significant reduction in plant height, flower head diameter and guard cell width were recorded after irradiation, however no change in chromosome number was recorded in the mutant. Gamma ray-induced flower head shape mutant of 'Lalima' was found very attractive and ideal for pot culture.

Key words: Gamma rays, Chrysanthemum, Chlorophyll variegation, Mutation

About 30% of cultivars have evolved due to spontaneous somatic mutations (Wasscher 1956). Induction of flower shape mutation in chrysanthemum (*Chrysanthemum morifolium* L.) has been extensively done and interesting cytomorphological changes have been reported (Banerji and Datta 1997, Datta 1992, Datta 2001). Many new cultivars induced by gamma rays, have been released by the National Botanical Research Institute, Lucknow (FAO/IAEA 1980). There is always demand for new varieties. The present experiment was carried out to study the effect of different doses of gamma rays on chrysanthemum cultivar 'Lalima' with particular reference to induction of flower shape mutation for novelty.

MATERIALS AND METHODS

Rooted cuttings of 'Lalima' were irradiated with 0, 15, 20 and 25 Gy of gamma rays at the dose rate of 100 Gy/ 51.8 sec in Gamma Chamber-900 ⁶⁰Co source of Mutation Breeding Laboratory, National Botanical Research Institute, Lucknow and planted in beds in 1998 immediately after irradiation along with equal number of the control. Each treatment consisted of 25 cuttings. The LD₅₀ dose was determined at the time of flowering in M_1V_1 generation.

For determination of chromosome number and ploidy level, root tips (1.5 to 2.0 cm long) were cut, pre-treated in a mixture of saturated aqueous solution of para dichlorobenzene and esculetin (1:1 v/v) for 10 min in ice chamber and 2.5 hr at 4°C. The root tips were fixed in propionic acid absolute ethanol

(1:3 v/v) for 2.5 hr. After washing, the roots were hydrolysed in N HCl at 60°C for 13 min. Temporary squash preparation were made using 45% propionic acid. For cytophotometric measurements of DNA content and chromosomal aberration studies young healthy root tips were fixed in acetic acid : ethanol (1:3 v/v) for 24 hr and then hydrolysed in 1N HCl for 13 min at 60°C stained in leucobasic fuchsin at pH 3.6 for 2 hr and washed thrice with SO₂ water for 10 min, each followed by washing in distilled water. Finally the root tips were squashed in glycerol. For determination of 2C nuclear DNA content, the relative absorption of feulgen stained nuclei was recorded at 570 nm using Vickers M-86 scanning microdensitometer. *Allium cepa*, where nuclear DNA value is 33.5 picogram, was used as a standard for the calculation of absolute value followed by method of Van't Hof (1965).

All the DNA measurement studies included at least 3 replications and 25 (2C) nuclei were scored in each root meristem. Chromosomal aberrations were scored from the slides after scanning. Anatomical studies were made from epidermal peelings of leaves after staining in 2% silver nitrate solution.

Pollengrains were collected soon after the anthesis in malachite green-jelly. The pollengrains which were regular in shape, full and had uniform stain were considered fertile, while those which were empty and hyaline were regarded sterile.

RESULTS AND DISCUSSION

The survival (%) decreased after exposure to 25 Gy of gamma rays. The plant height and growth rate were reduced

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after gamma irradiation over the control. Branches per plant were reduced after gamma irradiation. The decrease was significant ($P < 0.01$) at 20 Gy treatment. A sharp decrease in leaf length and numbers were also recorded. Significant ($P < 0.01$) reduction in leaf width was recorded after 15 Gy treatment. The length of petiole decreased with increase in dose of gamma rays. In general abnormal plant growth involving leaves, stems and flowers was noticed. The plant with morphological abnormalities appeared as chimeras. The leaf abnormalities included changes in shape, size, margin, apex, fission and fusion of leaves (Fig 1). The development of forked and double leaves occurred regularly in the treated populations.

Chlorophyll variegations were observed only in few leaves in M_1V_1 (Fig 2). The frequency of plants with leaf

abnormalities at 45 days under all the treatment increased with increase of doses. Decrease in flower head production was observed at 25 Gy treatment. Some of the flowers in higher doses were abnormal due to unequal growth of florets. The frequency of abnormal flowers increased with the increase in dose of gamma rays. Flowering time was not affected much by radiation; however, delay of 2–3 days in full bloom was recorded from treated population (Table 1). Floral abnormalities included fasciation in bud, asymmetrical development of flower head and reduction in flower head and floret size. Percentage of floral abnormalities increased with increase in exposure to gamma rays. Somatic mutations in flower colour and shape could be detected in chimeric form in M_1V_1 generation. Percentage of somatic mutations increased with the increase in exposure to gamma rays and maximum somatic mutation, ie

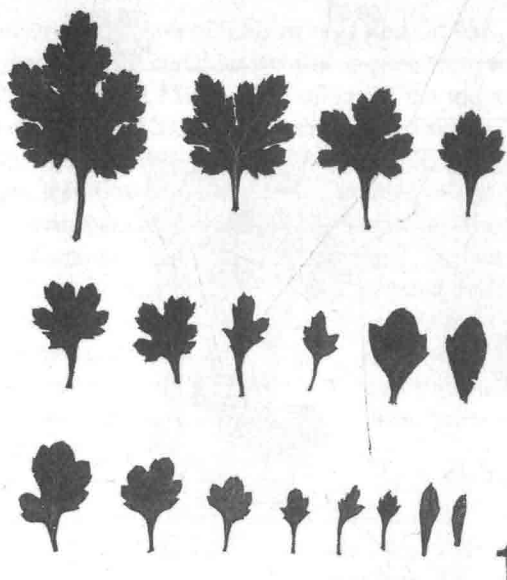


Fig 1 Normal (top left corner) and abnormal leaves of chrysanthemum cv. 'Lalima'

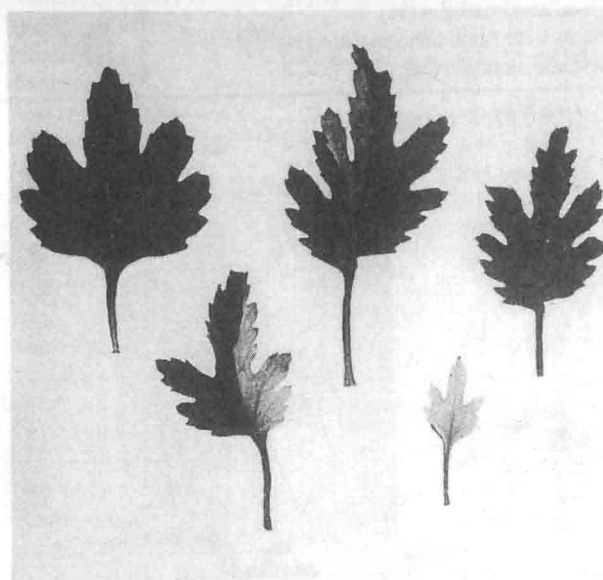


Fig 2 Normal (top left corner) and chlorophyll variegated leaves induced by gamma rays

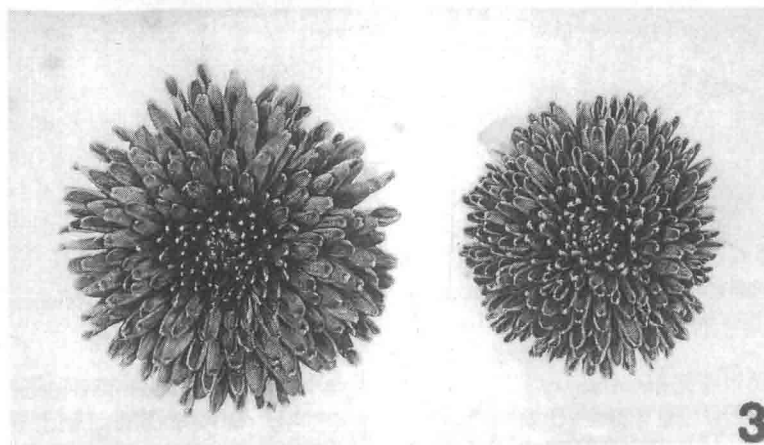


Fig 3 'Lalima' (original cultivar) left and flower head shape mutant

Table 1 Effects of gamma irradiation on vegetative and floral characters of 'Lalima' chrysanthemum in M1V1 generation

Character	Gamma ray (Gray)			
	0 (control)	15	20	25
Survival (%)	100	89.47	88.89	80.0
Plant height (cm)	81.67 ± 1.42	80.50 ± 1.32	75.59** ± 1.20	65.18** ± 4.16
Branch number	4.38 ± 0.34	4.39 ± 0.33	3.29** ± 0.04	3.47* ± 0.26
Leaf number	34.06 ± 2.41	33.33 ± 2.24	32.64 ± 2.32	28.64 ± 2.80
Leaf length (cm)	5.33 ± 0.15	5.56 ± 0.17	5.55 ± 0.17	4.85** ± 0.08
Leaf width (cm)	4.38 ± 0.07	3.94** ± 0.15	3.81** ± 0.13	3.78** ± 0.11
Petiole length (cm)	2.03 ± 0.04	2.00 ± 0.03	1.93 ± 0.06	1.97 ± 0.02
Abnormal plant (%)	0	100	100	100
Abnormal leaves (%)	0	9.67	27.21	56.00
Days to bud initiation	69.94 ± 0.88	69.00 ± 1.71	66.87 ± 2.28	66.30 ± 1.23
Days to first colour shown	96.06 ± 1.22	98.44 ± 1.64	98.88 ± 2.01	98.42 ± 2.25
Days to full bloom	111.00 ± 0.89	113.50 ± 0.88	115.12 ± 1.57	114.50 ± 1.53
Flower head /plant	27.55 ± 1.64	27.00 ± 1.00	27.75 ± 0.42	24.40 ± 0.83
Floral abnormalities (%)	0	4.72	6.42	13.41
Plants with floral abnormalities(%)	0	38.89	50.00	78.57
Somatic mutation (%)	0	35.29	37.50	56.25

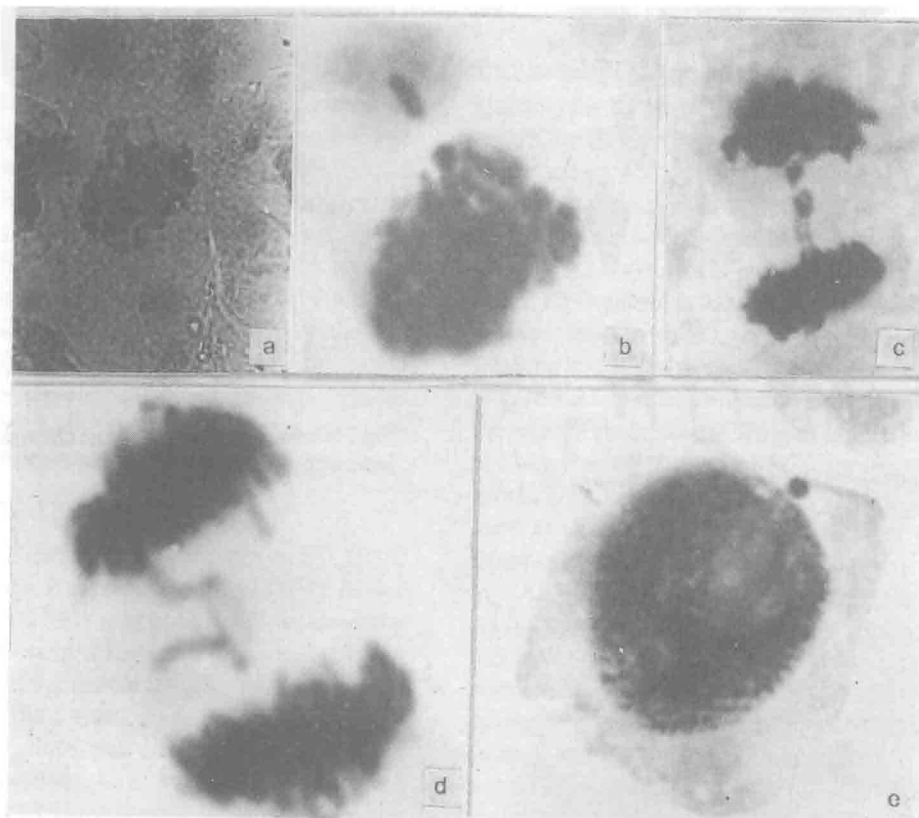
* $P = 0.02$; ** $P = 0.01$ 

Fig 4 Chromosomal abnormalities in chrysanthemum. a. Clumping; b. early separation; c. bridges; d. laggards; e. micronuclei

56%, was observed in 25 Gy treatment (Table 1).

Different types of chromosomal aberrations were recorded after gamma irradiation (Table 2). The major type of chromosomal aberrations recorded were clumping, bridges,

laggards, early separation and micronuclei (Fig. 4). There was no dose-specific abnormalities, with increase in dose of gamma rays there was increase in number of cells with chromosomal aberrations. The maximum chromosomal

Table 2 Per cent cells with chromosomal aberrations after gamma irradiation during root tip mitosis in 'Lalima' chrysanthemum

Chromosomal aberration (%)	Gamma rays (Gray)			
	0 (control)	15	20	25
Number of cell examined	746	302	353	702
Clumping				1.28
Bridges	0	3.33	4.82	6.26
Laggards	0	0.33	0.28	0.14
Early separation	0	0.33	0.28	0.14
Micronuclei	0	0.66	0.28	0.43
Total	0	4.65	5.66	8.25

aberrations were recorded after the highest exposure of 25 Gy (8.25%).

The original colour of 'Lalima' was Red Gr. 46A, fan-1. Head shape mutant could be isolated in pure form out of 4 mutants detected in M1V1. The colour of the mutant was yellow-orange Gr. 22B, fanal and shape pompon type (Fig 3).

The comparative data on plant height, number of branches, leaf, flower heads per plant, number of ray-florets/head, stomata per unit area, chloroplast/stomata, size of leaf, flower, stomata, chromosome number, chromosomal abnormalities, INV, ICV, 2C DNA content and pollengrain sterility and size were recorded for original cultivar and its flower shape mutant. Colour of original cultivar and its flower shape mutant is given in Table 3. Significant differences were observed in some characters among original cultivar and head shape mutant.

Somatic chromosome number of $2n (=6x)=54$ was observed in 'Lalima' and its flower head mutants. Both the control and mutant showed hexaploidy. No chromosomal aberration was observed during root tip mitosis in the original variety. Changed flower head mutant showed 0.41% cells each with clumping and bridges and 0.20% cells with micronuclei and 1.02 cells with total chromosomal aberrations. The INV, ICV and 2C nuclear DNA content were almost same in the original and the mutants (Table 3). No difference in pollengrain fertility and size was observed in 'Lalima' and its mutants. Here the variation in pollengrain size in changed flower head mutant (25.50 to 51.25 μ) was more than the original cultivar 'Lalima' (23.76 to 42.25 μ).

Jain *et al.* (1961), Banerji (1989), Datta (1992) and Banerji and Datta (1997) reported gamma ray-induced somatic flower colour and shape mutants. The present findings indicate that gamma rays can also induce mutation in flower shape for novelty.

Reduction in survival to maturity and plant height after treatment with gamma rays was observed. Inactivation of auxin and decrease in auxin content with increase radiation doses is responsible for plant height reduction. Survival of plants to

Table 3 Characters of the original cv. 'Lalima' and its gamma ray induced flower head shape mutant in chrysanthemum

Character	Original cultivar 'Lalima'	Flower head shape mutant of 'Lalima'
Morphology		
Plant height (cm)	68.50 $\pm$ 1.07	49.43** $\pm$ 0.40
Branch number	12.50 $\pm$ 0.37	11.92 $\pm$ 0.30
Leaf number	182.25 $\pm$ 3.44	176.58 $\pm$ 2.65
Leaf length (cm)	3.94 $\pm$ 0.07	3.74 $\pm$ 0.11
Leaf width (cm)	3.25 $\pm$ 0.13	2.74 $\pm$ 0.08
Petiole length (cm)	1.30 $\pm$ 0.07	1.41 $\pm$ 0.05
Leaf colour	Green	Green
Flower head colour	Red Gr. 46 A, Fan1	Yellow-Orange Gr. 22B, Fan1
Number of flower head/plant	171.40 $\pm$ 11.83	155.90 $\pm$ 16.73
Flower head diameter (cm)	5.20 $\pm$ 0.10	4.29** $\pm$ 0.07
Flower head height (cm)	2.02 $\pm$ 0.04	1.94 $\pm$ 0.03
Flower head weight (g)	1.88 $\pm$ 0.07	1.44 $\pm$ 0.06
Number of ray florets	230.56 $\pm$ 26.47	253.88 $\pm$ 8.45
Ray floret length (cm)	2.39 $\pm$ 0.04	2.11 $\pm$ 0.04
Ray floret width (cm)	0.51 $\pm$ 0.02	0.23 $\pm$ 0.01
Moisture content of florets (%)	65.0	64
Anatomy		
Number of stomata/unit area	4.20 $\pm$ 0.11	4.27 $\pm$ 0.11
Guard cell length (μ m)	39.47 $\pm$ 0.83	38.67 $\pm$ 0.83
Guard cell width (μ m)	24.60 $\pm$ 0.41	28.27** $\pm$ 0.47
Pore length (μ m)	24.80 $\pm$ 0.53	25.67 $\pm$ 1.10
Pore width (μ m)	4.26 $\pm$ 0.03	5.93 $\pm$ 0.34
Number of chloroplast/stoma	25.33 $\pm$ 0.57	24.87 $\pm$ 0.65
Chloroplast size (μ m)	3.92 $\pm$ 0.03	3.94 $\pm$ 0.15
Cytology		
Chromosome number	54	54
Polidy level $2n=6x$	Hexaploid	Hexaploid
Interphase nuclear volume (INV) (μ m ³)	336.91 $\pm$ 11.71	344.29 $\pm$ 12.13
Interphase Chromosome Volume (ICV) (μ m ³)	6.23 $\pm$ 0.22	6.38 $\pm$ 0.22
DNA in pg 2C	16.74 $\pm$ 0.17	16.92 $\pm$ 0.08
Palynology		
Pollengrain fertility (%)	96.75	96.33
Pollengrain size (μ m)	42.25 $\pm$ 0.25	42.10 $\pm$ 0.25

** $P = 0.01$

maturity and reduction in height depends on the nature and extent of chromosomal damage. The percentage of abnormal leaves/plant increased with increase in exposure to gamma rays.

Decrease in leaf and flower head production with higher doses is mainly due to decrease in branch number. Floral abnormalities increase along with plants with somatic mutations. Banerji (1989), Datta *et al.* (1985), Datta and Gupta

(1984) Dwivedi *et al.* (2000) and Datta (2001) also reported similar abnormalities in different cultivars of chrysanthemum.

In the present investigation mutation could be induced in chrysanthemum cultivar 'Lalima'. The flower colours were identified from Royal Horticulture Society Colour Chart (1966). Gamma ray-induced flower head mutant could be isolated and established in pure form by vegetative propagation. Radiation induced phenotypic variation including several interesting change in flower form has been reported viz 'Cosmonaut' (Datta and Gupta 1984), 'Tulika' (Datta *et al.* 1985), 'Shabnam' (Datta 1990) and 'Jaya Tubular' (Banerji and Datta 1992).

Gamma ray-induced flower head shape mutant of Lalima is very attractive due to pompon flower head. This additional novelty is ideal for pot culture.

ACKNOWLEDGMENT

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Effect of dose and mode of metribuzin application on *Phalaris minor* and yield of wheat (*Triticum aestivum*)

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ABSTRACT

A study was conducted during winter (Rabi) season of 1998–2000 to find out optimum dose and mode of metribuzin application on its effect on *Phalaris minor* (Retz) and yield of wheat (*Triticum aestivum* L. emend. Fiori and Paol). The results showed that there was severe competition between wheat and little canary grass (*Phalaris minor*). Competition by yellow sweet clover (*Melilotus indica*), swinncress (*Coronopus didymus*) and wood sorrel (*Rumex* sp.) which also invaded the field was insignificant. The average reduction in grain yield due to P. minor competition was 36%. Weed control treatments lowered weed population and weed biomass accumulation and boosted up crop yield. Application of metribuzin as post-emergence resulted in better control of weeds than its pre-emergence application. At 200 g/ha, it killed all the plants of swinncress, yellow sweet clover and wood sorrel (*Rumex* sp.) and gave excellent control of *Phalaris minor* (94%). At 150 g/ha, its effect on *C. didymus* and *Rumex* sp. was almost similar to that of 200 g/ha, but slightly lower on *P. minor* (86%) and poor on *M. indica*. Pendimethalin gave moderate control of P. minor and good control of *M. indica*, *C. didymus* and *Rumex* sp. The highest yield was recorded in hand weeding which was significantly superior to all other treatments. Metribuzin as post-emergence at 100 and 150 g/ha caused significantly higher increase compared to its application at 200 g/ha pre and post emergence and 150 g/ha pre emergence. It caused marked increase in productive tillers and yield attributes. The increase in yield attributes in pendimethalin was similar to that of metribuzin 100 g/ha pre-emergence.

Key words: Metribuzin, Pendimethalin, and Wheat

In India wheat (*Triticum aestivum* L. emend. Fiori and Paol.) is the most important cereal crop, it occupies 26.74 million ha and contributes 70.1 million t to total food grain production and is backbone of food security. Of late its productivity is declining. A major factor that limits its productivity is severe weed infestation. Of weed species which invade the crop, preponderance of *Phalaris minor* is of great concern. Crop yield losses due to weed infestation is estimated to vary between 30 to 50% (Pandey and Singh 1997). It is therefore imperative to control it in time to insure better crop growth environment to realise higher crop yield. Herbicides have been found effective against it and other weed species but most of them are narrow in their selectivity and do not completely eliminate crop-weed competition. Metribuzin at lower dose is reported to be very effective against *Phalaris minor* and other weeds (Singh et al. 1999). However, little information is available on its dose and mode of application. Hence a study was undertaken to find out optimum dose and proper mode of metribuzin application and its effect on

Phalaris minor and yield of wheat.

MATERIALS AND METHODS

An experiment comprising 9 treatments (Table 1) was conducted in a randomised block design with 3 replications at the Institute, New Delhi during winter (rabi) season of 1998–99 and 1999–2000.

The soil was sandy clay loam having 52.8% sand, 21.5% silt and 25% clay, pH 8 (1:2.5 soil water ratio), 275 kg N/ha, 205 kg P/ha and 180 kg K/ha.

'HD 2285' wheat was sown 23 cm apart in rows with tractor drawn seed drill on December 2 and harvested in first week of May in both years. The crop was fertilized with 100 kg N, 18 kg P and 35 kg K/ha. Full dose of P and K and half of N was applied at sowing. The remaining N was applied at first irrigation given 25 days after sowing. The sources of N, P and K were urea, single super phosphate and muriate of potash, respectively. Pendimethalin just after sowing and metribuzin pre- and post-emergence were applied 1 and 35 days after sowing respectively with the help of knap sack sprayer fitted with flat fan nozzle using a volume spray of 500 litres/ha.

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Weed data were transformed $\sqrt{x+0.5}$ before statistical analysis.

RESULTS AND DISCUSSION

Weed dynamics

Competition between wheat and little canary grass (*Phalaris minor*) (184 plants/m²) was fierce. Other weed species which invaded crop were yellow sweet clover (*Melilotus indica*) (80/m²), wood sorrel (*Rumex* sp.) (129/m²) and swincress (*Coronopus didymus*) (118/m²). Competition by these weed species was negligible as they emerged late and were quelled by *Phalaris minor* owing to its preponderance and luxuriant growth. The crop-weed competition was markedly reduced by weed control treatments as is evident from the significant decrease in weed population and dry matter accumulation (Table 1). Removing the weeds twice (hand weeding) markedly reduced the build up of weed population and weed biomass which was significantly superior to other treatments except weed population in metribuzin at 200 g/ha applied as post-emergence. Pendimethalin caused significant decrease in weed population and their dry weight compared to all treatments except metribuzin applied post-emergence at 150 and 200 g/ha (Table 1). With increasing doses of metribuzin there was gradual decrease in population and dry matter accumulation in pre-emergence application but there was sharp decrease in its post-emergence application. Growth of little canary grass (*Phalaris minor*) plants was completely ceased after a week of metribuzin post-emergence spray and plants died gradually 20 and 40 days after at higher and lower doses, respectively.

In pre-emergence applied metribuzin plots, at lower level little canary grass (*Phalaris minor*) plants growth was completely ceased, plant became thin, leaves drooped but remained green till crop remained green while at higher doses

they gradually died. Pendimethalin and metribuzin had different effects on each weed species, but the trend was similar in both years (Table 1). Pendimethalin gave good control of wood sorrel, swincress and yellow sweet clover but slightly lower control of *Phalaris minor*. Metribuzin as pre-emergence was less effective against little canary grass and yellow sweet clover. Similar results were reported by Pandey et al. (2001). Metribuzin as post-emergence killed all the plants of yellow sweet clover, swincress and wood sorrel and gave remarkable control of little canary grass (Table 1).

Growth attributes

Weed control treatments had significant effects on plant height and productive tillers though they produced similar increase in both years. Hand weeding caused maximum increase and proved statistically superior to other treatments. The effect of pendimethalin was similar to that of metribuzin 100 g/ha pre-emergence. Post-emergence caused slightly higher decrease. At 150 g/ha as post-emergence it effected significantly higher increase in productive tillers compared to other herbicide treatments. Pendimethalin and metribuzin 100 g/ha pre-emergence effected similar but significantly superior than other metribuzin applications.

Hand weeding showed significantly higher ear weight, number of grains/ear and 1000 grain weight compared to other treatments (Table 2). The increase may be attributed to better crop growth owing to decreased crop-weed competition during critical growth stages and increased nutrient supply. Herbicide treatments produced similar increase in yield attributes in both years. The effect of pendimethalin on number of grains and 1 000 grain weight was similar to metribuzin pre-emergence at 200 g/ha but significantly higher than its post-emergence at same dose while significantly lower on ear weight. Post-emergence application of metribuzin at 200 g/ha resulted in

Table 1 Effect of treatments on weed species (60 days after sowing-pooled mean)

Treatments	Dose (ai g/ha)	Weed population (weeds/0.25 m ²)	Weed dry weight (g/0.25 m ²)	Weed species (%) decrease			
				<i>P. minor</i>	<i>M. indica</i>	<i>Rumex</i> sp.	<i>C. didymus</i>
Weedy check		11.47(131)	5.7(33.6)				
*Hand weeding		2.46(6)	1.38(1.9)	95	92	94	96
Pendimethalin (pre-em)	1000	3.73(14)	2.07(4.3)	83	89	91	90
Metribuzin (pre-em)	100	6.93(48)	2.82(7.1)	23	74	92	91
Metribuzin (pre-em)	150	6.5(42)	2.58(6.2)	40	65	89	90
Metribuzin (pre-em)	200	5.79(33)	2.27(4.6)	54	68	100	100
Metribuzin (post-em)	100	5.42(29)	2.40(5.8)	53	70	99	99
Metribuzin (post-em)	150	3.05(9)	2.91(8.0)	86	89	98	98
Metribuzin (post-em)	200	2.03(4)	1.69(3.4)	94	100	100	100
SEm+		0.10	0.07				
CD (P=0.05)		0.32	0.13				

P, *Phalaris*; M, *Melilotus*; C, *Coronopus*, em., emergence

* Hand weeding = 20 and 35 days after sowing

Figures in parentheses indicate original

Table 2 Effect of treatments on growth, yield attributes and yield (pooled mean)

Treatment	Dose (ai g/ha)	Plant height (cm)	Productive tillers/running m*	Grains/ear	1 000-grain weight (g)	Weight/year (g)	Grain yield (kg/ha)
Weedy check		87.6	85.8	40.8	38.0	1.75	3 529
Hand weeding		101.6	124.1	49.2	42.5	2.27	5 544
Pendimethalin (pre-em.)	1000	96.6	105.3	47.1	41.6	2.09	5 081
Metribuzin (pre-em.)	100	96.4	104.5	44.9	41.0	2.05	5 093
Metribuzin (pre-em.)	150	96.1	92.2	45.5	41.5	2.05	4 855
Metribuzin (pre-em.)	200	94.5	99.4	47.7	41.4	2.15	4 577
Metribuzin (post-em.)	100	97.6	98.1	47.8	41.3	2.15	5 217
Metribuzin (post-em.)	150	95.2	109.5	45.8	41.1	2.06	5 242
Metribuzin (post-em.)	200	92.8	97.0	42.4	41.1	1.97	5 012
SEm ±		0.46	0.75	0.26	0.1	0.03	0.52
CD at (P=0.05)		1.34	2.17	0.76	0.3	0.09	1.51

* r.m., running meter

significantly lower number of grains/ear compared to its pre-emergence application at the same dose and other applications. This may be ascribed to its adverse effect on crop growth. Metribuzin at 150 g/ha as post-emergence resulted in significantly higher increase in yield attributes compared to its pre-emergence application at 150 g/ha and post-emergence application at 100 g/ha.

Grain yield

Weed competition lowered crop yield by 36%. Hand weeding resulted in highest yield which was significantly superior to all other treatments (Table 2). This may be attributed to marked decrease in weed population, weed dry weight and there by better crop growth, increased productive tillers and yield attributes. Similar results were earlier reported by Pandey and Singh (1983). Metribuzin at 100 and 150 g/ha as post-emergence effected significant increase compared to its pre- and post-emergence application at 200 g/ha and pre-emergence at 150 g/ha. Its pre-emergence application at 100 g/ha gave significantly higher yield compared to 150 and 200 g/ha as pre-emergence but was statistically at par with pendimethalin in both years. The increased yield with post-emergence application of metribuzin at 100 and 150 g/ha may be ascribed to excellent control of *Phalaris minor*, marked increase in crop growth, productive tillers and yield attributes. Similar were the observations of Singh et al. (1999). Lower yield in pre-emergence at 150 and 200 g/ha and post-emergence at 200 g/ha may be assigned to detrimental effect of metribuzin on growth, productive tillers and yield attribute despite good control of dominant weed species *Phalaris minor*. In both the years, pendimethalin resulted in significantly higher yield compared to pre-emergence applied metribuzin at 150 and 200

g/ha and post-emergence at 200 g/ha. The higher yield may be attributed to elimination of weed competition in early crop growth stages favouring better growth and development. Significantly lower yield with pendimethalin compared to metribuzin applied post-emergence at 100 and 150 g/ha may be attributed to its failure to control little canary grass and other weed species which emerged 40 to 45 days after sowing.

Pre-emergence application of metribuzin at 100 to 200 g/ha paralysed the growth of little canary grass (*P. minor*) plants in the very early crop growth stages to the extent that they became ineffective and failed to bring about any tangible loss in crop yield. Post-emergence application of metribuzin gave remarkable control of little canary grass (*P. minor*) and other weed species there by resulting in higher increase in crop yield. The maximum increase in crop yield was obtained with metribuzin applied at 150 g/ha as post-emergence while its application at 200 g/ha as post-emergence resulted in maximum reduction in the population of little canary grass (*P. minor*) and other weed species.

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Hand weeding showed significantly higher ear weight, number of grains/ear and 1000 grain weight compared to other treatments (Table 2). The increase may be attributed to better crop growth owing to decreased crop-weed competition during critical growth stages and increased nutrient supply. Herbicide treatments produced similar increase in yield attributes in both years. The effect of pendimethalin on number of grains and 1 000 grain weight was similar to metribuzin pre-emergence at 200 g/ha but significantly higher than its post-emergence at same dose while significantly lower on ear weight. Post-emergence application of metribuzin at 200 g/ha resulted in

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*Hand weeding		2.46(6)	1.38(1.9)	95	92	94	96
Pendimethalin (pre-em)	1000	3.73(14)	2.07(4.3)	83	89	91	90
Metribuzin (pre-em)	100	6.93(48)	2.82(7.1)	23	74	92	91
Metribuzin (pre-em)	150	6.5(42)	2.58(6.2)	40	65	89	90
Metribuzin (pre-em)	200	5.79(33)	2.27(4.6)	54	68	100	100
Metribuzin (post-em)	100	5.42(29)	2.40(5.8)	53	70	99	99
Metribuzin (post-em)	150	3.05(9)	2.91(8.0)	86	89	98	98
Metribuzin (post-em)	200	2.03(4)	1.69(3.4)	94	100	100	100
SEm+		0.10	0.07				
CD (P=0.05)		0.32	0.13				

P, *Phalaris*; M, *Melilotus*; C, *Coronopus*, em., emergence

* Hand weeding = 20 and 35 days after sowing

Figures in parentheses indicate original

Table 2 Effect of treatments on growth, yield attributes and yield (pooled mean)

Treatment	Dose (ai g/ha)	Plant height (cm)	Productive tillers/running m*	Grains/ear	1 000-grain weight (g)	Weight/year (g)	Grain yield (kg/ha)
Weedy check		87.6	85.8	40.8	38.0	1.75	3 529
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Metribuzin (post-em.)	100	97.6	98.1	47.8	41.3	2.15	5 217
Metribuzin (post-em.)	150	95.2	109.5	45.8	41.1	2.06	5 242
Metribuzin (post-em.)	200	92.8	97.0	42.4	41.1	1.97	5 012
SEm ±		0.46	0.75	0.26	0.1	0.03	0.52
CD at (P=0.05)		1.34	2.17	0.76	0.3	0.09	1.51

* r.m., running meter

significantly lower number of grains/ear compared to its pre-emergence application at the same dose and other applications. This may be ascribed to its adverse effect on crop growth. Metribuzin at 150 g/ha as post-emergence resulted in significantly higher increase in yield attributes compared to its pre-emergence application at 150 g/ha and post-emergence application at 100 g/ha.

Grain yield

Weed competition lowered crop yield by 36%. Hand weeding resulted in highest yield which was significantly superior to all other treatments (Table 2). This may be attributed to marked decrease in weed population, weed dry weight and there by better crop growth, increased productive tillers and yield attributes. Similar results were earlier reported by Pandey and Singh (1983). Metribuzin at 100 and 150 g/ha as post-emergence effected significant increase compared to its pre- and post-emergence application at 200 g/ha and pre-emergence at 150 g/ha. Its pre-emergence application at 100 g/ha gave significantly higher yield compared to 150 and 200 g/ha as pre-emergence but was statistically at par with pendimethalin in both years. The increased yield with post-emergence application of metribuzin at 100 and 150 g/ha may be ascribed to excellent control of *Phalaris minor*, marked increase in crop growth, productive tillers and yield attributes. Similar were the observations of Singh et al. (1999). Lower yield in pre-emergence at 150 and 200 g/ha and post-emergence at 200 g/ha may be assigned to detrimental effect of metribuzin on growth, productive tillers and yield attribute despite good control of dominant weed species *Phalaris minor*. In both the years, pendimethalin resulted in significantly higher yield compared to pre-emergence applied metribuzin at 150 and 200

g/ha and post-emergence at 200 g/ha. The higher yield may be attributed to elimination of weed competition in early crop growth stages favouring better growth and development. Significantly lower yield with pendimethalin compared to metribuzin applied post-emergence at 100 and 150 g/ha may be attributed to its failure to control little canary grass and other weed species which emerged 40 to 45 days after sowing.

Pre-emergence application of metribuzin at 100 to 200 g/ha paralysed the growth of little canary grass (*P. minor*) plants in the very early crop growth stages to the extent that they became ineffective and failed to bring about any tangible loss in crop yield. Post-emergence application of metribuzin gave remarkable control of little canary grass (*P. minor*) and other weed species there by resulting in higher increase in crop yield. The maximum increase in crop yield was obtained with metribuzin applied at 150 g/ha as post-emergence while its application at 200 g/ha as post-emergence resulted in maximum reduction in the population of little canary grass (*P. minor*) and other weed species.

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Annual carbon input to soil through rainfed soybean (*Glycine max*)–wheat (*Triticum aestivum*) cropping sequence in mid-hills of North-West Himalaya*

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In any agro-ecosystem, even after the removal of harvestable above-ground biomass, considerable amount of carbon input is added to the soil inadvertently through leaf fall, root, nodules and left-over stubble. Many studies indicated strong positive relationship between the amount of carbon incorporated annually into the soil and organic carbon content of the soil (Havlin *et al.* 1990, Paustian *et al.* 1992) and changes in soil organic carbon content were linearly related to gross carbon input into the soil either through crop residues or from external sources such as manures and composts. Continuous cropping, inclusion of high-yielding leguminous crops, retention of residues in soil, reduced soil disturbance and increasing crop productivity through external addition of fertilizer and manures all contribute to improvement of organic carbon in soil (Kundu *et al.* 2001). Therefore in the present investigation an attempt was made to study the effect of continuous application of fertilizers and manures on the annual addition of biomass carbon input to the soil from soybean [*Glycine max* (L.) Merr.] and wheat (*Triticum aestivum* L. emend Fiori. & Paol.) cropping sequence in a long-term experiment at mid-hills of North-West Himalaya.

A fixed plot (5.4 m × 2.0 m) long-term fertilizer experiment involving 'Bragg' soybean and 'VL 616' wheat rainfed crop rotation, was initiated in the rainy season of 1973 on an Inceptisol (pH 6.2, EC 0.2 dS/m, CEC 8.72 Cmol (p⁺)/kg, bulk density 1.32 Mg/m³, silt 16.1%, clay 5.8%, organic C 5.77 g/kg soil, total N 0.045%) at the experimental farm, Almora (29°36' N and 79°40' E, 1 250 m above mean sea-level). The experiment involved 6 treatments with 6 replications distributed in randomized block design over 3 levelled terraces. The treatments were: control (T₁), 20 kg N + 35 kg P/ha (T₂), 20 kg N + 33.2 kg K/ha (T₃), 20 kg N + 35 kg P + 33.2 kg K/ha (T₄), 20 kg N + 10 tonnes farmyard manure/ha (T₅) and T₄ + 10 tonnes farmyard manure/ha (T₆). All the fertilizer and manures were applied to soybean crop, whereas wheat was grown on residual

fertility. Both the crops were grown under rainfed condition. On an average, during growing periods of soybean and wheat 800 mm and 315 mm rainfall was received respectively. Harvestable above-ground biomass of both soybean (seed and trash) and wheat (grain and straw) were removed every year and dry weights were recorded. Using the average biomass yield data of soybean (22 years) and wheat (21 years), annual input of carbon added to the soil was computed. After the harvest of wheat crop in 1999–2000, soil samples (0–15 cm) from all the treatments were collected, dried, passed through 0.2-mm sieve, and total carbon and nitrogen contents in < 0.2 mm soil fraction was measured by CHN analyser.

In soybean, inadvertent addition of biomass carbon was through leaf fall, roots and nodules. Leaf fall data were collected during (1989–91) from all the treatments. From each plot, shedded leaves were manually collected from 45 days after sowing till harvest, dried and dry weight were recorded. Computation of root biomass and nodule biomass of soybean under different treatments were done as per the procedure (Kundu *et al.* 2001) using the root : shoot and nodule : root biomass ratios recorded in our earlier pot culture experiment (1989) conducted on the same soil. In T₁, T₂, and T₃, 42% of the above ground biomass of soybean was considered as contribution of root biomass, while in T₄, T₅ and T₆ the contribution of root biomass were 37.2, 30.4 and 33.8% of the above-ground biomass respectively. Studies elsewhere showed that root biomass constituted 31.2% of the above-ground biomass of soybean (Kundu *et al.* 1997). In T₁, T₂, T₃, T₄, T₅ and T₆ treatments, nodule biomass constituted 11.3, 11.5, 11.6, 15.3, 15.0 and 13.0% of the estimated root biomass of soybean, respectively, and similar values were also used by others (Kundu *et al.* 1997). During 1999 samples of soybean leaves (collected after senescence), nodules (sampled through single plant excavation on 65 days after sowing) and roots (sampled through excavation at 85 days after sowing) were collected from all the replications of each treatment and analysed for total carbon content using CHN analyser for calculation of carbon inputs. In case of wheat entry of biomass to soil was through stubbles (4.70–6.73%) of the straw yield

* Short note

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as observed in our sample survey) and roots (30% of the harvestable above-ground biomass as observed by Chander *et al.* 1997). Samples of stubbles and roots of wheat collected after the harvest of wheat in 2000 were analysed for carbon content for computation of carbon input to soil.

Estimated organic biomass from soybean through leaf fall, roots and nodules under different treatments showed large variation due to differential biomass yield response of soybean to applied fertilizers and manures (Table 1). Annual addition of biomass through leaf fall, roots and nodules was

organic biomass addition of the 6 treatments, organic biomass 431.6, 879.7 and 118.9 kg/ha was added annually to the soil through leaf fall, roots and nodule/tonnesed grain yield of soybean.

The carbon contents of the soybean leaves and below-ground roots showed variations, depending on the fertilizer and manurial treatments whereas treatment effects on carbon contents of nodules were found non-significant (Table 1). On an average, the leaves, root and nodules contained 37.8, 34.2 and 31.5% carbon respectively.

Table 1 Average annual input of organic biomass to soil from soybean and wheat under different fertilizer or manurial treatments

Treatment	Harvestable biomass yield (kg/ha)				Annual biomass addition to soil (kg/ha)		
	Soybean	Wheat	Soybean Leaf fall	Wheat Roots	Nodules	Stubbles	Roots
T ₁	1 520 (652)*	2 106 (639)*	144 (38.1)**	641 (35.2)**	73 (32.5)**	95 (42.8)**	632 (39.6)**
T ₂	2 420 (980)	2 583 (938)	390 (36.5)	1 016 (34.1)	117 (30.3)	88 (43.6)	775 (40.1)
T ₃	1 843 (733)	2 370 (801)	132 (39.1)	772 (33.2)	90 (31.5)	95 (42.5)	711 (41.1)
T ₄	3 804 (1580)	3 160 (1 148)	836 (38.5)	1 437 (35.1)	220 (32.8)	99 (40.3)	948 (39.5)
T ₅	5 686 (2 302)	4 533 (1 571)	1 137 (37.1)	1 729 (34.5)	259 (30.7)	139 (41.6)	1360 (40.5)
T ₆	6 918 (2 776)	5 367 (1 860)	1 254 (37.6)	2 338 (33.2)	313 (31.2)	169 (42.6)	1610 (38.9)
CD (P=0.05)	308.0 (132.1)	321.5 (122.3)	57.4 (1.38)	122.5 (1.62)	18.6 (NS)	10.9 (NS)	92.6 (NS)

Details of treatments are given in text

* Data in the parentheses indicate average seed/grain yield; ** data in the parentheses show the carbon content (%) of the plant biomass

144–1 254, 641–2 338 and 73–313 kg/ha respectively. The treatment consisting of regular application of farmyard manure @ 10 tonnes/ha in combination with NPK (T₆) or N alone (T₅), showed considerable increase in total biomass addition to the soil by 56.6 and 25.3%, respectively, over that observed in T₄ treatment. Based on the mean values of grain yields and

The annual carbon inputs to the soil through leaf fall, roots and nodules also showed large variation from treatment to treatment, ranging from 54.8 to 471.5, 225.6 to 776.2 and 23.7 to 97.6 kg carbon/ha, respectively, depending on the biomass yield response of soybean to applied fertilizer and manurial inputs (Table 2). The results also indicate that carbon input to

Table 2 Average annual carbon input to soil from soybean-wheat sequence and status of total organic carbon and total nitrogen in soil under different treatments

Treatment	Average and annual carbon inputs (kg/ha) to soil					Gross annual carbon input (kg/ha)	Soil status	
	Soybean			Wheat			Total C (g/kg)	Total N (g/kg)
	Leaf fall	Roots	Nodule	Stubbles	Roots			
T ₁	54.8	225.6	23.7	40.7	250.3	595.0	6.22	0.560
T ₂	142.4	346.5	35.4	38.4	310.8	873.5	7.33	0.680
T ₃	51.6	256.3	28.4	40.4	292.2	668.9	5.83	0.595
T ₄	321.9	504.4	72.2	39.9	374.4	1 312.8	6.89	0.719
T ₅	421.8	596.5	79.5	57.8	550.8	1 706.4	10.07	0.755
T ₆	471.5	776.2	97.6	72.0	626.3	2 043.6	11.21	0.832
CD (P=0.05)	23.7	43.2	5.3	4.5	36.8		0.71	0.56

* Details of treatments are given in text

soil through root biomass of soybean was 2 times more than the carbon inputs added through leaf fall. Kemper et al. (1998) reported that in soybean, around 13% of the total organic matter (roots and tops) was found in roots alone at the end of growing season. Because of the beneficial effects of continuous farmyard manure application, the T_6 treatment showed 46.5, 53.9 and 35.2% increase in carbon input through leaf fall, roots and nodules biomass, respectively, over T_4 treatment. The results also showed that on an average 500 kg C/ha (of which 163, 300 and 37 kg C/ha was contributed by leaf fall, roots and nodule biomass respectively) was added to the soil annually by the soybean crop for each tonne yield of soybean grain yield.

As the succeeding wheat crop was grown continuously on residual fertility, the average annual biomass yields in different treatments were very low (Table 1), resulting in low inputs of organic biomass to soil through left-over stubbles and roots. Annual addition of stubble biomass to the soil ranged from 95 to 169 kg/ha, which constituted 4.70–6.73 % of the harvested straw yields.

In the present experiment, We indirectly estimated the annual entry of root biomass to the soil under different treatments based on root : shoot ratio of 0.3 in wheat, as observed by Chander et al. (1997) under Indian condition. Root : shoot ratio of 0.25 in wheat was also reported by Kemper et al. (1998). Based on indirect estimation, annual biomass entry through wheat roots in different treatments were around 6–10 times higher than those added through left-over stubble (Table 1), and quantitatively annual root biomass addition to the soil was ranging from 632 kg/ha in the control to as high as 1 610 kg/ha in T_6 treatment. The treatment effect on carbon contents in wheat stubble and roots was found non-significant, however, mean carbon content was higher in stubble (42.2% C) than in roots (39.9% C).

Computation of carbon input to soil based on observed carbon contents of stubbles showed significantly higher carbon input in T_5 and T_6 treatments than the remaining treatments (Table 2), indicating that preceding farmyard manure application had marked residual effect on total biomass yield vis-à-vis contribution of stubble biomass carbon to the soil.

The annual carbon input through wheat root biomass ranged from 250.3 kg C/ha in the control to as high as 626.3 kg C/ha in T_6 treatment. Because of the higher biomass yield responses of wheat to farmyard manure applied to the preceding crop, annual carbon input through root biomass increased by 47.1% and 67.3% in T_5 and T_6 treatments, respectively, over that observed in T_4 treatment. Based on average wheat yield and annual carbon input, it was observed that both root and stubble biomass of wheat annually contributed 385 kg C/ha per tonne grain yield.

The annual gross carbon input from crop biomass to the soil under soybean–wheat sequence ranged from 595.0 kg C/ha in the control to as high as 2043.6 kg C/ha in T_6 treatment (Table 2). Continuous soil application of 10 tonnes farmyard

manure/ha in T_5 or T_6 showed 30.0% and 55.7% increase in gross carbon input to the soil over T_4 treatment respectively (Table 2).

Because of continuous addition of biomass carbon from the left-over residues of soybean and wheat, the total carbon and nitrogen content in the soil showed increasing trend depending on the above-ground harvestable biomass yield response of the crops to applied fertilizer or manurial input (Table 2). Considerable increase in total carbon and nitrogen content in soil under T_5 and T_6 compared with other treatments could be attributed to additional annual entry of organic biomass to soil as farmyard manure. Our analysis showed that on an average 1 587 kg C/ha and 55.8 kg N/ha were continuously added to the soil every year in these 2 treatments through 10 tonnes farm yard manure/ha.

It is to mention that while computing carbon inputs, we did not include the inputs through rhizodeposition of carbon from root turn over and exudates. Shamoot et al. (1968) observed that rhizodeposition of carbon from root turnover and exudates represented 5 to 20% of the above-ground biomass in greenhouse study with 11 plant species. In wheat, considerable amount of carbon input to the soil is contributed through rhizodeposition compared to soybean. Keith et al. (1986) reported in a study with ^{14}C that rhizodeposition during the growing season of wheat was 30% of the total carbon accumulated above ground. The results, thus, showed that by maintaining better productivity of the crops through external application of NPK in combination with farmyard manure, annual carbon input to the soil could substantially be increased which, in turn, would help in improving soil organic matter status.

SUMMARY

Average annual carbon input to soil through left-over biomass (leaf litter, nodule, roots and stubble) of soybean [*Glycine max* (L.) Merr.] and wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crops under different fertilizer or manurial treatments were estimated from a long-term rainfed experiment. Annual biomass carbon from soybean through leaf fall, roots and nodules raised from 54.8 to 471.5, 225.6 to 776.2 and 23.7 to 97.6 kg C/ha, respectively, depending on the above-ground yield responses to applied fertilizer or manures. The succeeding wheat crop grown on residual fertility annually supplied carbon input through left-over stubbles and roots was 40.7 to 72.0 and 250.3 to 626.3 kg C/ha respectively. The estimated annual gross carbon input from crop biomass to soil under soybean–wheat sequence ranged from 595.0 kg C/ha in control to as high as 2 043.6 kg C/ha in the treatment receiving continuously recommended dose of NPK and farmyard manure. On an average 500 kg C/ha and 385 kg C/ha were annually added to the soil through left-over biomass/tonne seed and grain yield of soybean and wheat respectively. The results showed that by maintaining better productivity of the crops through application of NPK in

combination with farmyard manure, annual carbon input to the soil could substantially be increased to maintain higher carbon and nitrogen status in soil.

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Maximisation of nitrogen resource for rainfed groundnut (*Arachis hypogaea*) alley cropped with nitrogen fixing trees*

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Groundnut (*Arachis hypogaea* L.) is an important crop and energy-rich crop, but grown in energy-starved conditions. Though research efforts are continuing to improve the productivity of the crop, the yield levels are remained stagnant over the years mainly because of poor management practices adopted and low efficiency of applied fertilizers. Alley cropping, a version of agroforestry with nitrogen-fixing trees (NFT) proved more viable approach for sustaining the yields of groundnut with increased efficiency of applied fertilizers, through application of lopped foliage in the system (Kang *et al.* 1981). Hence the present study was initiated.

An experiment was initiated at Students Farm, College of Agriculture, Hyderabad, to optimize the efficiency of applied fertilizers to groundnut crop alley cropped with nitrogen-fixing trees during rainy season of 1998 and 1999. The treatments consisted of 2 alley cropping systems with NFTs like *Dalbergia sissoo* Roxb. ex DC. (DAC), *Leucaena leucocephala* (Lam.) De Wit (LAC) during both the years and sole cropping with application of lopped green foliage of respective trees was included in the second year (SCD and SCL) as main treatments. The sub-treatments were 6 with 2 levels of green-leaf manuring (GLM and no GLM) and 3 levels of nitrogen (0, 20 and 40 kg/ha). All the treatments replicated thrice under split-plot design. The site of the experiment was under 10 years old plantations of *Dalbergia* and *Leucaena* spaced at 4 m × 3 m. The trees were pollarded at 3 m height and lopped foliage was applied at 5 tonnes/ha, 15 days before sowing to all the green-manure plots both under alley cropping and sole cropping. Nitrogen was applied as per treatments while phosphorus was applied at 60 kg/ha basal at the time of green-leaf incorporation. Gypsum was applied at 500 kg/ha at the time of peg penetration. The tree area was medium in organic carbon, available nitrogen and phosphorus but low in available potash, while open area was low in organic carbon and available nitrogen. The groundnut crop variety 'K 134' ('Vemana') was sown in 24 m² plots of experimental area on 7

July 1998 and 10 July 1999. The crop was harvested on 15 October 1998 and 28 October 1999.

The pod yields of groundnut did not vary significantly except during 1999 due to cropping systems (Table 1). However, *Delbergia* (DAC) and *Leucaena* (LAC) alley cropping systems resulted in higher yields of 1 239 and 1 238 kg/ha (1998) and 1 158 and 1 148 kg/ha (1999), respectively, which were at par and superior to the pod yields obtained under sole cropping (1 002 and 1 001 kg/ha). Improved site conditions coupled with greater uptake of nutrients might have contributed for higher yields under alley cropping systems. The results confirm the findings of Kang *et al.* (1981) and Bheemaiah *et al.* (1998).

Significant differences were observed due to application of green-leaf manuring (GLM). More pod yields of 1 381 kg/ha (1998) and 1 229 kg/ha (1999) were obtained with GLM and found much higher than those without GLM (1 096 and 926 kg/ha). Presumably increased organic matter and timely release of nutrients might have resulted in higher pod yields with GLM. The findings confirm the results obtained by Subba Reddy *et al.* (1991).

Nitrogen levels significantly influenced the pod yields of groundnut with higher pod yield at 20 kg/ha than other levels. Though interaction effects were not significant, pod yield obtained at 20 kg N/ha with GLM was more than the pod yield obtained at 40 kg N/ha without GLM both in alley cropping and sole cropping, because of conjunctive use of organic and inorganic sources of nitrogen, which increased the availability of nutrients. Subba Reddy *et al.* (1991) and Palled *et al.* (1997) also reported similar results.

Uptake of N, P and K were influenced significantly by the cropping system. *Dalbergia* alley cropping increased the uptake of N, P and K with values of 176, 21.8 and 156 kg/ha (1998) and 97, 17.2 and 107 kg/ha (1999) and found improved over *Leucaena* alley cropping which resulted in 155 19.1 and 141 kg/ha (1998) and 82, 15.2 and 95 kg/ha (1999) of N, P and K uptake respectively. Both alley cropping systems showed greater uptake of all these 3 major nutrients than the uptake in

* Short note

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Table 1 Pod yield and nutrient uptake of groundnut as influenced by cropping systems and integrated nutrient management practices

Treatment	Pod yield (kg/ha)	Nutrient uptake (kg/ha)			Optimum dose of N (kg/ha)	Pod yield (kg/ha)	Nutrient uptake (kg/ha)			Optimum dose of N (kg/ha)
		N	P	K			N	P	K	
1998						1999				
Dalbergia alley cropping										
GLM										
N ₀	1 026	153	19.0	125	26.0	998	73	14.2	87	25.4
N ₂₀	1 635	186	23.7	168		1 515	112	19.4	118	
N ₄₀	1 498	273	28.5	215		1 380	128	22.9	147	
Mean	1 387	192	23.7	169		1 297	104	18.8	117	
No GLM										
N ₀	835	124	16.1	108	34.3	801	55	12.1	72	34.3
N ₂₀	1 113	164	19.9	147		1 032	101	16.2	102	
N ₄₀	1 328	194	23.3	171		1 225	117	18.3	119	
Mean	1 092	160	19.8	142		1 019	91	15.5	97	
Overall mean	1 239	176	21.8	156		1 158	97	17.2	107	
Leucaena alley cropping										
GLM										
N ₀	1 050	143	17.7	117	24.9	970	61	13.2	78	25.0
N ₂₀	1 631	164	20.8	173		1 519	96	16.7	114	
N ₄₀	1 448	198	23.9	179		1 355	114	19.1	131	
Mean	1 376	168	20.8	156		1281	91	16.3	107	
No GLM										
N ₀	850	109	14.4	96	34.3	797	45	11.3	56	33.6
N ₂₀	1 120	148	17.6	132		1 040	76	14.2	86	
N ₄₀	1 328	169	20.2	149		1 210	101	16.6	109	
Mean	1 099	142	17.4	126		1 015	74	14.0	83	
Over all mean	1 238	155	19.1	141		1 148	82	15.2	95	
Sole cropping of <i>Dalbergia</i> green-leaf manuring										
N ₀						910	41	10.2	61	24.7
N ₂₀						1 373	63	9.4	92	
N ₄₀						1 226	85	15.7	119	
Mean						1 169	63	11.8	90	
Sole cropping of <i>Leucaena</i> green-leaf manuring										
N ₀						933	42	10.4	63	24.4
N ₂₀						1 359	65	13.3	93	
N ₄₀						1 211	83	15.5	115	
Mean						1 167	63	13.1	90	
Sole cropping without green-leaf manuring										
N ₀						601	26	8.1	42	34.7
N ₂₀						864	49	11.1	77	
N ₄₀						1 039	59	13.2	94	
Mean						834	44	10.8	71	
Overall mean										
GLM	1 381	175	21.7	159		1 229	80	15	101	
No GLM	1 096	147	18.2	131		926	63	12.8	80	
CD (<i>P</i> = 0.05)										
Cropping systems	NS	10.1	1.28	9.21		61.3	4.5	1.8	3.9	
Green leaf manures	54.8	11.5	0.88	8.1		28.0	2.2	1.0	2.7	
Nitrogen levels	40.1	8.9	0.76	5.4		55.0	2.1	0.92	3.8	
Interaction	NS	NS	NS	NS		NS	NS	NS	NS	

sole cropping of groundnut, which could be due to higher dry-matter of groundnut (Subba Reddy *et al.* 1991).

Green-leaf manuring significantly increased the uptake of N with values of 175 kg/ha (1998) and 80 kg/ha (1999) than without green-leaf manuring (147 and 63.5 kg/ha). Uptake of P and K followed similar trend. Increased availability of nutrients through better microbial activity and growth of crop because of high organic matter under GLM are the reasons ascribed for increased uptake. Rao *et al.* (1991) observed similar results.

Application of nitrogen resulted in significantly higher uptake of N, P and K nutrients at 40 kg N/ha and found comparable with 20 kg N/ha due to high dry matter and better growth.

Interaction effects, though, did not vary significantly; alley cropping systems with GLM at 20 kg N/ha showed much similar nutrients uptake with that of 40 kg N/ha without GLM, indicating advantage of integrated use of GLM and nitrogen.

The economic optimum dose of nitrogen was 26 kg/ha and 25.4 kg/ha under *Dalbergia* alley cropping during 1998 and 1999, respectively, which was found to be at par with the values (24.9 and 25.0 kg/ha) under *Leucaena* alley cropping. However, under sole cropping without green-leaf manuring the economic optimum dose of nitrogen was increased to 34.7 kg/ha. It clearly indicates the advantage of green-leaf manuring in supplementing part of nitrogen to groundnut crop under alley cropping systems.

Thus it is clear that alley cropping of groundnut with *Dalbergia* and *Leucaena* proved more beneficial to boost the crop yields than sole cropping. Green-leaf manuring of respective nitrogen-fixing trees augmented in substituting part of nitrogen to the groundnut crop and helped to reduce the cost of production by maximizing the efficiency of applied

nitrogen.

SUMMARY

Alley cropping of groundnut with *Dalbergia* and *Leucaena* nitrogen-fixing trees resulted in much higher yields than sole cropping. Green leaf-manuring of respective trees produced significantly higher yields than without green-leaf manuring. Application of manuring with 20 kg N/ha gave significantly higher pod yields of groundnut than without green-leaf manuring at 40 kg N/ha.

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Response of Indian mustard to sources and levels of sulphur in patrially reclaimed salt affected soil

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Key words: Indian mustard, *Brassica juncea*, Sulphur, Reclaimed salt-affected soil

Sixteen treatments comprising 4 sources (elemental sulphur, gypsum, pyrites and pressmud) and 4 levels (0, 20, 40, and 60 kg/ha) of sulphur were evaluated in randomized block design, replicated thrice. Elemental sulphur (99% S), gypsum (16% S) pyrites (22% S) and pressmud (8% S) were applied in respective treatments. Pyrites was applied on the soil surface ensuring sufficient moisture in the plots and left for oxidation for 3 weeks. Elemental sulphur, gypsum and pressmud were applied at the time of final land preparation and mixed in the shallow depth. 'Varuna' Indian mustard was sown in rows 40 cm apart using 6 kg seed/ha. A uniform dose of N, P and K @ 80, 34.4 and 32.2 kg/ha was applied through urea, diammonium phosphate and muriate of potash respectively. Half dose of N and full dose of P and K were applied basal and remaining half N was top-dressed after the first irrigation. The oil content was estimated by Oxford Analytical Newport 4000 NMR. Oil yield was calculated by multiplying the seed yield with oil content. The N, P, K, S and Fe contents in Indian mustard seed were determined as per procedure described by Jackson (1973). The nutrient uptake was calculated by adding the uptake of seed and stover of Indian mustard, determined separately by multiplying their respective yields and nutrient content. The various soil properties were determined as per standard procedures. Economics and benefit: cost ratio was calculated by dividing gross income with total cost of cultivation.

Among various sources of sulphur, gypsum being at par with pyrites recorded higher seed yield than elemental sulphur and pressmud (Table 1). The seed yield (Table 1) increased significantly with the levels of sulphur which might be attributed to improvement in yield attributes viz siliquae/plant, length of siliquae, seeds / siliquae and 1000 - seed weight. The increase in number and length of siliquae as well as seeds/siliquae may be assigned to resemblance of S to N in increasing

cell-division, cell elongation or expansion, and favourable effect of S on chlorophyll synthesis, leading to increase in number and length of siliquae and stimulation of flowering and seed formation in siliquae due to S (Ghose et al. 2000). The oil yield followed the trend of seed yield.

The N, P, K, S, and Fe uptake by Indian mustard increased significantly with gypsum over elemental sulphur and pressmud. However, pyrites was statistically at par with gypsum. The uptake of N, P, K, S, and Fe increased with levels of sulphur. The increased N uptake was mainly due to increase in concentration of N in seed and stover along with increase in yield. The increasing trend in P uptake with S application was ascribed to the beneficial role of the sulphur in mobilizing soil-P and its utilization by Indian mustard (Jain and Saxena 1991). The increase in K uptake might be due to the role of S in growth, development and chlorophyll formation, resulting in its greater utilization (Aulakh et al. 1980). The increased of S was owing to increase in seed and stover yields, which in turn increased their uptake (Singh et al. 1991). As S is a vital part of ferredoxins occurring in the chloroplast, it might have increased the uptake of Fe (Tisdale et al. 1995).

The maximum gross and net returns were obtained with gypsum @ 60 kg S/ha, followed by pyrites (Table 2). The minimum net return with the elemental sulphur was attributed to higher cost of input and low yield in the treatment. Identical benefit : cost ratio was observed with gypsum, pyrites and pressmud perhaps owing to approximately same net income based on their cost of cultivation and yield.

Thus 60 kg S/ha may be applied through gypsum to obtain higher yield of Indian mustard, pyrites and pressmud may also be used as an alternative source of sulphur subject to its availability in the locality.

SUMMARY

An experiment was conducted during winter season of 1998-99 and 1999-2000 to study the response of Indian mustard [*Brassica juncea* (L) Czernj. and cosson] to sources and level of sulphur. Among various sources of sulphur, gypsum was found significantly superior to elemental sulphur and pressmud

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Table 1 Effect of sources and levels of sulphur on yield attributes, yield and nutrients uptake of Indian mustard (mean data of 2 years)

Treatment source of sulphur	seed yield (tonnes/ha)	Oil yield (tonnes/ha)	Siliqueae/plant	Siliqueae length (c m)	Seeds/siliqueae	1000 seed weight(g)	Nutrient uptake (Kg/ha)				
							N	P	K	S	Fe
Sulphur source											
Element sulphur	1.625	0.635	446.07	5.76	12.31	3.92	89.93	13.58	71.63	27.78	0.96
Gypsum	1.636	0.672	452.43	5.99	12.50	4.05	95.17	14.42	74.79	29.84	0.99
Pyrite	1.632	0.663	449.07	5.93	12.47	4.01	93.20	14.02	73.84	28.31	0.99
Pressmud	1.619	0.649	442.11	5.34	12.29	3.90	88.47	13.37	71.11	27.56	0.95
SEm ±	0.002	0.002	1.24	0.06	0.08	0.03	1.61	0.19	0.57	0.66	0.01
CD (P=0.05)	0.005	0.006	3.59	0.18	0.26	0.09	4.67	0.57	1.65	1.92	0.03
Sulphur level (Kg/ha)											
0	1.378	0.528	411.75	5.55	10.83	3.62	68.12	10.19	54.73	20.21	0.63
20	1.571	0.635	436.55	5.76	12.61	3.79	87.58	13.57	70.41	26.67	0.88
40	1.754	0.720	465.56	5.97	12.67	4.05	102.54	15.47	81.23	32.75	1.14
60	1.809	0.756	475.85	6.17	13.42	4.43	108.58	16.77	85.06	33.77	1.87
SEm ±	0.002	0.002	1.24	0.06	0.08	0.03	1.61	0.19	0.57	0.66	0.01
CD (P=0.05)	0.005	0.006	3.59	0.18	0.26	0.09	4.67	0.57	1.65	1.92	0.03

Table 2 Economics of different treatments of sulphur in Indian mustard

Treatment S source and levels (Kg/ha)	Gross Income (Rs)	Cost of cultivation (Rs)	Net income (Rs)	Benefit : cost ratio
Element sulphur	0	15 806.80	9 917.22	5 889.58
	20	18 483.20	11 694.82	6 788.38
	40	20 113.75	13 472.42	6 641.33
	60	20 113.75	15 250.02	6 563.98
Gypsum	0	15 875.65	9 917.22	5 958.43
	20	18 667.60	10 046.62	8 620.98
	40	20 287.0	10 175.28	10 111.72
	60	20 964.80	10 304.30	10 660.48
Pyrite	0	15 944.65	9 917.22	6 027.43
	20	18 561.25	10 053.72	8 507.53
	40	20 229.75	10 190.22	10 039.53
	60	20 862.80	10 326.72	10 536.08
Pressmud	0	15 864.20	9 917.22	5 946.98
	20	18 437.25	10 023.47	8 413.78
	40	20 011.00	10 129.72	9 881.28
	60	20 769.40	10 235.97	10 533.43

in increasing yield and yield components. However, it was

statistically at par with pyrites. As regards the level of sulphur, 60 kg/ha was proved superior to rest of levels in increasing yield and yield components, concentration, uptake of nutrients and net economic gains. The maximum net income was obtained from gypsum treatment, followed by pyrites, pressmud and elemental sulphur.

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Effect of doses and methods of nitrogen application on growth, bulb yield and quality of 'Pusa Red' onion (*Allium cepa*)*

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Key words: Onion, *Allium cepa*, N, Growth, Bulb yield, Quality

Onion (*Allium cepa* L.) is one of the most important vegetable crops grown commercially in India and ranks first in respect of foreign exchange earner. Its acreage in India is about 0.44 million ha and production is over 5.57 million tonnes but productivity is very low (10.67 tonnes/ha) (Pandey 2000). Of the several production inputs essential for onion, the nutritional requirement plays a key role on various growth traits among which nitrogen has vital role in yield and quality enhancement (Bottcher and Kolbe 1975, Shukla and Prabhakar 1989). Application of various nutrients as foliar spray is beneficial for increasing yield and quality of onion (Singh and Tiwari 1993) and tomato (*Lycopersicon esculentum* Miller nom. cons.) (Sharma 1994). As there is no information regarding adequate method and quantity of nitrogen application for onion crop in *tarai* or foothills region, the investigation was carried out to maximize economic onion production in this area.

The present investigation was carried out at Vegetable Research Centre, Patharchatta, of the university with onion 'Pusa Red' during winter season (*rabi*) of 1995–96, 1996–97 and 1997–98. The experiment was laid out in randomized block design with 3 replications, consisting of 3 levels of nitrogen (50, 75 and 100 kg/ha) and 3 methods (basal, top dressing and foliar spray) for each level constituting 9 treatments, viz T₁, 50 kg N basal; T₂, 30 kg N basal + 2 top-dressings of 10 kg N; T₃, 20 kg N basal + 3 foliar sprays of 10 kg N; T₄, 50 kg N basal + 25 kg N top-dressing; T₅, 55 kg N basal + 2 top-dressings of 10 kg N; T₆, 50 kg N basal + 10 kg N top-dressing + 2 foliar sprays of 10 kg and 5 kg N; T₇, 60 kg N basal + 40 kg N top-dressing; T₈, 60 kg N basal + 2 top-dressings of 20 kg N; T₉, 60 kg N basal + 4 foliar sprays of 10 kg N. Regarding application of nitrogen, first top-dressing was done 25–30 days after planting, while second top-dressing was done 40 days after planting. First, second and third foliar sprays (2% urea) were done 30, 40 and 50 days after planting, respectively, in each

year. Phosphorus (single superphosphate) and potash (muriate of potash) were applied @ 80 and 60 kg/ha respectively with each nitrogen level as basal application. Planting was done at a spacing of 15 cm × 10 cm. The observations were recorded on plant height, leaves/plant, neck diameter, bulb diameter, bulb weight, bulb length, total soluble solids (TSS), specific gravity and bulb yield.

Although plant height was affected non-significantly by different treatments (Table 1), treatment T₆ exhibited plants with maximum height. Singh *et al.* (1993) reported decreasing trend in plant height at higher nitrogen levels in onion. Verma *et al.* (1996) also reported similar results in garlic (*Allium sativum* L.). Sharma (1994) reported beneficial effect of foliar spray of nitrogen in tomato. Number of leaves/plant was affected non-significantly by various treatments, though it was the maximum under treatment T₉. Application of N fertilizer as spray results in higher number of leaves/plant at all doses. Similar trends of increase in number of leaves with increasing nitrogen doses was reported by Verma *et al.* (1996) in garlic.

Thin necked bulbs have been reported to have better storage life. Thinnest neck of bulb was recorded under treatment T₂, followed by T₃. Although response of fertilizer dose was not very clear, an application of nitrogen dose as spray increased the neck thickness. Different treatments also showed significant effect on bulb diameter during all 3 years. Application of 100 kg N/ha (T₉) showed bigger bulbs while lower N dose as spray 75 kg/ha (T₆) was also at par for bulb diameter. Nitrogen as spray resulted in bigger bulbs than those which did not receive nitrogen as spray. An increase in volume of bulbs with increase in nitrogen was also reported by Singh and Battra (1972) in garlic and Singh *et al.* (1993) in onion. Treatment T₆ showed bulbs with higher weight although effect of dose and application method was not very clear, the higher nitrogen levels showed increase in bulb weight than lowest (50 kg/ha) nitrogen level. Similar findings were also reported by Verma *et al.* (1996) in garlic. Bulb length was also affected significantly with a maximum for both T₆ and T₉. Nitrogen as spray showed slight increase in bulb shape. Results are in accordance with the findings of Naik and Hosmani (2000).

* Short note

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Table 1 Effect of nitrogen application on growth, yield, quality and economics of onion (average of 3 years)

Treatment	Plant height (cm)	Leaves /plant	Neck diameter (cm)	Bulb diameter (cm)	Bulb weight (g)	Bulb length (cm)	TSS (°Brix)	Specific gravity g/cm ³	Yield (t/ha)	Cost of cultivation (Rs/ha)	Total return (Rs)	Net profit (Rs/ha)	Benefit cost ratio
T ₁	47.25	7.89	0.747	4.07	44.50	4.14	12.57	0.956	12.437	15,410	49,748.00	34,338.00	2.23
T ₂	45.95	7.96	0.641	3.99	37.70	4.10	11.55	0.980	11.920	15,610	47,680.00	32,070.00	2.05
T ₃	48.48	8.61	0.750	4.09	44.40	4.09	12.37	0.950	13.687	15,610	54,748.00	39,138.00	2.51
T ₄	49.44	8.32	0.780	4.15	49.80	4.18	11.90	0.873	16.983	15,678	67,932.00	52,254.00	3.33
T ₅	48.31	7.95	0.760	4.15	47.96	3.95	11.73	0.903	17.313	15,778	69,252.0	53,474.00	3.39
T ₆	50.60	8.37	0.810	4.18	53.97	4.22	12.50	0.953	18.237	15,878	72,948.00	57,070.00	3.59
T ₇	49.82	7.92	0.713	4.12	46.50	4.17	12.76	0.960	18.347	15,800	73,388.00	57,588.00	3.64
T ₈	49.12	8.57	0.680	4.22	48.73	4.19	13.51	0.953	17.240	15,900	68,960.00	53,060.00	3.34
T ₉	48.44	8.78	0.770	4.16	45.72	4.22	12.43	0.960	15.597	16,100	62,388.00	46,288.00	2.87
CD at 5%NS	NS	NS	NS	NS	8.24	0.161	NS	0.044	5.22	-	-	-	

NS, non significant

The TSS content was also affected non-significantly by various treatments, being highest under T₈ followed by T₇, T₁ and T₆ treatments indicating the irregularity in response which may be due to the difference in application method of total nitrogen dose. Increase in TSS with increase in nitrogen level up to 150 kg N/ha was reported by Naik and Hosmani (2000). Plants of treatment T₂ yielded bulbs with higher specific gravity while at higher fertilizer levels specific gravity showed decreasing trend. The results are not in accordance with findings of Verma *et al.* (1996), who reported a increase in specific gravity of garlic bulbs with increase in nitrogen.

Bulb yield affected significantly by various treatments with a maximum under treatment T₇, followed by T₆. Increase in bulb yield at higher nitrogen level might be attributed to increase in plant height, number of leaves, length and width of bulbs and increase in net assimilation rate resulting in higher production of photosynthates (Kato 1965). Beneficial effect of foliar spray of nitrogen in yield enhancement was reported by Sharma (1994) in tomato. Maximum benefit : cost ratio was obtained under T₇, followed by T₆ treatment. The results showed that at lower N levels the spraying of N appears beneficial for enhancing yield but at higher N levels (100 kg/ha) spraying did not prove beneficial, may be due to the fact that spraying has extended to later dates of plant growth or even beyond start of bulb development resulting in poor bulb development because bulb formation occurs at the cost of plant growth and vegetative growth is required to be substantial before bulbing starts (Mann 1952). Thus the maximum benefit from lower doses of nitrogenous fertilizer (75 kg/ha) may be obtained by including foliar spray.

SUMMARY

Three nitrogen levels (50, 75, 100 kg/ha) and its 3 methods of application (basal, top-dressing and foliar spray) affected

bulb yield significantly in onion (*Allium cepa* L.). Application of 75 kg N/ha gave the better yield than 100 kg N/ha. Incorporation of foliar spray proved better than non-spray treatment for growth and yield traits. Considering the benefit : cost ratio 100 kg N/ha as 60 basal and 40 as single top-dressing was at par with 75 kg N/ha as 50 kg N/ha basal + 10 kg N as top-dressing + 10 Kg N foliar spray + 5 kg N foliar sprays.

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Sulphur status and response of onion *Allium cepa* to applied sulphur in soils of Jammu districts

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Key words : Total S, Organic S, Sulphate S, Non-sulphate S, Soil great groups, Onion, *Allium cepa*, Bulb yield

Forty six soil samples each from surface (0–22.5 cm) and subsurface (22.5–45.0) were collected from 4 Great soil groups of Jammu districts, viz, Haplaquent, Ustifluent, Ustorthent and Eutrochrepts. The samples were analysed for pH, organic carbon, CaCO₃, sand silt and clay (%) by standard methods (Jackson 1973). Total S was estimated by the method of Tabatabai (1952) and organic S by digesting with H₂O₂ (Evans and Rost 1945) and subsequently extracted with NaCl solution (Williams and Steinberg 1959). The sulphate S was extracted with 0.15% CaCl₂ solution (Williams and Steinberg 1959) and determined by turbidimetric method (Chesnin and Yien 1951). The values of non-sulphate S were worked out by subtracting the sum of the sulphate and organic S forms from total S. The simple correlation coefficients were worked out to see the relationship of various soil properties with different forms of sulphur.

Besides, 1 pot culture experiment on onion crop was conducted during 1997 at Regional Research Station of the University in 2 types of soils (light and heavy textured) to study the response of onion to applied S. The initial values of pH, organic carbon, available S, and per cent sand and silt + clay in light and heavy textured soils were 7.0 and 6.8, 0.8 and 0.44%, 6.2 and 8.5 mg S/kg of soil, 67 and 33, 35 and 65% respectively. The experiment was laid out in completely randomized design with 5 levels of S (0, 15, 30, 45 and 60 kg S/ha) through gypsum in 4 replicates. The 28-day-old onion seedlings ('Pusa Red') were transplanted and dose of N, P and K @ 100, 50 and 50 kg/ha were applied through urea, diammonium phosphate and muriate of potash respectively to all the pots. Five kg soil was used and 4 seedlings were grown per pots. The crop was irrigated as per need with deionized water. The data on various growth parameters, yield attributes and bulb yield were recorded. The bulb samples were also analysed for S content.

The highest mean value of total S was found in Haplaquent, followed by Ustifluent, Ustorthent and

Eutrochrept groups (Table 2). Its contents in general, decreased with depth in all the Great groups. The results confirm the findings of Tripathi and Singh (1992). This may be due to the fact that most of the S is primarily in organic form which also decreased with depth in this investigation. Total S content showed significant correlation with organic carbon ($r=0.089^{**}$, $r=0.92^{**}$) and clay ($r=0.43^{**}$, $r=0.31^{*}$) in both surface and subsurface soils respectively. These observations are in line with those reported by Evans and Rost (1945) and Ganeshmurthy et al. (1995).

The mean value of organic S was highest in Haplaquent, followed by Ustifluent, Ustorthent, while the lowest in Eutrochrept. This form of S constituted on an average about 51.7% of total S in all the Great groups. Its content also declined in subsurface soils and followed the trend of organic matter. These findings support the observation of Dharaknath et al. (1995). It also showed significant correlation with organic carbon ($r=0.83^{**}$, $r=0.83^{**}$) and clay ($r=0.43^{*}$, $r=0.33^{*}$) in surface and subsurface soils respectively.

The mean value of sulphate S was also highest in great group Haplaquent, followed by Ustifluent, Ustorthent, whereas its content was lowest in Eutrochrept great group. This fraction constituted about 7.36 and 6.34 % of total S in Haplaquent and Eutrochrept Great groups respectively in surface soils. The higher content of this form of S in surface soils is possible due to greater plant and microbial activities resulting in the subsequent accumulation of organic matter (Tripathi and Singh 1992). Sulphate S had significant correlation with organic carbon ($r=0.075^{**}$, $r=0.74^{*}$) and clay ($r=0.30^{*}$, $r=0.029^{*}$) in surface and subsurface soil respectively, while no relationship was observed with sand and silt.

The mean value of soil of non-sulphate S form was highest in great group Haplaquent followed in order by Ustifluent and Ustorthents, while Great group Eutrochrept showed the lowest value in surface soil. Non-sulphate S constituted 41.38 and 43.0 % of total S under Haplaquent and Eutrochrept Great groups respectively. Its content increased with depth in all the Great groups except Eutrochrept. Such distribution trend

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Table 1 Soil characteristics of Great groups of Jammu district

Soil Great group	pH	Organic carbon (%)	CaCO ₃ (%)	Clay (%)	silt (%)	Sand (%)
Ustifluent						
A	6.2–7.3 (6.8)	0.34–0.98 (0.64)	0.33–0.80 (0.55)	16.9–42.2 (30.51)	18.9–42.2 (30.75)	18.0–62.1 (37.64)
B	6.0–7.4 (6.7)	0.28–0.85 (0.49)	0.32–0.89 (0.52)	16.8–42.3 (32.71)	16.1–44.1 (32.54)	20.1–61.6 (33.67)
Haplaquent						
A	6.9–7.9 (7.0)	0.32–1.10 (0.72)	0.34–0.68 (0.55)	10.4–42.2 (26.37)	15.9–47.9 (29.92)	21.1–67.9 (42.48)
B	6.1–7.8 (7.2)	0.24–0.82 (0.56)	0.31–0.85 (0.59)	12.8–39.1 (29.7)	12.8–48.1 (28.65)	18.8–69.0 (39.91)
Ustorthent						
A	5.8–8.1 (6.9)	0.30–0.87 (0.62)	0.33–0.81 (0.58)	15.0–45.2 (27.96)	12.2–38.1 (25.05)	31.8–61.0 (45.91)
B	6.1–7.8 (6.8)	0.24–0.78 (0.47)	0.32–0.89 (0.54)	16.1–45.2 (29.3)	12.0–32.3 (23.74)	34.6–57.1 (45.44)
Eutrochrept						
A	6.3–7.9 (7.2)	0.28–0.72 (0.54)	0.43–0.80 (0.57)	16.5–37.1 (28.82)	14.8–46.1 (33.7)	19.0–59.7 (36.34)
B	6.3–8.1 (7.3)	0.22–0.51 (0.38)	0.31–0.72 (0.55)	15.9–35.1 (26.36)	16.1–49.7 (35.26)	17.0–61.9 (37.58)

Figures in parentheses indicate mean values

A, Surface soil (0–22.5 cm); B, subsurface (22.5–45cm)

Table 2 Various forms of sulphur (mg, S/kg soil) in the soils of Jammu district

Soil Great group	Total S	Organic S	Sulphate S	Non-sulphate S
Ustifluent				
A	98.7–178.5 (124)	48.0–110.0 (63.4)	4.4–14.9 (8.5)	39.2–75.5 (51.9)
B	81.8–149.0 (102.2)	30.5–66.0 (41.7)	2.9–10.7 (6.3)	40.1–79.3 (54.1)
Haplaquent				
A	109–189.7 (142.0)	57.5–97.8 (73.3)	5.4–13.9 (10.6)	46.1–78.0 (58.1)
B	89.7–165.6 (117.0)	34.5–67.5 (47.7)	4.5–11.7 (7.5)	50.7–86.4 (62.00)
Ustorthent				
A	86.8–178.0 (113.1)	36.8–87.0 (58.8)	3.2–12.8 (8.4)	37.6–62.2 (46.0)
B	75.0–137.0 (94.6)	26.0–68.0 (39.2)	2.9–10.4 (5.9)	39.0–59.8 (49.5)
Eutrochrept				
A	67.0–116.8 (95.1)	34.0–59.8 (47.5)	3.5–12.0 (7.3)	29.5–45.7 (40.7)
B	57.8–97.0 (80.8)	28.8–46.0 (38.1)	2.9–8.4 (5.4)	26.2–44.2 (38.41)

Figures in parentheses indicate mean values

A, Surface soil (0–22.5 cm); B, subsurface (22.5–45cm)

may be attributed to the variation in S compounds in these soils. Moreover, this form of S is mostly made up of insoluble S compounds which remain occluded in or adsorbed on CaCO₃ of the soil (Evans and Rost 1945). This fraction did not show relationship with pH organic carbon, sand silt and clay both in surface and subsurface soils. These findings confirm the observation made by Dharakanath *et al.* (1995). Considering 10 mg S/kg soil as the critical limit of available S in the soil Great groups, viz Ustifluent, Ustorthent and Eutrochrept, were found deficient in available S indicating the need of sulphur application in these soils.

The data pertaining to plant height, bulb diameter and bulb yield increased significantly with each successive increase in dose of S up to 30 kg/ha in heavy and 45 kg/ha in light-textured soil (Table 3). The response of onion to higher dose of S in light-textured soil may be due to low initial S content (6.2 mg, S/kg soil). The increase in bulb yield at S₁₅ and S₃₀ were 8.44 and 14.66% over control in heavy-textured soil while in light textured soil the values were 8.30, 15.20 and 20.27% at S₁₅, S₃₀ and S₄₅ respectively. The increase in bulb yield may be attributed to increase in growth and yield attributes (Jana and Kabir 1990, Singh *et al.* 1995). Total S content and its uptake also increased significantly with increase in levels of sulphur and was found to be highest at S₃₀ and S₄₅ under heavy and light-textured soils respectively. Moreover, S uptake followed the pattern of bulb yield in both types of soils. The increase in these two parameters may be due to

Table 3 Effect of different levels of S on growth attributes and bulb yield of onion

Treatments	Plant height (cm)		Bulb diameter (cm)		Bulb yield (kg/pot)		S-content (%)		S-uptake (mg S/pot)	
	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS
S ₀	35.5	28.5	4.0	3.88	0.217	0.225	0.338	0.391	842.4	880.0
S ₁₅	39.5	33.5	4.7	4.70	0.235	0.244	0.432	0.479	959.5	1048.0
S ₃₀	42.0	37.0	5.1	5.20	0.250	0.258	0.451	0.533	1057.7	1180.0
S ₄₅	44.0	38.0	5.4	5.10	0.261	0.254	0.465	0.508	1146.2	1126.0
S ₆₀	43.0	36.5	5.3	4.80	0.257	0.249	0.463	0.493	1125.3	1065.0
CD (P=0.05)	1.98	3.42	0.32	0.52	0.0106	0.0125	0.013	0.052	86.8	17.0

LS and HS stands for light- and heavy-textured soils respectively

better availability of S to the crop (Jana and Kabir 1990, Singh *et al.* 1995) had also obtained similar results.

SUMMARY

The results of studies on sulphur status and its response in onion (*Allium cepa* L.) crop have revealed higher content of total S, organic S and sulphate S in Haplaquent Great group and minium in Eutrochrept. Except non-sulphate S, the content of other forms decreased with depth. The results of pot culture studies on this crop have showed higher response to sulphur in light-textured soil than heavy-textured soils.

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Analysis of chemical composition influencing shelf-life of tomato (*Lycopersicon esculentum*)

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The tomato (*Lycopersicon esculentum* Miller nom. cons.) has become one of nature's most ubiquitous crops, which provides an array of fresh as well as processed products. Stored tomatoes are bound to differ in taste from a plant-ripened fresh tomato. Any perishable produce must have a reasonable shelf-life to move through the commercial distribution system. The time gap between the harvesting and consumption plays a vital role in terms of economy, particularly in India where the middleman regulates the market price. Besides, there are situations like glut in the marketing chain when fruits with high shelf-life prove to be a better option. The purpose of this study was to characterize some chemical factors influencing shelf-life variation of tomato in different genotypes.

The field experiment was conducted for during 1996–99 at the research farm of the Institute, Varanasi. The soil was sandy loam, Typic Ustochrept. The soil had pH 7.2, organic carbon 0.42%, CEC 6.9 cmol (p⁺)/kg, AEC 1.1 cmol (e⁻)/kg, EC 0.38 dS/m, available N, P and K 258, 22 and 185 kg/ha respectively. The experimental materials comprised 8 tomato hybrids, ('BSS 99', 'ARTH 128', 'ARTH 16', 'ARTH 4', 'SC 2', 'SC 28', 'Himlata' and 'Gotya'). Uniform bold 4-week-old seedlings were transplanted in the main field. The experimental layout adopted was randomized block design with 3 replications. Plot size was kept 3 m × 3 m and distance from row to row and plant to plant was maintained at 90 cm and 50 cm respectively. Full P, K and one-third of N were applied basal. The remaining N was top-dressed 30 and 45 days after transplanting. Time-to-time irrigation and other standard intercultural operations were practised for the maintenance of the crop. All plants were staked as per crop growth. Tomato fruits were harvested at breaker stage from each subplot and only marketable fruits only weighed for yield determination.

Laboratory experiment was conducted for 2 years for determination of spoilage (%) and associated chemical

parameters influencing variation of shelf-life. Ten randomly selected fruits from each replication for each hybrid were kept open in a single layer on the cement floor of the laboratory under ambient conditions and were inspected regularly. The mean minimum and maximum temperature during experimentation varied between 15 and 25°C and relative humidity between 55 and 65%. Shelf-life and spoilage (%) were measured based on visual analysis (Behboudian and Tod 1995) of texture, firmness, surface moulds, water soaking, presence of necrosis, development of undesirable patch, ie lesion, and any obvious signs of deterioration appear on the harvested fruits (Lange and Cameron 1994). The tomato fruits were blended, filtered through a muslin cloth and used for measurement of pH, electrical conductivity (model-1260, Orion) and acid equivalence (AOAC 1985).

The spoilage (%) at 14, 21 and 28 days after harvest was calculated based on the visual observation of 10 fruits of each hybrid. The acid equivalence, ie total acidity of tomato juice was calculated as (milli equivalent of total acidity/litre tomato juice, meq/litre = ml NaOH consumed × normality × 1 000/v), wherein v = volume of tomato juice titrated. The TSS concentration of the juice at breaker stage and 21 days after harvest was measured with a hand refractometer. Nitrogen was analysed by Kjeldahl digestion and colorimetry; P by sulphuric acid digestion and colorimetry; K, Mg and Ca by nitric acid digestion followed by flame photometry and versene titration (Novozamsky *et al.* 1983). The data were pooled and statistical analysis was carried out.

A significant variation for yield and quality parameters was recorded among the 8 hybrids. The average shelf-life of tomato fruits ranged from 12 to 25 days among the hybrids. The lowest average shelf-life was noted in 'ARTH 4' (12 days) and highest (25 days) in 'BSS 99'. Highest pericarp thickness was noted in 'BSS 99' (6.5 mm), followed by 'SC 2' (6.2 mm) and lowest in 'ARTH 4' (2.6 mm). Total soluble solid ranged from 3.9% in 'Gotya' to 5.2% in 'Himlata'. Highest yield (57.6 tonnes/ha) was recorded in 'BSS 99', followed by 'SC 28' (51.1 tonnes/ha) and the lowest yield (34.8 tonnes/ha) in 'ARTH 4' (Table 1).

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Table 1 Variation in yield and qualitative parameters of tomato hybrids

	'BSS 99'	'ARTH 128'	'Gotya'	'ARTH 16'	'SC 2'	'SC 28'	'Himlata'	'ARTH 4'	CD (p=0.05)
Yield (tonnes/ha)	57.6	43.1	40.8	47.7	49.2	51.2	50.1	34.8	2.78
Pericarp thickness (cm ²)	6.5	5.6	5.7	5.9	6.2	6.0	5.2	2.6	0.03
Shelf-life (days)	25.4	20.0	23.1	20.6	23.0	18.2	23.7	12.0	0.64
Spoilage% at 14 DAH	0.0	1.9	0.0	0.0	0.0	0.0	0.0	40.4	
Spoilage% at 21 DAH	0.0	17.5	21.3	3.8	3.8	31.3	7.5	91.25	
Spoilage% at 28 DAH	16.3	80.0	75.0	42.5	42.5	90.0	46.3	100	
TSS (%) at BS	5.1	4.3	3.9	4.1	4.1	4.2	5.2	4.4	0.12
TSS (%) at 21 DAH	5.6	4.9	4.4	4.8	4.4	4.8	5.3	5.1	0.15
pH at BS	4.26	4.18	4.15	3.9	3.98	3.87	3.96	3.77	0.03
pH at 21 DAH	4.38	4.08	3.94	4.07	3.9	3.98	4.13	3.86	0.04
EC (mS/m) at BS	129.6	118.9	112.9	130	122.5	112.5	115.1	121.1	
EC (mS/m) at 21 DAH	105.7	106.3	102.5	103.1	106.1	107.1	106.9	107.1	

BS, Breaker stage; DAH, days after harvest

At 14 days after harvest 40% spoilage was recorded in 'ARTH 4', while no spoilage was recorded in other hybrids. The highest spoilage at 21 days after harvest was recorded in 'ARTH 4' (91%), followed by 'SC 28' (31%), 'Gotya' (21.3%) and 'ARTH 128' (17.5%). Minimum spoilage was recorded in 'BSS 99' (16%) (Table 1). 'BSS 99' and 'ARTH 4' were observed as good and poor keepers respectively; therefore, composition analysis was carried out in these 2 hybrids only. A potentiometric titration of tomato juice in 'BSS 99' and 'ARTH 4' conducted with 0.01 N NaOH solution showed that hybrid 'BSS 99' had a lower acid equivalence 22 meq/litre and higher shelf-life (25 days) compared with the 'ARTH 4' with higher acid equivalence 31.5 meq/litre and lower shelf-life (12 days).

The changes in pH and EC of the tomato juice at breaker stage and 21 days after storage showed that at both the stages the highest acidity of tomato juice was observed in hybrid 'ARTH 4' (pH 3.8–3.9) and lowest acidity in 'BSS 99' (pH 4.3–4.4) (Table 1). The change of electrical conductivity of the juice during storage in 'BSS 99' (106–130 mS/m) was higher than that of 'ARTH 4' (107–121 mS/m). The relatively higher concentration of Ca (1.2 %), Mg (0.5 %) and K (2.6 %) in tomato sap of 'BSS 99' compared with the 'ARTH 4' (0.9 %, 0.3 % and 2.4 % respectively) may be the cause of higher electrical conductivity of the juice in 'BSS 99'. The higher concentration of anion forming macronutrient P (0.26 %) and S (0.12 %) in tomato fruits of 'ARTH 4' compared with 0.23 % and 0.1 % P and S respectively in 'BSS 99' may be the cause of higher acidity of the juice in 'ARTH 4'. The results indicated that hybrids having high acidity loose firmness earlier and showed a lower shelf-life. On the contrary, 'BSS 99' showed a lower acid equivalence and less acidic juice with more shelf-life. An increased concentration of total soluble solids under storage was noted in all the 8 hybrids (Table 1), which was probably due to hydrolysis of polysaccharides and increased concentration of the juice as a result of dehydration (Jain and Chauhan 1995). Except 'ARTH 128', 'Gotya' and 'SC 2', the pH of the tomato juice increased during storage in all the

tested hybrids. The EC of the tomato juice decreased irrespective of hybrids under storage. This may be due to ionic substitution of H⁺ by Na⁺, K⁺, Ca²⁺ and Mg²⁺ ions in the active site of different acids present in the tomato juice. However, the experimental resolution is inadequate to explain the nature and cause of this observation.

The Ca and N play important roles in post-harvest fruit quality aspects of apple (Fallahi *et al.* 1997) and tomato (Caines and Shennan 1999). Calcium serves as an intermolecular binding agent that stabilizes pectin-protein complexes of the middle lamella (Dey and Brinson 1984) and induces rigidification of cell membrane surface of apple fruit tissue. Higher Ca (1.2 %) and N (1.5 %) concentration in tomato fruits of 'BSS 99' probably induces high degree of cell-to-cell adhesion in membrane tissue to retain firmness for prolonged time compared to tomato fruits of 'ARTH 4' with 0.9 % Ca and 1.3 % N. The ratio of phloem mobile element, K to phloem immobile element, Ca (Behboudian and Tod 1995) was higher (K:Ca = 30:1) in hybrid 'ARTH 4' compared with the 'BSS 99' (22:1), signifying that the flow of sap containing nutrients through the phloem into the tomato fruit was slower in 'BSS 99'. The higher K:Ca ratio in hybrid 'ARTH 4' induces early attainment of breaker stage (84.4±0.3 days) compared with the 94.1±1.4 days in 'BSS 99'.

A significant positive correlation ($r^2=0.81$) was observed between pericarp thickness and yield of tomato as well as pericarp thickness and shelf-life of tomato ($r^2=0.80$). The pH of the tomato juice was also positively correlated ($r^2=0.68$) with the shelf-life. The spoilage (%) of stored tomato fruit was negatively correlated ($r^2=-0.95$) with the pericarp thickness.

SUMMARY

A field experiment and laboratory study was conducted during 1996–99 on 8 hybrids of tomato (*Lycopersicon esculentum* Mill. nom. cons.) to characterize factors influencing the variation of shelf-life under natural condition. The lowest shelf-life was recorded in 'ARTH 4' (12 days) and the highest

in 'BSS 99' (25 days). At the end of shelf-life 40% spoilage was recorded in 'ARTH 4', whereas only 16% in 'BSS 99'. Low acid equivalence (22 meq/litre), higher concentration of N, Ca, Mg, K and lower concentration of P and S were recorded in tomato fruits of 'BSS 99' compared with 'ARTH 4'. More acidic juice (pH 3.8) and less total soluble solid (4.4 %) were noted in 'ARTH 4' than 'BSS 99'. Variations in total soluble solid, pH and electrical conductivity of tomato fruits at breaker stage and 21 days after harvest were observed among the hybrids. A positive correlation with pericarp thickness, initial pH of juice and shelf-life was noted in tomato fruits. Low titrable acidity and higher concentration of Ca in tomato fruits induced better keeping quality.

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Weed population dynamics and wheat (*Triticum aestivum*) productivity with eucalyptus (*Eucalyptus tereticornis*) under shallow water-table conditions*

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The general opinion at global level is that chemical-based energy-intensive modern agriculture is threatening the natural resources through contamination of environment like soil and water and ecological degradation. The diversified agroforestry systems are considered to be most vital tool for conservation and protection of the environment. The farming techniques need to be changed for maximum production and optimal utilization of natural resources. Agroforestry, a new land-use system, where field crops and trees are grown on the same piece of land seems to be potential alternative. Research studies conducted under All India Co-ordinated Research Project on Agroforestry at Pantnagar have consistently shown that germination and ear emergence are fast in the intercrop wheat (*Triticum aestivum* L. emend. Fiori and Paol) in comparison to monocrop wheat. It has widely been recognized that intercropping with tree increases the productivity as well as income compared to sole cropping without trees under shallow water-table conditions (Singh et al. 1998, Saini and Sharma 2000). Therefore this field study was undertaken to test the hypothesis that modified radiation climate under tree canopies has the potential to provide more favourable microclimate to intercrop wheat which in turn also helps in weed control.

The present investigation was carried out at the Horticultural Research Center, Pantnagar, during the winter (rabi) season of 1998–99 under the 10-year-old tree canopies of *Eucalyptus tereticornis* Smith. The experiment was laid down in a Nelder design (Nelder 1962) with zero degree corresponding to north direction. Treatments consisted of 15 tree row orientation from 0–36° with an angle of 24° between 2 adjacent tree rows in anticlockwise direction and a sole crop without trees. All these treatments were replicated 3 times in randomized block design. Area/tree was 30 m² thus providing planting density of 333 trees/ha with 10 trees in each row. Tree height at different tree row orientations varied from 14.73 m at 240–264° to 17.77 m at 72–96°, whereas tree diameter (at

breast height) ranged between 19.83 cm at 240–264° and 23.30 cm at 144–168°. Average pruning of 60% of total tree height was maintained before wheat sowing. Wheat ('Raj 3077') was sown on November 28 1998 at the seed rate of 100 kg/ha in rows 18 cm apart. Recommended package of practices of water and nutrients of sole crop were adopted to grow the intercrop. In each plot, 1 site was selected between the sixth trees of adjacent rows. Weed density and their dry weight at 2 stages of crop growth were recorded from 2 randomly selected quadrates (0.25 m²) in each treatment. The soil of the experimental field was silty clay loam in texture, high in organic carbon, medium in available phosphorus and nitrogen and high in available potassium and neutral in pH. Net radiation readings were taken with net radiometers at 75 and 117 days after sowing (DAS). The observations on net radiation were recorded with portable battery operated digital microvoltmeters.

Wheat plant height and tillers/m differed significantly. Plant height was significantly lower at 288–312°, 312–336° and 336–360° tree rows orientations compared with the control (without tree); however, it was at par with rest of the tree row orientations. Average plant height was maximum (94.3 cm) at 144–168° and minimum (70.8 cm) at 312–336° tree rows orientations. Similarly, tillers/m were significantly lower at orientations of 0–24°, 24–48°, 48–72° and 312–336° than the control, but at par with the remaining tree row orientations. Average tillers/m were maximum (87.1) at 120–144° and minimum (46.8) at 0–24° tree rows orientations. Water table fluctuation during wheat-growing period showed that average water table-depth was minimum (45 cm) at the time of sowing and maximum (105 cm) at maturity. There was continuous decrease in water-table depth during the wheat-growing season.

The radiation environment over intercrop wheat in an agroforestry system is highly dynamic. In addition to variations in cloudiness and change in the sun angle during the day, tree canopy shading and wind movement of tree canopy also produce frequent fluctuations. Diurnal net radiation (R_n) were recorded in all the treatments; however the

Short note

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same was recorded at tree row orientation of 168-192° (highest grain yield and maximum weed control efficiency) and in the control only (Fig. 1). At 75 DAS, net radiation ranged from 20 W/m² at 1700 hr to 420 W/m² at 1200 hr in agroforestry treatment and from 36 W/m² and 470 W/m² in the control treatment during the same time. At 117 days after sowing, maximum R_N was recorded at 1300 hr (566 W/m²) and minimum R_N was observed at 1700 hr (68 W/m²) in agroforestry

treatment and these values were 586 W/m² and 82 W/m² at 1200 and 1700 hr respectively in the control treatment. The average daily R_N on these 2 days was equal (69%). Whenever the sunrays pass through tree canopy, R_N decreased depending on sun angle and tree canopy length. However, when solar radiation is not intercepted by tree canopy and reaches over intercrop wheat as sunflecks, R_N equal to control treatment can be observed (Fig. 1).

Experimental field was infested with *Phalaris minor* Retz., *Chenopodium album* L., *Melilotus indica* All.; syn *M. parviflora* Desf.; *Melilotus alba* Medikus, *Fumaria parviflora* Lam., *Anagallis arvensis* L., *Lathyrus aphaca* L., *Spergulla arvensis* L., *Rumex acetosella* L., *Avena ludoviciana* L. and *Medicago hispida* Gaertn.; syn *M. denticulata* Willd. The dominating weed throughout the cropping season was *Phalaris minor*. The density and dry-matter accumulation by the weeds recorded at 60 and 90 days after sowing was significantly reduced in all the tree orientation treatments compared with that of sole crop without trees. Maximum weed control efficiency (Table 1) with minimum competition as recorded at the tree orientations of 168-192° was mainly due to early germination, fast growth and profuse tillering of wheat causing less emergence and poor growth of weeds. Although, *Eucalyptus* is an evergreen tree species, it provided more favourable microclimate with two-thirds pruning through 69% R_N over and within the intercrop to facilitate early crop growth which along with tree canopies provided more shades for suppression of weeds. Although the reduction in R_N at the same hours of day was different (Fig. 1) equal availability of R_N (69%) on both the observation dates indicates that with

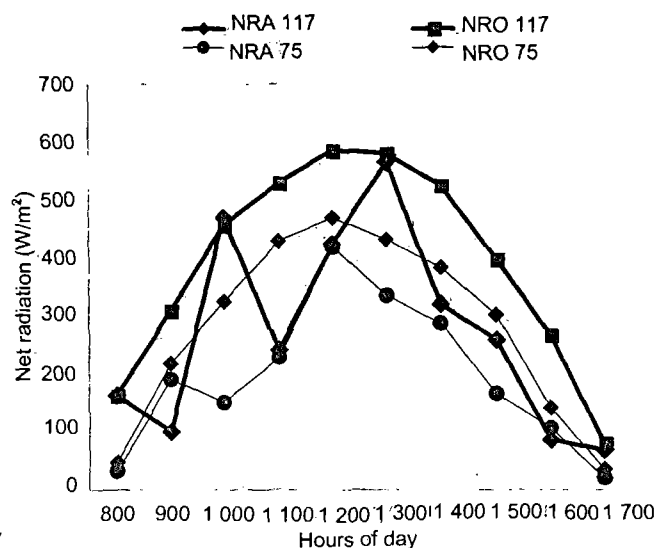


Fig 1 Diurnal patterns of net radiation at 168-192° orientation (NRA) and in control (NRO) at 75 and 117 days after sowing.

Table 1 Weed density, dry-matter accumulation, weed-control efficiency and grain and straw yield as influenced by different tree rows orientations in *Eucalyptus tereticornis*

Treatment (tree rows orientations)	Weeds/m ²		Weed dry matter(g/m ²)		Weed-control efficiency (%)		Grain yield (tonnes/ha)	Straw yield (tonnes/ha)
	60	90	60	90	60	90		
0-24°	2.33 (223)*	2.30 (204)*	0.88 (7.56)*	1.44 (30.76)*	84	54	2.185	3.820
24-48°	2.27 (185)	2.22 (180)	0.83 (5.85)	1.39 (26.39)	88	61	2.989	4.990
48-72°	2.26 (183)	2.17 (167)	0.83 (5.84)	1.28 (18.19)	88	73	2.827	4.950
72-96°	2.24 (177)	2.11 (132)	0.76 (5.25)	1.21 (15.85)	89	77	2.814	4.920
96-120°	2.22 (169)	1.99 (112)	0.74 (5.08)	1.21 (15.44)	89	77	3.000	5.250
120-144°	2.21 (163)	2.01 (113)	0.75 (4.75)	1.19 (14.84)	90	78	3.012	5.270
144-168°	2.03 (113)	1.87 (75)	0.69 (4.00)	1.12 (12.43)	92	82	3.753	6.570
168-192°	1.96 (96)	1.62 (41)	0.66 (3.85)	1.09 (11.49)	92	83	4.032	7.060
192-216°	2.12 (133)	1.93 (84)	1.12 (12.57)	1.18 (14.69)	74	78	3.643	6.370
216-240°	2.14 (148)	1.93 (84)	1.07 (13.49)	1.20 (15.12)	72	78	3.025	5.290
240-264°	2.19 (155)	1.94 (92)	1.14 (18.08)	1.28 (20.05)	63	70	3.150	5.040
264-288°	2.24 (171)	2.21 (160)	1.26 (23.57)	1.39 (24.40)	51	64	3.037	4.860
288-312°	2.23 (179)	2.19 (159)	1.41 (29.17)	1.53 (34.80)	40	48	2.679	4.290
312-336°	2.29 (197)	2.18 (158)	1.55 (37.49)	1.58 (40.80)	22	39	2.222	3.550
336-360°	2.33 (215)	2.26 (187)	1.62 (41.36)	1.74 (54.32)	14	20	2.173	3.480
Control	2.46 (291)	2.22 (180)	1.69 (48.35)	1.83 (67.56)	0	0	3.807	6.660
CD (P=0.05)	0.20	0.26	0.37	0.25			0.402	1.064

* Original data given in parentheses were subjected to log (x+1) transformation

evergreen tree like *Eucalyptus* about 31% decrease in R_n is beneficial for optimizing the microclimate over wheat crop.

Highest grain and straw yields of wheat were also recorded at 168–192° tree orientation compared with sole crop (Table 1). This was probably due to vigorous growth of weeds in sole crop, as they were not controlled either manually or chemically, whereas under tree canopies weeds were automatically controlled because of unfavourable microclimate for weeds at 168–192° tree orientation. However, a marked reduction in the grain and straw yields compared to sole crop was noted with increased shade duration at the tree orientation of 0–24°, 312–336° and 336–360° (Table 1). Green leaves of tree species absorb up to 90% of photosynthetically active radiation (Zavitkovski 1982). Therefore the decrease in grain as well as straw yield with excessive shade at different tree orientations might be due to decrease in photosynthetic activity of intercrop wheat due to poor quality of light under the evergreen tree canopies of *Eucalyptus*. Similar observation were also recorded by Hooda *et al.* (1998) and Kumar *et al.* (2000) with various wheat varieties in *Eucalyptus* and poplar plantations. Broad-leaved as well as grassy weeds can effectively be managed under the modified microclimate of 168–192° tree orientation. For higher production and optimal utilization of various resources the intercrop wheat may successfully be grown under shallow water-table conditions.

SUMMARY

A field experiment to identify the prospectus of growing wheat (*Triticum aestivum* L. emend Fiori and Paol) under *Eucalyptus tereticornis* Smith planted in Nelder design to produce more grains and for effective management of weeds was conducted during winter season of 1998–99 at Pantnagar. The average reduction of 5.6% in grain yield was recorded in sole crop without trees compared with the intercrop grown at the tree orientation of 168–192° in which the maximum weed-control efficiency and highest grain yield of intercrop wheat

was observed under 10-year-old *Eucalyptus* trees. *Phalaris minor* dominated over all other weeds throughout cropping season. Density and dry-matter accumulation by weeds as recorded at 60 and 90 days after sowing was significantly reduced in all the tree orientation treatments compared with that of sole crop. Broad-leaved as well as grassy weeds can effectively be managed under the modified microclimate of 168–192° tree orientation. For higher production and optimal utilization of various resources the intercrop wheat may successfully be grown under shallow water-table conditions.

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Performance of pasture grasses and legumes in arable lands*

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Growing of cereals and legumes in combination is an established cropping system followed under rainfed conditions throughout the country, as it has many advantages. In addition to higher monetary benefits, the combination is known to improve soil fertility (Niranjan *et al.* 1995). This practice could be followed in fodder crops also. Feeding a mixture of legume and cereal fodder is more desirable in view of better palatability and nutrition, as it provides higher crude protein (Subramanian *et al.* 1990). Rai and Kanodia (1982), Rai (1985) and Singh *et al.* (1988) reported beneficial effect of grass–legume mixture over pure stand. Grass–legume mixture at 3:1 ratio enhances the nutritive value of the mixture compared with grass alone (Vijendra Das 1988). Further, Channakeshava *et al.* (1993) reported higher biomass yield in anjan (*Cenchrus ciliaris* L.) + *Stylosanthes* combination. Many a times, drylands in red soil regions do not support a successful field crop due to erratic rainfall. Besides, there is a need to convert some drylands to pasture lands as there is fodder scarcity throughout the country. Therefore it is appropriate to evolve a suitable pasture for such red soil areas, as they provide some quantity of fodder even with erratic rainfall and support livestock.

A field experiment was conducted at Zonal Agricultural Research Station, Konehalli, Tiptur, Karnataka, from 1997 to 2000 but yields were obtained from 1998 onwards under rainfed conditions to identify a suitable grass–legume mixture for arable lands. The soil was red sandy with pH 6.8, organic carbon 0.7 %, available P 13.2 kg/ha and available K 249 kg/ha. The annual rainfall received was 805.8 mm, 888.9 mm and 959.9 mm in 62, 52 and 52 rainy days during 1998, 1999 and 2000 respectively. The gross and net plot sizes were 5.4 m × 3.0 m and 3.6 m × 2.4 m respectively. The experiment was laid out in randomized block design with 3 replications. The experiment involved 11 treatments, comprising pure crop of 3 pasture grasses, viz anjan, dhaman (*Cenchrus setigerus* Vahl) and guinea (*Panicum maximum* Jacq.) and 2 pasture legumes [*Stylosanthes hamata* (L.) Taubert and *Stylosanthes scabra* J. Vogel] and their combinations. The pasture grasses and

legumes were planted at 3:1 ratio with 45 cm row spacing. All the grass species were planted using 2 rooted slips/hill on 11 September 1997 and the legumes were sown on the same day in lines using seeds (8 kg/ha) at 45 cm row spacing. An intra-row spacing of 30 cm was provided for grasses. A basal dose of 20 kg N and 30 kg P/ha was given at the time of planting and also each year after receipt of rains. Nitrogen was top-dressed @ 10 kg N/ha, 35 days after planting in the first year and after each cut in all the years to the grass alone both in pure and in mixture stands. The inter-cultivation and weeding operations were carried out after each cut. The pasture was cut at 50% flowering stage of grass component in the mixture. The number of cuts were 3, 2 and 2 in 1998, 1999 and 2000 respectively and pooled data of 3 years were utilized. The data were statistically analysed using the Fisher's method and the results are discussed at 5% significance level (Wahua 1999).

The mean yield (mean of 3 years) of grasses and legumes were utilized to estimate land-equivalent ratio and grass-equivalent yield. The price of forage prevalent during 2000 were considered.

The green fodder yield of grasses in the mixture did not decrease significantly due to intercropping with legumes, viz *S. scabra* or *S. hamata* compared with their pure stands (Table 1). All the grass–legume combinations gave green fodder yield at par with their respective pure crop yield of anjan, guinea or dhaman grass. Neither *S. scabra* nor *S. hamata* had any negative impact on the performance of all the 3 pasture grasses. The plant height of pasture grasses did not differ significantly. The green fodder yield of pasture legumes decreased significantly due to intercropping with different pasture grasses compared with pure crop of pasture legume, which might be due to tall growth of grasses has smothered the growth of legumes. The pure crop of *S. hamata* (8.23 tonnes/ha) was significantly higher than *S. scabra* (4.87 tonnes/ha) and both as pure crops gave significantly higher green fodder yield than their respective intercroppings in association with any pasture grass. The cumulative green fodder yield of grass + legume mixture varied significantly due to intercropping (Table 1). All the intercropping systems and the pure crop of anjan and dhaman grasses recorded significantly higher cumulative green fodder yield (10.97 to

* Short note

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Table-1: The green fodder yield, grass equivalent yield and Land equivalent ratio of grass-legume mixture in arable pasture lands (Pooled data for 3 years).

Treatments	Green fodder yield (tonnes/ha) (pooled data for 3 years)			Plant height of grasses (cm)	Plant height of legumes (cm)	Land equivalent ratio	Grass equivalent yield (tonnes/ha)
	Grass	Legume	Cumulative				
(<i>Cenchrus ciliaris</i>)	12.35		12.35	43.3		1.00	12.35
(<i>Panicum maximum</i>)	10.71		10.71	41.2		1.00	10.70
(<i>Cenchrus setigerus</i>)	12.19		12.19	38.7		1.00	12.19
<i>Stylosanthes scabra</i>		4.80	4.80		26.8	1.00	6.38
<i>Stylosanthes hamata</i>		8.23	8.23		26.7	1.00	10.96
<i>C. uliaris</i> + <i>S. scabra</i>	13.82	0.76	14.58	43.6	26.0	1.28	14.82
<i>C. uliaris</i> + <i>S. hamata</i>	11.11	2.10	13.21	46.7	30.5	1.15	13.89
<i>P. maximum</i> + <i>S. scabra</i>	9.67	1.30	10.97	41.8	23.4	1.17	11.39
<i>P. maximum</i> + <i>S. hamata</i>	10.70	1.30	12.00	41.7	22.1	1.16	12.42
<i>C. setigerus</i> + <i>S. scabra</i>	10.34	0.91	11.25	39.4	25.0	1.04	11.55
<i>C. setigerus</i> + <i>S. hamata</i>	10.56	2.19	12.74	36.2	28.2	1.14	13.46
SEm+	1.81	1.01	2.06	2.3	2.2		
CD (P=0.05)	NS	2.85	6.01	NS	NS		

* Pooled data of 3 years

14.58 tonnes/ha) than pure crop of *S. scabra* (4.8 tonnes/ha). The combination of anjan grass + *S. scabra* recorded significantly higher cumulative green fodder yield (14.58 tonnes/ha) than the pure crops of *S. scabra* (4.80 tonnes/ha) or *S. hamata* (8.23 tonnes/ha).

The higher advantage owing to intercropping as envisaged by higher land-equivalent ratio was observed in all the combinations of pasture grasses and legumes. All the pasture grass-legume combinations recorded higher land-equivalent ratio (1.04 to 1.28) over their respective pure crops. It was more beneficial with anjan grass + any legume or guinea or dhaman grass with *S. hamata* for intercropping instead of pure pasture grass alone. In addition, the grass-legume combinations yield palatable and nutritious fodder which is highly relished by the livestock, as reported by Rai and Kanodia (1982), Rai (1985) and Singh *et al.* (1988). Added to the intercropping advantages, pasture grass : legume association was also beneficial as evident by higher equivalent grass yields. Intercropping of anjan grass either with *S. scabra* or *S. hamata*, dhaman grass with *S. hamata* at 3:1 row proportion resulted in higher grass-equivalent yield (13.46 to 14.82 tonnes / ha).

SUMMARY

A field experiment was conducted from 1998 to 2000 to identify a suitable pasture grass-legume mixture for arable lands. Three pasture grasses, viz. anjan (*Cenchrus ciliaris* L.), dhaman (*Cenchrus setigerus* Vahl) and (*Panicum maximum*

Jacq.) and 2 pasture legumes [*Stylosanthes scabra* Vogel and *S. hamata* (L.) Taubert] were included both in sole and combinations for the study under rainfed conditions. The performance of pasture grass-legume (3:1) combination was superior to their respective sole crops. Among the combinations, *Cenchrus ciliaris* either with *Stylosanthes hamata* or *S. scabra*, *Cenchrus setigerus* with *S. hamata* showed better performance for forage yield.

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Wetting front distribution under drip as affected by system parameters in clay loam soils

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Key words: Wetting front, Drip, Emitter discharge, Volume of irrigation water

The precise information on soil water distribution under drip and its behaviour with respect to changed system parameters must be known to wet 'certain minimum portion' of root zone applying predetermined quantity of water under drip system. The soil water regime in drip differs from other irrigation systems mainly due to the flow regime is 2 or 3 dimensional rather than vertical only, the water is added at a high frequency and soil water is maintained within a relatively narrow range. Bresler (1978) suggested the possibility of controlling wetted volume of soil by regulating the emitter discharge according to soil properties. Moreover, to minimize the system cost without affecting the efficiency of system the design and operation of drip system must integrate the plant, soil and system parameters in a way. Of these, soil and plant parameters are invariant and thus, system parameters can only be manipulated to reduce the cost. Thus, for economical design of drip system the knowledge on wetting distribution in soil profile as affected by system parameters is necessary.

The experiment comprised 20 treatments, viz 5 emitter discharges (2, 4, 8, 10, 12 lph) and 4 irrigation volumes (4, 8, 16 and 32 litres). Each treatment was replicated 4 times. The study of moisture movement in soil is based on the moisture status of soil at different depth and at different spacing from point source of water application. For measuring moisture at depth 15, 30, 45, 60, 75 and 90 cm below and at a lateral distance of 0, 15, 30, 45, 60, 75 and 90 cm from point source a observation grid was formed. The moisture content was measured at every grid point using neutron moisture meter. For this purpose, after installation of drip system, access tubes were fixed at all grid points. Tubes were fitted in each hole 100 cm below and 50 cm above the ground level.

The observations on moisture content at various grid points before irrigation and 6, 12, 24, 48 and 72 hr after irrigation were used to find out movement of moisture within soil profile. This information was used to determine the maximum depth and maximum lateral distance to which wetting front has been

reached in that particular case using graphical method.

Effect of emitter discharge on wetting distribution

The radial movement of moisture was inversely related to emitter discharge (Table 1). The maximum radial spread for 2, 4, 8, 10 and 12 lph emitter discharge was 1.24, 1.12, 1.04, 1.00 and 0.90 cm respectively. However, the vertical movement was found directly related with emitter discharge. The maximum vertical movement for 2, 4, 8, 10 and 12 lph emitter discharges was observed to be 1.19, 1.31, 1.29, 1.36 and 1.50 cm respectively. The increase in vertical movement was due to influence of gravity in case of higher discharges (Roth 1974).

Table 1 Maximum radial and vertical movement of wetting front as affected by various treatments

Emitter discharge (lph)	Irrigation scheduling	Volume of water added (liters)	Maximum radial movement (m)	Vertical movement (m)
2.0	Daily	4	0.67	0.81
	Alternate days	8	0.87	0.90
	3 Days	16	1.03	0.92
	4 Days	32	1.24	1.19
4.0	Daily	4	0.66	0.88
	Alternate days	8	0.87	0.97
	3 Days	16	0.98	1.20
	4 Days	32	1.12	1.31
8.0	Daily	4	0.62	0.92
	Alternate days	8	0.86	1.01
	3 Days	16	0.94	1.19
	4 Days	32	1.04	1.29
10.0	Daily	4	0.63	0.97
	Alternate days	8	0.87	1.17
	3 Days	16	0.93	1.28
	4 Days	32	1.00	1.36
12.0	Daily	4	0.57	1.00
	Alternate days	8	0.81	1.25
	3 Days	16	0.84	1.30
	4 Days	32	0.90	1.50

* Short note

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Effect of volume of water applied on wetting distribution

The volume of water added during each irrigation directly influenced the radial and vertical movement (Table 1). As the volume of water added increased, the moisture distribution pattern became wider and more elongated in vertical direction. For larger times, which results into larger volumes, the wetting fronts were much deeper but horizontal movement was not much more than for earlier times (Warric 1975).

Depth to which maximum radial spread occurs

The average depth to which maximum radial spread occurred was found to be 40 to 60 cm for different emitter discharges and volumes of water added. It also indicated that, depth for maximum radial distribution was increased with emitter discharge.

Relationship between wetting distribution and emitter discharge and volume of water applied

The different forms of equations were tried for developing relationship between maximum lateral and vertical movement and system variables such as emitter discharge and volume of water added. For both the cases, power relationship was found better on the basis of correlation coefficient (Keller and Karmeli 1974).

For maximum lateral movement the equation fitted was as:

$$W = 0.50 q^{-0.09} \times v^{0.24}$$

$$r^2 = 0.94$$

where W, maximum lateral movement (m); q, emitter discharge (lph); V, volume of water added (litres)

For maximum vertical movement the equation fitted was as:

$$Z = 0.48 q^{0.14} \times v^{0.18}$$

$$r^2 = 0.96$$

Where Z, maximum vertical movement (m)

Thus, in clay loam soils, the lateral movement of wetting front under drip was increased with volume of water applied and decreased with emitter discharge, whereas the vertical movement was increased with volume of water applied and emitter discharge. For commonly used emitters (4 and 8 lph) the maximum lateral movement of 0.62 m to 1.12 m and maximum vertical movement of 0.88 m to 1.31 m were observed. The wetting distribution varied considerably with total volume of water applied and found to become wider and more elongated in vertical direction with increase in volume.

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Influence of tree growth on reclamation of sodic soil*

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Key words: Tree growth, Sodic soil reclamation

In India the forest area is decreasing at an alarming rate resulting in the diminishing supplies of fuelwood and timber to meet the demands of the burgeoning population. Therefore, it has become essential to bring more lands under forest. Degraded sodic soils of the Indogangetic plains may be utilized for fuelwood production. Although soil sodicity is injurious to plant growth, some woody tree species are able to tolerate this stress (Singh *et al.* 1994, Jain and Garg 1996). Knowledge of sodicity tolerance by tree species is largely limited to pot conditions (Singh *et al.* 1992, 1996). Survival and growth of a few species with the increasing EC or ESP up to sapling stage was reported by Jain *et al.* (1983). A few field trials monitored the growth performance of some species in sodic soils (Singh 1989, Jain and Singh 1998). In this experiment, the efficacy of 2 species was tested to assess their productivity as well as soil-reclamation potentials after a modest growth stage.

One-year-old saplings of *Acacia auriculiformis* A. Cunn. and *Albizia procera* Benth. were planted in 1991 in 1 m³ refilled pits. The experimental plots, measuring 37.5 m × 37.5 m, had 625 plants spaced at 1.5 m with a mean of 4 444 plants/ha, arranged in randomized block design with 3 replications. The height growth of *A. auriculiformis* was greater than *A. procera* against the diameter growth. Mortality was relatively high in *A. procera* plantation. As a consequence, *A. auriculiformis*

produced about 55 tonnes/ha above-ground biomass compared with *A. procera* (36 tonnes/ha), at the age of 9 years.

Soil samples were taken before the plantation as also over a period of 9 years from the inner plots of 20 m × 20 m to avoid boundary effects. The samples were collected from areas between the main stem and the canopy edge from 4 depths, each at 15-cm intervals. Three composite samples from each of the 3 replications were analysed. Soil samples were air-dried, homogenized, passed through a 2-mm sieve, and analysed to ascertain the effect of these plantations on soil characteristics. Soil pH, electrical conductivity (EC), organic carbon, cation-exchange capacity (CEC) and exchangeable sodium percentage (ESP) were determined following standard procedures (Richards, 1954, Jackson 1967). Exchangeable cations (Na⁺, K⁺, Ca⁺⁺ and Mg⁺⁺) were extracted in 1 N (pH 7) ammonium acetate solution and were examined by spectroflame photometer with the known standards of NaCl, KCl and CaCO₃. Exchangeable Mg⁺⁺ was determined by Versenate method.

Soil properties changed markedly under both the species during 9 years (Tables 1, 2), but the differences between the 2 species was rather inconspicuous. The improvement under both the species was almost identical and did not vary significantly with each other (Table 2). Although the biomass of *A. auriculiformis* was considerably greater than *A. procera*,

Table 1 Soil properties of sodic wasteland before plantation

Depth (cm)	pH	EC (dS/m)	OC (%)	Exchangeable cation (cmol (+)/kg)				CEC	ESP
				Na	K	Ca	Mg		
0–15	9.70	0.41	0.03	9.18	0.88	8.25	5.00	22.85	30.52
15–30	10.40	0.41	0.03	18.09	0.80	8.25	4.25	23.26	35.85
30–45	10.60	0.52	0.03	19.50	0.75	6.30	2.76	25.32	39.60
45–60	10.80	0.60	0.02	21.60	0.72	4.25	1.25	28.18	42.15
Mean	10.37	0.48	0.027	17.09	0.787	6.76	3.32	24.90	37.03
CD	0.081	0.003	0.007	0.70	0.06	0.11	0.37	NS	2.44

EC, Electrical conductivity; OC, organic carbon; CEC, cation-exchange capacity; ESP, exchange sodium %

Note-Data are the mean of 3 samples, each representing 1 replication, composited in turn from sampling of 3 soil pits from each plot

* Short note

^{1,2}Scientist E II, ^{3,4} Research Fellow, ⁵ Scientist F

Table 2 Improvement in soil properties after 9 years under *Albizia procera* and *Acacia auriculiformis*

Depth (cm)	pH	EC (dS/m)	OC (%)	Exchangeable cation (cmol (+)/kg)1				CEC	ESP
				Na	K	Ca	Mg		
<i>Albizia procera</i>									
0–15	8.68	0.454	0.295	4.96	0.760	8.95	5.06	20.50	19.00
15–30	9.15	0.389	0.212	6.18	0.642	7.85	4.02	23.90	22.50
30–45	9.35	0.196	0.165	8.54	0.591	6.59	3.30	24.40	27.93
45–60	9.80	0.182	0.112	10.32	0.382	5.32	1.78	25.50	32.50
Mean	9.42*	0.305	0.196*	7.50*	0.593	7.17	3.54	23.57	25.48*
CD	0.115	0.014	0.011	0.07	0.01	1.77	0.07	NS	3.28
<i>Acacia auriculiformis</i>									
0–15	8.60	0.448	0.325	4.78	0.815	9.79	5.55	20.80	18.5
15–30	9.10	0.336	0.250	6.78	0.752	8.93	3.92	22.00	21.50
30–45	9.40	0.219	0.210	8.52	0.585	7.78	3.86	22.90	26.00
45–60	9.90	0.198	0.134	10.30	0.435	4.78	2.40	24.10	32.25
Mean	9.25*	0.300*	0.229*	7.595*	0.646	7.82	3.93	22.45	24.57*
CD	0.63	0.017	0.014	0.9	0.01	2.45	0.09	2.06	3.84

EC, Electrical conductivity; OC, organic carbon; CEC, cation-exchange capacity; ESP, exchange sodium %

Note- Data are the mean of 3 samples, each representing 1 replication, composited in turn from sampling of 3 soil pits from each plot

* significant at 0.05 probability from the soil property before plantation.

even then their effect on soil properties was almost identical. This might be possible due to thick coarse and waxy leaf litter (phyllode) of *A. auriculiformis* which decayed very slowly and remained accumulated on soil surface over the years. In contrast, leaf litter of *A. procera* decomposed and humified quickly. There was a significant reduction in pH, exchangeable Na⁺ and ESP in soil under both the species compared with initial data ($t_{e>t_{0.05}}$), whereas organic carbon content increased during 9 years. During litter decomposition CO₂ is liberated which reacts with water and sulphate of soil solution forming carbonic and sulfuric acids. This process along with the humic and fulvic acid liberated during humification helps to dissolve the Ca⁺⁺ from the precipitated forms. Thus the higher concentration of Na⁺ is replaced by Ca⁺⁺ due to monovalent weak electrolyte which is leached down reducing the soil sodicity and pH levels. Reduction in pH, exchangeable Na⁺ and an increase in organic carbon content are good indicators of reclamation of sodic soils through tree growth (Yadav and Singh 1970, Singh *et al.* 1982, Gill *et al.* 1990, Singh 1996, Jain and Garg 1996). The level of exchangeable Ca⁺⁺ increased slightly under planted soils because of changes in ionic equilibrium which decreased the ESP to about 36% in surface soil of 0-15 cm depth. The Na : Ca decreased markedly from 1.4 to 0.5 during this period in surface soil of 0 to 30 cm. At lower depth, the reduction in pH and ESP was very less because movement of exchangeable cation could not leach below the hard impervious Kankar pan layer and incorporation of humus into the subsoil was limited to few cm depth of about 20-30 cm. Therefore, the ameliorative effects were smaller at lower soil depths as also observed by Singh (1996, 1998) in a 37 year-old semi-natural forest at Lucknow.

SUMMARY

An attempt was made to rehabilitate and reclaim sodic soils of Indogangetic alluvium through 2 salt-tolerant species, viz *Albizia procera* Benth. and *Acacia auriculiformis* A. Cunn. Biomass production of *A. auriculiformis* was greater than that of *A. procera*. On an average, a considerable reduction in pH (9%), exchangeable Na⁺ (39%) and ESP (36%) was observed in surface soil of 0-15 cm depth as a result of plantation over 9 years, whereas organic carbon (88%), exchangeable Ca⁺⁺ (58%), Mg⁺⁺ (37%) and CEC (24%) increased substantially during this period. The exchangeable K⁺ declined slightly. The Na : Ca decreased markedly from 1.4 to 0.5 in the 0-30 cm surface soil. Reduction in Na : Ca was more under *A. auriculiformis* (55%) than that under *A. procera* (46%).

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Fertility status and phosphorus fractionations in lateritic soils under different agro-ecosystems of West Bengal*

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Key words: Agro-ecosystems, Fertility status, Lateritic soils, P fractions

Red and lateritic soils occupy an area of about 2.8 million ha (28% of the total geographical area) in West Bengal. Productivity of these soils is usually low due to light texture, low organic matter content, low water retentivity, acidic soil reaction, inadequacy of N, P and K, and some micronutrients in toxic concentrations (Panda *et al.* 1991). Since the lateritic soils are acidic in nature and characterized by high P-fixing capacity, most of the water-soluble P added to such soils is transformed into relatively insoluble inorganic compounds of Al and Fe and thereby reduce the available P immediately. However, in course of time when intensity factor of soil solution goes down, these inorganic P fractions may contribute to the P nutrition of the crops (Lindsay *et al.* 1962). On the other hand, chemical extractants are selective to dissolve one or more fractions of inorganic P and hence differ in their ability to extract available P. Therefore studies of P fraction in relation to its availability and uptake help in selecting suitable soil P test (Chang and Jackson 1957, Sharma *et al.* 1995). In this context, the present study was carried out to study the fertility status and distribution of P fractions in soils in and around Santiniketan and Sriniketan area representing lateritic soils under different agro-ecological systems.

Nine profile soil samples (0–15, 15–22 and 22–38 cm) were collected from Santiniketan and Sriniketan area representing different agro-ecosystems, viz pastures, cultivated fields, orchards, grazing land and eroded soil, during 1999–2000. The description of sampling sites are as follows:

Soils were collected from grass + legume pasture of *Paspalum dilatatum* Poiret, *Brachiaria decumbens* Stapf and *Centrosema pubescens* Benth. raised for 3 years by annual fertilization of 20 tonnes/ha of farmyard manure, N₈₀P₂₂K₃₃ kg/ha. Food–fodder intercropping of Guinea *Panicum maximum* Jacq. and cowpea [*Vigna unguiculata* (L.) Walp.]/lentil (*Lens culinaris* Medikus) was also maintained similarly. For rice (*Oryza sativa* L.)-based monocropping and double cropping systems, no organic matter was applied except recommended dose of fertilizers (N₆₀P₁₃K₂₅ kg/ha). Guava and mango orchard

soils have been left uncared without manuring for the last 30 years, casually grazed by cattle. Undulated eroded soil is characterized by ferruginous concretions at the surface with very scanty poor growth of weeds.

To evaluate the overall fertility status of profile soils, the processed soil (< 2 mm) were analysed for pH, organic carbon, cation-exchange capacity (CEC), available P and available K following standard procedures. Fractionation of inorganic P was carried out by the method of Chang and Jackson (1957).

Fertility status and important soil properties of soils under different Agro-ecosystems

Soil pH: The results indicate that the soils in and around Santiniketan and Sriniketan were acidic and the pH ranged from 5.0 to 6.1 for surface soils (0–15 cm), 5.0 to 7.6 at the depth of 15–22 cm and 5.1 to 7.7 for the depth of 22–38 cm (Table 1). The surface soils were more acidic than subsurface soils under pastures and cultivated soils. However, reverse trend was observed in case of orchard soils. This might be due to the formation of humic acids as a result of decomposition of leaves of orchards and leaching to the subsurfaces. Grazing land and highly eroded soils (locally known as khoai), which are highly porous in nature showed no such variations in acidity both in surface and subsurface layers.

Organic carbon: The soils of both surface and subsurfaces were poor in organic status under various agro-ecosystems. The depth-wise distribution of organic carbon reflected that the surface soils contained more organic carbon than subsurface soils (Table 1). Only the surface soil of mango grove recorded medium organic carbon status. The lowest organic carbon was recorded under eroded soil irrespective of the depth. These soils are barren and highly eroded. Although pasture soils and soils under cropping are manured regularly but no improvement of organic matter status was noticed. This might be due to the fact that lateritic soils are highly porous and due to high temperature and rainfall, the oxidation of organic matter takes place quickly, whereas guava and mango orchards despite the same climatic conditions were of medium in organic carbon status as a result of good canopy

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coverage and continuous additions of falling leaves. Cation-exchange capacity of the soils (Table 1) also reflected the poor fertility status of the soils.

Soil phosphorus: The surface soils of pastures, mono and double-cropped land showed high available P status (Table 2). This might be attributed to accumulation of P in soils as a result of regular fertilization of soils. However, fallow grazing land, eroded soil and orchard soils were of low in available P status irrespective of soil depth. The decreasing trend of available P was observed down to the profiles. The soils below 22 cm onwards had low available P status in all the soils under different agro-ecological systems.

Soil potassium: The pasture soils of the region were low in available K, irrespective of soil depth, whereas cultivated (mono or double cropped) soils irrespective of depth were of medium in available K (Table 1). Excessive accumulation of available K in soils was observed under double cropping. There is increasing evidence that the non-exchangeable (fixed) K fraction can supply significant quantities of available K

during a crop season. The role of cropping in releasing K from non-exchangeable K fraction has long been recognized (Tandon and Sekhon 1988). The variation in available K in fertilized soils is mainly due to the fertilization and leaching. On the other hand, the availability is attributed mainly to the mineralogical make up of the soils.

Inorganic P fractions

The forms of different inorganic P fractions are presented in Table 2. The content of Fe-P in *Paspalum* + *Centrosema*, signal grass + *Centrosema* and food + fodder cropping pastures varied from 47.3 to 92.9 kg/ha up to 15 cm and 11.5 to 34.1 kg/ha for 15–22 cm and 4.6 to 19.2 kg/ha for 22–38 cm of soil depths. The cultivated soils contained higher amount of Fe-P, followed by pastures, orchards and grazing land over Al-P and Ca-P. Eroded soil contained lowest amount of Fe-P, Al-P and Ca-P than other soils. However, Fe-P was the dominant P fractions over Al-P and Ca-P. In general, the surface soils contained higher amount of P fractions than the

Table 1 Physico-Chemical properties of soils under different agro-ecosystems

Agro-ecosystems	pH (1:2) at depth (cm)			Organic carbon (%) at depth(cm)			CEC(Cmol(p+))kg at depth(cm)			Available K (kg/ha) at depth (cm)		
	0–15	15–22	22–38	0–15	15–22	22–38	0–15	15–22	22–38	0–15	15–22	22–38
Paspalum + Centrosema pasture	5.9	7.6	7.7	0.31	0.17	0.12	6.0	7.4	7.6	44.8	84.0	84.0
Signal grass + Centrosema pasture	6.0	6.7	6.8	0.32	0.10	0.13	6.9	7.4	8.0	44.8	56.0	74.6
Food-fodder intercropping	6.1	6.6	6.7	0.36	0.11	0.12	5.2	9.0	10.4	44.8	56.0	112.0
Mono-cropping (Rice-fallow)	5.0	5.8	6.2	0.29	0.15	0.15	6.4	7.9	11.2	44.8	56.0	56.0
Double-cropping (Rice-Wheat/ Indian mustard)	5.1	5.8	6.2	0.44	0.13	0.15	6.2	8.2	10.0	137.5	124.0	140.0
Mango orchard	5.8	5.9	5.6	0.68	0.30	0.23	7.6	9.0	10.2	179.2	252.0	280.0
Guava orchard	5.4	5.1	5.0	0.54	0.20	0.13	7.6	9.2	12.0	44.8	56.0	56.0
Fallow grazing land	5.7	5.8	5.7	0.22	0.16	0.12	5.5	6.2	6.8	134.4	140.0	168.0
Eroded land	5.9	5.9	5.9	0.16	0.05	0.05	3.0	5.2	7.6	104.6	134.4	144.4

Table 2 Fractions of soil phosphorus in lateritic soils under different agro-ecosystems

Agro-ecosystems	Available P (kg/ha) at depth (cm)			Fe - P (kg/ha) at depth (cm)			Al - P (kg/ha) at depth (cm)			Ca - P (kg/ha) at depth (cm)		
	0–15	15–22	22–38	0–15	15–22	22–38	0–15	15–22	22–38	0–15	15–22	22–38
Paspalum + Centrosema pasture	44.0	16.8	3.3	47.3	19.8	4.6	19.8	7.7	4.3	24.7	21.6	6.6
Signal grass + Centrosema pasture	58.8	26.9	12.6	67.6	34.1	19.2	25.8	11.3	7.0	33.0	18.4	13.0
Food-fodder intercropping	94.3	11.0	8.2	92.9	11.5	7.1	42.3	25.6	11.4	45.1	13.6	11.0
Mono-cropping (Rice-fallow)	34.6	13.5	9.1	85.2	37.9	23.1	17.3	9.0	6.0	22.0	12.6	8.2
Double-cropping (Rice-Wheat/ Indian mustard)	64.1	14.0	9.9	282.1	48.8	12.6	132.5	26.4	13.0	35.1	11.3	7.7
Mango orchard	7.7	6.6	6.0	37.9	33.0	17.0	18.8	16.4	7.9	8.8	6.4	2.3
Guava orchard	9.3	9.1	6.6	24.7	21.0	13.7	17.0	12.5	9.9	11.3	9.9	5.4
Fallow grazing land	9.0	8.1	5.3	24.3	14.1	9.1	12.1	7.2	3.1	14.3	7.2	4.2
Eroded land	6.4	3.9	2.2	22.0	14.0	11.0	6.0	3.3	2.1	11.3	9.1	3.9

profiles beneath it. Applications of phosphatic fertilizers to cultivated and pasture soils for a long time has resulted in build up of Fe-P, Al-P and Ca-P quite markedly than non-fertilized soils like orchards, grazing land and eroded soils.

Highest build up of Fe-P (282.1, 48.8 and 12.6 kg/ha), Al-P (132.5, 26.4 and 13.0 kg/ha) and Ca-P (35.1, 11.3 and 7.7 kg/ha) in successive soil profiles was recorded in double cropped (rice-wheat / Indian mustard), followed by mono cropped (rice-fallow) and pasture soils where recommended doses of fertilizers are applied regularly. Higher activity of Fe and Al cations in complexing P in these Oxisol soils may be attributed to the build up of Fe-P and Al-P over Ca-P (Sharma *et al.* 1995).

The Ca-P was more than Al-P in pasture soils due to continuous manuring and cropping. The Fe-P and Al-P are the main sources of available P in acid soils as most of the water soluble P added to such soil gets transformed into products relatively insoluble inorganic compounds of Al and Fe. The value of phosphoric fertilizers depends primarily on the release of phosphorus from these reaction products rather than the fertilizer *per se* (Lindsay *et al.* 1962, Ghosh and Sarkar 1996).

It was noticed that Fe-P fraction dominates over Ca-P. The dominance of Fe-bound phosphates over Ca-P indicates that the soils have undergone an intense weathering. The weathering intensity of the soils based on the dominance of Fe-bound phosphorus over Ca-P in different agro-ecosystems are as follows: Double cropping > Food-fodder intercropping > monocropping > signal grass + *Centrosema* > *Paspalum* + *Centrosema* > mango orchard > guava orchard > fallow grazing land > Eroded land. Sharma and Tripathi (1992) explained the degree of weathering or the stage of maturity of the soil on the basis of the relative abundance of the P fractions. According to them, in early stage of weathering, the Ca-P and Al-P are the most dominant in comparison to Fe-P but as the weathering reaches an advanced stage, there is a shift in the relative abundance from Ca-P towards Al-P and Fe-P. This leads to infer that the lateritic soils in the present investigation, in general, are in advanced stage of weathering which have the abundance of Fe-P and in some soils Al-P over Ca-P.

SUMMARY

The fertility status and fractionation of soil phosphorus in lateritic soils under different agro-eco systems viz pasture,

cultivated fields (mono- and double-cropped), orchards (mango and guava), grazing land and eroded soil, were studied during 1999–2000. The soils under different agro-eco systems were poor in fertility except where fertilization practices were made regularly. The surface soils were acidic (pH 5.0–6.1), whereas increase in soil pH (5.0–7.7) were observed in subsurfaces. The organic carbon status of surface soils was low (0.12–0.44%) except mango and guava orchards (0.68 and 0.54%) whereas the subsurface soils were very low in organic carbon status (0.05–0.30%) in all types of agro-eco systems. The available P status was high in surface soils (34.6–94.3 kg P/ha), medium (11.0–26.9 kg P/ha) in subsurface layer (15–22 cm) and low beyond 22 cm depth in grass-legume pastures and cultivated land and eroded soils were low in available P status throughout the soil profiles. The available K status irrespective of soil depths, agro-eco systems and management practices were low except cultivated land. The lateritic soils were light-textured and low in cation-exchange capacity (CEC). The P-fractionation of profile soils revealed the dominance of Fe-P and Al-P over Ca-P. The relative sequence of P fractions indicated that the lateritic soils under different agro-eco systems are in advanced stage of weathering.

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Comparative efficiency of nearest neighbour techniques over randomized block design for data analysis in fertilizer experiments

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It has been felt that when blocks are too large because of large number of treatments, there may be a considerable variability in fertility levels within each block. Yates (1936) introduced incomplete block and lattice designs so as to reduce the block size thus increasing the precision. Usually fertility levels are slowly changing over space and thus they are likely to be highly correlated among neighbouring plots. Classical method of analysis completely ignores the information regarding the relative position of each treatment in the block. Shukla (1994) stressed on the use of spatial information in the analysis of field experiments as ancillary devices. Bartlett (1976, 1978) gave theoretical development to Papadakis (1937) method of analysis in 1 and 2 dimensions. Wilkinson *et al.* (1983) suggested another neighbouring technique which is a continuous form of local detrending in contrast to the step-wise (fixed) block detrending of classical method of analysis. This technique was useful when applied to wheat (*Triticum aestivum* L. emend Fiori & Paol.) yield data on sodic soil (Katyal 1994) and also to potato (*Solanum tuberosum* L.) yield grown in sodic soil (Katyal *et al.* 1994). Pearce and Moore (1976) reduced experimental error in perennial crops, using adjustment by neighbouring plots. In this article, an attempt was made to utilize the spatial information and compare efficiency of different methods of analysis in fertilizer field experiments being conducted at different places in rice-wheat cropping system.

A field experiment on integrated nutrient supply is being conducted at Ludhiana and Pantnagar centres of All-India Co-ordinated Research Project on Cropping Systems in rice-wheat cropping system in randomized block design having 3 and 4 replications with net plot sizes 60 m² and 64 m² respectively. At Ludhiana, there were 14 treatments but at Pantnagar there were 12 treatments. The details of the treatments are:

Characteristics of sites are given in Table 1. Coefficient

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of variation (%) of grain yields of rice and wheat were obtained

Treatment	Rainy season	Winter season
T ₁	Control (No fertilizer, No organic matter)	Control (No fertilizer, no organic matter)
T ₂	50% recommended NPK dose through fertilizer	50% recommended NPK dose through fertilizers
T ₃	50% recommended NPK NPK dose through fertilizers	100% recommended dose through fertilizers
T ₄	75% recommended NPK dose through fertilizers	75% recommended NPK dose through fertilizers
T ₅	100% recommended NPK dose through fertilizers (120:60:40 at Pantnagar while 120:00:00 -Zn 25 at Ludhiana)	100% recommended NPK dose through fertilizers (120:60:40 at Pantnagar while 120:60:30 at Ludhiana)
T ₆	50% recommended NPK dose through fertilizers + 50% N through compost/ FYM/Gobar gas slurry	100% recommended NPK dose through fertilizers
T ₇	75% recommended NPK dose through fertilizers+ 25% N through compost/ FYM/Gobar gas slurry	75% recommended NPK dose through fertilizers.
T ₈	50% recommended NPK dose through fertilizers + 50% N through crop residues /rural farm wastes etc.	100% recommended NPK dose through fertilizers
T ₉	75% recommended NPK dose through fertilizers + 25% N through crop residues/ rural farm wastes etc (rice or wheat cut straw)	75% recommended NPK dose through fertilizers
T ₁₀	50% recommended NPK dose through fertilizers+50% N through green organic matter (green manuring)	100% recommended NPK dose through fertilizers

T ₁₁	75% recommended NPK dose through fertilizers+ 25% N through green organic matter (green manuring)	75% recommended NPK dose through fertilizers
T ₁₂	Farmer's practice (120:00:00 matter (green manuring) matter (green manuring)	Farmer's practice (120:60:30 at Ludhiana while 60:30:20 at Pantnagar)
In addition to the above twelve treatments at Ludhiana, two more treatments are:		
T ₁₃	N ₁₈₀ P ₃₀ K ₃₀ during rainy season and	N ₁₅₀ P ₆₀ K ₃₀ during rabi
T ₁₄	100% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers + 20 kg N/ha to cowpea during summer

by conducting analysis of variance of 1998–99 data with reference to randomized block design. In order to make use of spatial information, residuals of experimental data were obtained plot-wise by subtracting the respective treatment mean. Covariates were developed for each plot by making use of Papadakis (1937) method in 2 dimensions. Theoretical development was made by Bartlett (1978). These covariates were used in analysis of covariance. Further, Wilkinson (1983) technique was applied to the above data sets by creating uniformity trial data after eliminating the respective treatment effects. Wilkinson *et al.* (1983) have made the following derivation:

$$\hat{\sigma}_{\omega}^2 = \frac{2}{3} \times \frac{\sum y_i'^2}{\{n - r(1 + 2\alpha_1\delta_1' + \alpha_2\delta_2')\}}$$

where n = total no. of observations

$$\alpha_1 = \frac{d-1}{d} \quad d \text{ is the number of residual observations in}$$

each column.

$$\alpha_2 = \frac{d-2}{d}$$

$\delta_1' = -2/3$ serial correlation of order 1 of detrended data in the population.

$\delta_2' = 1/6$ serial correlation of order 2 of detrended data in the population

r = number of columns,

$$y_i' = y_i - (y_{i-1} + y_{i+1})/2,$$

Where i runs from 2 to $(d-1)$ th residual observation in each column.

$y_i'' = y_i' - \bar{y}_i'$, where y_i' is the deviation of y_i'' from its respective column mean and

$\sum y_i'^2$ is the sum of squares of deviations.

Let $\hat{\sigma}_R^2$ be the variance of randomized block design for a

particular plot size. Let $\hat{\sigma}_R^2$ and $\hat{\sigma}_{\omega}^2$ be the variances after application of Papadakis method (1937) and Wilkinson *et al.* (1983) neighbouring technique.

$$\text{Then RE (\%)} = \frac{\hat{\sigma}_R^2}{\hat{\sigma}_P^2} \quad \text{and RE (\%)} = \frac{\hat{\sigma}_R^2}{\hat{\sigma}_{\omega}^2}$$

In case of rice, wheat and wheat-equivalent yields of the system CV (%) worked out were 8.59, 8.54 and 7.15 respectively at Ludhiana. With Papadakis method of analysis it turned out to be 8.67, 8.97 and 5.73 respectively. With

Table 1 Characteristics of experimental sites

Characteristics/ location	Ludhiana	Pantnagar
Latitude	30 to 32° N	29° N
Longitude	75° to 76° E	79° E
Elevation (m)	247	243.8
Annual rainfall (mm)	681	869
Temperature (°C)		
Maximum	35–38	43.5
Minimum	4.5–8.5	3.6
Soil type	Alluvium, sandy and sandy loam soil	Alluvium, coarse loamy
Soil taxonomic class	Ustochrepts, Ustic psamment association (very deep 90 cm depth)	Hapludolls (very deep 90 cm depth)

Wilkinson (1983) neighbouring technique, CV was 6.17, 4.83 and 3.84 for rice, wheat and wheat-equivalent yields of the system respectively at Ludhiana. But at Pantnagar coefficient of variation (%) for rice, wheat and wheat-equivalent yields of

Table 2 Relative efficiency of neighbouring techniques over randomized block designs in rice–wheat cropping system

Methods of analysis	Coefficient of variation (%)		Relative efficiency (%)		Wheat equivalent CV(%) RE(%)	
	Rice	Wheat	Rice	Wheat	CV(%)	RE(%)
Ludhiana (net plot size 60 m ²)						
RBD	8.59	8.54	100	100	7.15	100
Papadakis technique	8.67	8.97	98	90	5.73	156
Wilkinson neighbouring technique	6.17	4.83	194	312	3.84	345
Pantnagar (net plot size 64 m ²)						
RBD	4.56	11.5	100	100	6.70	100
Papadakis technique	4.65	11.07	96	108	5.40	154
Wilkinson neighbouring technique	3.51	7.71	169	222	4.07	350

RBD, Randomised block design

the system were 4.56, 11.5 and 6.70 for randomized block design. But the same for Papadakis method of analysis were computed to be 4.65, 11.07 and 5.40 for rice and wheat yield and wheat-equivalent yields of the system respectively. Wilkinson (1983) neighbouring technique yielded 3.51, 7.71 and 4.07 coefficient of variation (%) for rice yield, wheat yield and wheat-equivalent yield of the system respectively. Thus relative efficiency (RE %) of Papadakis method over randomized block design were turned out to be 98%, 90% and 156% for rice, wheat and wheat-equivalent yields of the system respectively at Ludhiana, but in case of Wilkinson technique (1983) these were 194, 312 and 345 respectively. At Pantnagar, while for Papadakis method of analysis, these figures turned out to be 96, 108 and 154 respectively. On the otherhand, for Wilkinson technique, these were 169, 222 and 350 for rice, wheat and wheat-equivalent yields of the system respectively (Table 2).

Thus, neighbouring techniques should be used as ancillary devices along with classical methods of analysis pertaining to Randomised block designs and incomplete block designs and should be invoked only when standard statistical design do not remove variation to a large extent and also in cases when number of treatments happen to be large.

SUMMARY

Relative efficiency of nearest neighbour (NN) techniques of analysis of field experimental data over randomized block designs was evaluated. It is observed that for net plot sizes of 60–64 m² wherein field experiments are going on in randomized block designs, relative efficiencies (%) for Papadakis method of analysis were computed to be 98, 90 and 156 for rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L. emend. Fiori & Paol.) yield and wheat-equivalent yields of the system respectively at Ludhiana, while in case of Wilkinson neighbouring techniques these turned out to be 194, 312 and 345 respectively. Further at Pantnagar, relative efficiencies (%) for Papadakis methods of analysis were 96, 108 and 154 for rice, wheat yields and wheat-equivalent yields of the system respectively. However, in case of Wilkinson techniques these are 169, 222 and 350 for rice, wheat and

wheat equivalent yields of the system respectively. Thus Wilkinson technique proved more effective than Papadakis method of analysis when compared to randomized block design in reducing experimental error and may be used as ancillary devices.

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Scab-resistant genotypes of field bean (*Phaseolus vulgaris*) under high rainfall conditions of Zambia*

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Key words: Field bean, *Phaseolus vulgaris*, scab-resistant genotypes, Zambia, high rainfall region

Field bean (*Phaseolus vulgaris* L.) is an important food legume crop after groundnut (*Arachis hypogaea* L.) in Zambia and mainly grown in high rainfall zone. The rainfall in this zone of Zambia ranges from 800 to 1 200 mm in general. Field bean is grown from October to April in Zambia and more than one crop is possible within a year. It is main cash crop and is cultivated during the rainy season as sole and companion crop with maize (*Zea mays* L.). The scab disease caused by *Elsinoe phaseoli* Jenk. is one of the most important diseases of fieldbean in high rainfall zone in Zambia and causes yield loss up to 70% (Hall 1991). A recommended variety for release, 'ZPV 292', could not perform in northern province of Zambia, due to its high susceptibility towards scab. Keeping in view of much importance of disease and lack of information on resistant varieties, an experiment was designed for screening of indigenous as well as exotic bean genotypes (dwarf and climbing types) against scab for their use in breeding programme.

The experiment was conducted at the research farm of Misamfu Regional Research Station, Kasama, Zambia, a known hot-spot location for this disease during crop season of 1995–96 and 1996–97. One hundred genotypes of fieldbean collected from all over Zambia as well as from CIAT, Colombia, were planted in 2-m row length and were evaluated under artificially inoculated conditions. A highly susceptible fieldbean variety 'ZPV 292' to scab was repeat planted after every 20 test entries and all around the screening block to provide enough inoculum of pathogen to test genotypes. The scoring of the disease was done at grain-formation stage, using 0–9 scale based on the per cent area of leaf and pods infected, where 0, no disease and 9, >90 % areas covered due to scab.

The genotypes varied much in their reaction towards scab (Allen 1983). The symptoms of scab developed on leaves, stems and pods as raised, wart protuberances tan to brown (up to 10 mm in diameter). Leaf spots occurred along with veins on either leaf surface, turn yellow and developed slightly

raised margins. Stem lesions were brown to gray with yellow margins. Pod lesions were brown to purple black, circular, punctuate and about 5 mm in diameter. Pods turned curved, brittle and were having no or poorly developed seeds.

Based on above rating following 26 genotypes were found resistant to scab (1–3 score) during 2 years of screening: 'A 197', 'PAT 10', 'Carioca', 'LB 281', 'Kabanimba', 'CAL 143', 'A 286', 'BAC 76', 'ICA PIJAO', 'MCM 5001', 'MCM 1016', 'Ikinimba', 'Lusale white', 'REC 1', 'ACV 8312', 'BAT 1373', 'DRK 57', 'Mbala Red', 'AFR 632', 'AFR 344', 'AFR 593', 'AFR 532', 'BAT 477', 'NW 590', 'A 321' and 'ZAV 205 A'.

Most of the local beans ('Mbala Local', 'Kablengethi', 'Senga Hill Local', 'Pembela' etc.) were highly susceptible to scab. Cultivation of mixed beans is therefore practised by the farmers in northern province in Zambia to prevent yield losses by genetically diverse beans in the same field. These scab-resistant bean genotypes may be used in breeding programme for transferring of resistant genes in local bean varieties.

SUMMARY

An experiment was conducted during 1995–96 and 1996–97 to screen scab (*Elsinoe phaseoli* Jenk.)-resistant genotypes of field bean (*Phaseolus vulgaris* L.) in high rainfall agroclimatic zone of Zambia. One hundred local and exotic genotypes were evaluated against scab disease at hot spot location under artificially inoculated conditions. The genotypes, 'A 197', 'PAT 10', 'Carioca', 'LB 281', 'Kabanimba', 'CAL 143', 'A 286', 'BAC 76', 'ICA PIJAO', 'MCM 5001', 'MCM 1016', 'Ikinimba', 'Lusale white', 'REC 1', 'ACV 8312', 'BAT 1373', 'DRK 57', 'Mbala Red', 'AFR 632', 'AFR 344', 'AFR 593', 'AFR 532', 'BAT 477', 'NW 590', 'A 321' and 'ZAV 205 A' were resistant to scab. Most of the local cultivars were susceptible to scab.

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* Short note

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Response of stem gall disease (*Protomyces macrosporus*) and yield of coriander (*Coriandrum sativum*) to soil pH*

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Key words: Coriander, Stem gall disease, Yield, pH, *Coriandrum sativum*, *Protomyces macrosporus*

Stem gall disease caused by *Protomyces macrosporus* Unger is an important disease of coriander (*Coriandrum sativum* L.) causes severe yield loss and quality of seeds (Singh *et al.* 1984, Lakra 1993). The disease is seed as well as soil-borne in nature and its pathogen survives in the form of Chlamydospores. Soil pH influences the disease development (Mathur 1962). The present investigation was undertaken with a view to study the effect of soil pH on stem gall disease intensity, growth characters and yield of coriander.

A pot culture experiment was laid out in completely randomized design with 6 treatments and 4 replications during the winter (*rabi*) season of 1998–99 and 1999–2000 in artificially inoculated conditions at Gwalior. Soil samples were collected from different places and 6 soil pH levels, viz 5.5, 6.5, 7.5, 8.5, 9.5 and 10, were maintained by using normal solution of sodium hydroxide and hydrochloric acid. Twenty seeds of

At crop maturity, the disease intensity was recorded following a scoring scale proposed by Lakra (1993), where a healthy plant scores 0, while a fully diseased plant scores 100 points divided into 4 parts: main stem (30 points), leaves (20 points), pedicles (20 points) and fruits (30 points). The total score will count for the per cent disease intensity (Gupta 1954). Growth characters were recorded at critical stages of the crop. At harvest, seeds were collected and recorded for healthy and diseased seeds. Loss in yield was calculated as suggested by Lakra (1998).

$$\text{Loss(\%)} = \frac{x - y}{x} \times 100$$

where x, total yield (healthy + diseased), y, yield of healthy seeds.

Although the plants were attacked in all the levels of soil

Table 1 Disease intensity, growth character and yield of coriander as influenced by soil pH (mean data of 2 years)

Levels of soil pH	Stem gall disease intensity	Plant height (cm)	Branches/plant	Umbels/plant	Umblets/plant	Seeds/umblet		Seed yield(g/plant)		Yield loss (%)
						Healthy	Diseased	healthy	Diseased	
5.5	8	70	5.2	3.0	3.2	2.8	0.8	2.1	0.7	25.0
6.5	14	91	6.9	3.8	4.0	3.4	1.2	2.2	1.0	31.2
7.5	26	105	7.7	4.1	4.2	3.0	1.9	3.8	1.6	29.6
8.5	19	113	8.3	4.3	4.7	4.1	1.4	4.2	1.1	20.7
9.5	24	94	7.1	3.9	3.4	3.1	1.9	2.6	1.5	36.5
10.0	15	82	6.1	3.4	3.7	3.4	1.3	2.4	0.9	27.2
CD (P=0.05)	5.1	12.9	1.2	0.6	0.6	0.3	0.6	1.5	0.3	

'CS 4' coriander was sown on 14 November 1998 and 16 November 1999 in each pot. Healthy plants were raised in uninoculated pots for comparison. After germination 10 plants were maintained in each pot.

* Short note

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pH, the degree of infection appeared to be affected by soil reaction (Table 1). Disease intensity in the crop at soil pH on 5.5, 6.5, 7.5, 8.5, 9.5 and 10 were 8, 14, 26, 19, 24 and 15% respectively. Disease intensity remained high at a soil pH of 7.5 and lowest at 5.5 pH but at this pH, growth characters and yield adversely affected. The results confirm the findings of Mathur (1962). The treatments significantly influenced the growth characters of coriander. Maximum plant height, branches/plant, umbels/plant, umblet/umbel and minimum

yield loss were recorded at 8.5 soil pH, whereas minimum growth characters were observed at 5.5 soil pH. Minimum disease intensity and comparative less yield loss were recorded minimum at 5.5 soil pH, which revealed the favourable effect for disease control but at this soil pH, growth and yield of coriander adversely affected. This results confirm the finding of Singh *et al.* (1995).

It clearly indicates that the stem gall disease needs to be controlled by other means or mode rather than soil pH for harvesting good yield. Stem gall intensity is pre-dominantly influenced by edaphic factors and environmental conditions.

It may be concluded that coriander crop responded significantly in term of growth characters, yield attributes, seed yield and less yield loss at pH 8.5.

SUMMARY

A pot culture experiment was conducted during the winter (*rabi*) season of 1998–99 and 1999–2000 in artificially inoculated conditions. The treatments included 6 pH levels, ie 5.5, 6.5, 7.5, 8.5, 9.5 and 10, replicated 4 times. Twenty seeds of 'CS 4' coriander were shown in November during both the

years. Healthy plants were raised in uninoculated soil for comparison with healthy plants. Coriander crop responded significantly in terms of growth character, yield attributes, seed yield and less seed yield loss at pH 8.5.

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Inter-relationships of flower, pod and seed damages by legume pod-borer (*Maruca vitrata*) (Lepidoptera: Pyralidae) in yard-long bean (*Vigna unguiculata* subsp *sesquipedalis*) *

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Key words: Yard-long bean, Legume pod-borer, Resistance evaluation

Yard-long bean [*Vigna unguiculata* ssp *sesquipedalis* (L) Verdcourt] is a distinct form of cowpea [*V. unguiculata* (L) Walp.] cultivated mostly in southern Asia and the Far East for its immature pods that are used as a vegetable. Quite different in morphology from cowpea grown for grain, yard-long bean is a trailing annual bearing long pendant pods that are inflated when young. Protracted flowering and fruiting habits of yard-long bean make it highly vulnerable to flower and fruit-feeding cowpea pests. Among such pests, legume pod-borer [*Maruca vitrata* (Fabr.) (Lepidoptera: Pyralidae)] stands out in view of its prodigious potential to severely damage yard-long bean crop in the event of serious infestation.

The usefulness of host-plant resistance in pest control is now well realized. Host-plant resistance can be well evaluated through measurement of insect damage employing damage criteria that reflect the ultimate crop loss (Tingey 1986). Jackai (1982) suggested that flower, pod and seed damages should be considered while evaluating cowpea varieties for legume pod-borer resistance. The present investigation was intended to study the inter relationships of flower, pod and seed damages by legume pod-borer in yard-long bean and to identify damage criteria to be considered for damage assessment-based resistance evaluation.

In the present study, 51 diverse cultivars of yard-long bean were selected. These cultivars were denoted by accession numbers, Vs 1 to Vs 51. The experimental crop was grown in the Instructional Farm, College of Agriculture, Vellayani, during November 1997 February 1998. This growing season was deliberately chosen to get optimum incidence of the target pest. The test entries were planted in randomized block design with 2 replications. Each plot consisted of 3 rows of 2.1 m length. Spacing was 1.0 m between rows and 0.3 m between plants. Plants were trailed on coir ropes tied between wooden stakes erected 70 cm apart along the rows of

plants. One week before planting, a susceptible grain cowpea cultivar was planted along the borders of the field to serve as multiplication foci for the test insect. Monocrotophos (as Nuvacron 40 EC) was sprayed twice at initial flowering phase and early podding stage @ 200 g a.i./ha to control aphids, flower thrips and pod-sucking bugs, so as to ensure that the population of these non-target pests would not build up to mask the effect of *Maruca vitrata* on the crop (Jackai 1983).

Flower, pod and seed damages were measured employing the parameters suggested by Jackai (1982) for assessment of legume pod-borer damage in cowpea. Flower damage was assessed as the number of larvae in a random sample of 25 flowers collected from each plot at peak flowering phases of the crop. For pod-damage assessment 2 different criteria, viz percentage pod infestation and pod damage severity (number of larval entry or exit points/pod), were used. Pod-damage measurements were made on random sample of 20 pods at vegetable maturity stage collected from each plot at peak podding phase of the crop. Seed-damage assessment was made using pod samples used for pod-damage measurements. Seed-damage index (ISD) of each cultivar was worked out:

$$ISD = \frac{ds \times 100}{pt}$$

Where ds number of seeds damaged; and pt number of pods sampled.

Data on larval count in flowers and percentage pod infestation were subjected to square root and angular transformations respectively before the analysis. A correlation analysis was done to assess the degree of association between different damage parameters.

The legume pod-borer damage parameters, viz number of larvae/25 flowers, pod infestation % pod damage severity and seed-damage index, relating to 51 yard-long bean varieties are given in Table 1. There was significant difference among the cultivars for larval count in flowers. Number of larvae in flowers was nearly 4 times in the most susceptible cultivar (Vs 33) compared with the least affected one (Vs 27). Significant

*Short note

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Table 1 Legume pod-borer damage parameter of 51 accessions of yard-long bean

Accession No.	No of larvae/ 25 flowers	Pod infestation %	Pod-damage severity	Seed-damage index
Vs1	40 (6.33)	65 (53.76)	1.10	100
Vs 2	45 (6.71)	25 (29.88)	0.35	50
Vs 3	32 (5.70)	70 (56.77)	1.85	110
Vs 4	40 (6.32)	70 (56.77)	2.05	160
Vs 5	25 (4.97)	70 (57.08)	1.60	130
Vs 6	27 (5.24)	60 (50.75)	1.40	120
Vs 7	25 (4.99)	65 (53.765)	1.65	60
Vs 8	21 (4.61)	50 (44.98)	1.10	75
Vs 9	43 (6.52)	80 (64.15)	1.30	40
Vs 10	21 (4.61)	55 (47.87)	0.75	90
Vs 11	23 (4.74)	70 (56.77)	2.35	155
Vs 12	20 (4.47)	75 (60.09)	2.15	160
Vs 13	38 (6.12)	75 (60.09)	1.55	15
Vs 14	2- (5.36)	80 (69.36)	1.70	65
Vs 15	40 (6.32)	75 (60.09)	0.95	100
Vs 16	36 (6.02)	75 (60.09)	1.30	90
Vs 17	51 (7.16)	88 (69.36)	2.20	200
Vs 18	52 (7.25)	75 (60.09)	3.05	230
Vs 19	34 (5.85)	30 (32.89)	0.70	90
Vs 20	27 (5.24)	60 (50.75)	1.20	195
Vs 21	38 (6.13)	40 (39.09)	0.90	105
Vs 22	49 (6.98)	90 (76.70)	1.80	330
Vs 23	40 (6.36)	60 (50.87)	1.30	130
Vs 24	24 (4.87)	40 (39.09)	1.10	135
Vs 25	31 (5.59)	75 (60.09)	1.40	255
Vs 26	38 (6.20)	85 (67.47)	2.35	240
Vs 27	16 (4.00)	55 (47.86)	0.95	40
Vs 28	36 (6.01)	25 (29.88)	0.35	50
Vs 29	41 (6.40)	50 (44.98)	0.75	80
Vs 30	60 (7.75)	45 (42.10)	0.55	35
Vs 31	50 (7.07)	35 (36.21)	0.75	25
Vs 32	49 (6.98)	50 (44.98)	0.80	85
Vs 33	63 (7.91)	50 (44.98)	0.75	140
Vs 34	45 (6.71)	80 (63.41)	2.15	120
Vs 35	39 (6.22)	45 (42.10)	0.95	55
Vs 36	45 (6.71)	75 (60.09)	1.75	130
Vs 37	48 (6.89)	65 (53.76)	1.40	210
Vs 38	33 (5.70)	75 (60.09)	1.75	90
Vs 39	32 (5.65)	80 (63.41)	1.40	115
Vs 40	23 (4.74)	55 (47.87)	0.80	110
Vs 41	19 (4.33)	90 (76.70)	2.55	230
Vs 42	30 (5.46)	90 (76.70)	1.95	270
Vs 43	43 (6.52)	75 (60.09)	2.00	220
Vs 44	29 (5.36)	80 (63.41)	2.30	105
Vs 45	43 (6.52)	90 (76.70)	1.90	65
Vs 46	30 (5.47)	90 (71.54)	3.05	320
Vs 47	29 (5.36)	90 (76.70)	2.15	185
Vs 48	49 (6.98)	95 (80.77)	1.90	180
Vs 49	44 (6.61)	75 (60.09)	1.60	145
Vs50	46 (6.80)	55 (47.87)	1.00	95
Vs 51	25 (5.00)	100 (90.00)	2.45	180
F _{50,50}	8.77**	6.14**	25.30**	12.41**
CD (P=0.05)	0.882	15.385	0.373	59.80
CV (%)	7.38	13.53	12.30	22.29

* P = 0.01, figures in parentheses are transformed values

difference among the cultivars for pod damage was evident irrespective of the criterion employed for damage assessment. Percentage of pod infestation ranged from 25% (Vs 2 and Vs 28) to 100 % (Vs 51), indicating substantial varietal variation for pod damage that is further supported by pod damage severity values. Incidentally, Vs 2 and Vs 28 with lowest percentage of infested pods were the cultivars with least pod-damage severity as well. Seed-damage index values also showed significant difference among the cultivars, the range of value, being 15 (Vs 13) to 330 (Vs 22). Cultivars Vs 8 and Vs 24 were statistically at par with Vs 27 for larval count in flowers and Vs 2 and Vs 28 for pod infestation %. Thus Vs 8 and Vs 24 could be considered to suffer low flower damage as well as low pod damage.

The correlation among the parameters used for the assessment of legume pod-borer damage to flowers, pods and seeds is presented in Table 2. Larval count in flowers was not correlated with either of the pod-damage measurements as well as seed-damage index values. The highly significant positive correlation ($r = 0.7729^{**}$) between pod infestation % and pod damage severity indicated that essentially similar results would be obtained when either of the criterion is employed for pod-damage assessment. Seed-damage index values showed positive and significant correlation with pod infestation (%) ($r = 0.5422^{**}$) and pod damage severity ($r = 0.6247^{**}$). This implies that a liner relationship exists between pod and seed damages by the pest. However, flower and pod

Table 2 Correlation among damage parameters of legume pod-borer

Damage parameter	Pod infestation (%)	Pod-damage severity	Seed-damage index
No. of larvae/25 flowers	-0.0807	-0.1662	0.0006
Pod infestation (%)		0.7729**	0.5422**
Pod damage severity			0.6247**

** P = 0.01

damages being uncorrelated, it is necessary to consider both flower and pod damages independently in field screening programmes. Independence of flower and pod damages indicated that larval preference for flower or pod as feeding site differed among varieties. Pod characters conferring resistance to pod infestation by the pest may be the reason for preferential attack of flowers in some varieties. Oghiakhe *et al.* (1992) identified density of trichomes on pod wall as an important factor deciding pod damage in cowpea by legume pod-borer. Highly significant positive correlation between pod and seed damages in the study suggested that seed damage need not be considered in legume pod-borer resistance evaluation in yard-long bean, had pod damage been taken into account.

Flowers and pods being the major feeding sites of legume

pod-borer larvae, the extent of damage to them would decide the ultimate crop loss in yard-long bean. The absence of correlation between flower and pod damages as evident from the present study prompt us to conclude that both flower and pod damages should be considered in field-screening programmes for evaluation of resistance to the pest in the crop. In view of the low flower and pod damages shown by Vs 8 and Vs 24, these cultivars were identified as the relatively resistant ones among the varieties under the present study.

SUMMARY

Legume pod-borer [*Maruca virata* (Fabr)]. A field experiment conducted during November 1997–February 1998 with 51 accessions of yard-long bean [*Vigna unguiculata* ssp *sesquipedalis* (L.) Verdcourt] revealed wide varietal variation in damage to flowers, pods and seeds by the interrelationships of damage measurements showed positive correlation between pod damage and seed damage but clearly demonstrated the independence of flower and pod damages. It indicated that damage to both flowers and pods should be

considered while legume pod-borer resistance screening based on insect damage is attempted in the crop.

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Life-table of Australian ladybird beetle (*Cryptolaemus montrouzieri*) feeding on mealybugs (*Maconellicoccus hirsutus* and *Dactylopius tomentosus*)

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Key words: *Cryptolaemus montrouzieri*, *Maconellicoccus hirsutus*, *Dactylopius tomentosus*, life-table

The Australian ladybird beetle (*Cryptolaemus montrouzieri* Mulsant) has been used to control mealybugs, scales, aphids, coccids and aleyrodids on a variety of plants in more than 40 countries (Bartlett 1977). The predator preys on citrus mealybug, (*Planococcus citri* Risso) (Singh 1978), pink mealybug [*Maconellicoccus hirsutus* (Green)] (Mani and Thontadarya 1988) and cochineal insect (*Dactylopius tomentosus* Lam.) infesting the wasteland weed, prickly pear (*Opuntia dillenii* Haw.) around Coimbatore. Murali Baskaran *et al.* (1999) studied the comparative life-history and feeding preference by *C. montrouzieri* on 3 mealybugs. This necessitated to study its relative rate of multiplication under abundant space and food supply of *M. hirsutus* and *D. tomentosus* which has not yet been studied so far. Hence the present study was carried out to compute the projected potential rate of *C. montrouzieri* on mealybugs, *M. hirsutus* and *D. tomentosus* as per the methods by Birch (1948), Howe (1953) and Atwal and Bains (1974).

Biology and rate of increase of population of *C. montrouzieri* on *M. hirsutus* and *D. tomentosus* were studied in laboratory at $27.8 \pm 2.2^\circ\text{C}$ and $63.3 \pm 9.2\%$ relative humidity during November 1999–January 2000 which were observed in a limited space as per the method described by Birch (1948). Five pairs of freshly emerged adults of *C. montrouzieri* were confined in a plastic container for a week along with 50% honey-soaked cotton as adult food for mating and pre-oviposition period (Mani and Krishnamoorthy 1997). They were subsequently released on red pumpkin (*Cucurbita moschata* Duchesne) infested with *M. hirsutus*, confined in a wooden cage measuring $0.3 \times 0.3 \times 0.3$ m for egg laying. Twenty-four hours after release, 160 yellowish cigar-shaped 1-day old eggs were collected and 80 eggs were used separately for each mealybug to study the life-table of *C. montrouzieri*. They were placed in a separate 5 ml penicillin glass vials in a batches of 10 each. After eclosion, first instars were separated individually, one in each vial and they were

grown on respective mealybug hosts.

Table 1 Life-table and age-specific fecundity for females of *Cryptolaemus montrouzieri* on *Maconellicoccus hirsutus*

Pivotal age (days) (X)	Age-specific longevity (I_x)	Age-specific fecundity (m_x)	Net reproductive rate ($R_0 = \sum I_x m_x$)	XI
1–26	Immature stages			
27–43	Mating and pre-oviposition period			
44	0.83	3.0	2.49	109.55
45	0.83	4.6	3.82	171.81
46	0.83	5.7	4.73	217.63
47	0.83	6.2	5.15	242.05
48	0.80	6.5	5.20	249.60
49	0.80	7.2	5.76	282.24
50	0.80	8.8	7.04	352.00
51	0.75	9.2	6.90	351.90
52	0.74	10.7	7.92	411.74
53	0.70	12.7	8.89	471.17
54	0.69	12.0	8.28	447.12
55	0.64	11.7	7.49	411.84
56	0.60	10.6	6.36	356.16
57	0.55	9.7	5.34	304.09
58	0.50	8.0	4.00	232.00
59	0.44	7.6	3.34	197.30
60	0.40	6.7	2.68	160.80
61	0.35	5.8	2.03	123.83
62	0.31	4.7	1.46	90.33
63	0.25	2.6	0.90	56.70
64	0.16	3.2	0.51	32.64
65	0.11	2.7	0.30	19.50
66	0.05	1.2	0.06	3.96
67	0.01	0.0	0.0	0.0
$\Sigma m_x = 162.1$ $\Sigma I_x m_x = 100.65$ $\Sigma XI_x m_x = 5295.97$				

*Short note

^{1,2}Assistant Professor, ^{3,4}Research Fellow, ⁵Professor and Head, Department of Agricultural Entomology

Table 2 Life-table and age-specific fecundity for females of *Cryptolaemus montrouzieri* on *Dactylopius tomentosus*

Pivotal age (days) (X)	Age-specific longevity (l_x)	Age-specific fecundity (m_x)	Net reproductive rate ($R_0 = \sum l_x m_x$)	$\sum l_x m_x$
1-32	Immature stages			
33-49	Mating and pre-oviposition period			
50	0.75	3.3	2.48	123.75
51	0.73	4.7	3.43	174.98
52	0.73	6.0	4.38	227.76
53	0.71	7.2	5.11	270.94
54	0.70	8.6	6.02	325.08
55	0.66	9.7	6.40	352.11
56	0.66	10.6	7.00	391.78
57	0.63	9.2	5.80	330.37
58	0.56	8.7	4.87	282.58
59	0.49	7.6	3.72	219.72
60	0.40	7.0	2.80	168.00
61	0.36	6.2	2.23	136.15
62	0.28	5.7	1.60	98.95
63	0.20	4.7	0.94	59.22
64	0.14	3.6	0.50	32.26
65	0.06	2.7	0.16	10.53
66	0.03	1.0	0.03	1.98
$\sum m_x = 106.5$ $\sum l_x m_x = 57.74$ $\sum X l_x m_x = 2907.43$				

Observations on hatching of eggs, larval development, per cent pupation and adult emergence and mortality occurred in these stages were taken. For determining the age specific fecundity, known number of adults emerged on a same day were transferred to a separate tube measuring 7.5 cm x 2.5 cm. The fecundity was assessed by counting the eggs daily till all the females died and the number of female births (m_x) for a given age interval was obtained by dividing total number of eggs laid by 2 as the sex ratio was 1:1. The column headings proposed by Birch (1948), Howe (1953) and Atwal and Bains (1974) including, X, pivotal age in days; l_x , survival of females at age 'x'; and m_x , age schedule for female births at age 'x' etc, were used for the construction of life-fecundity table.

The developmental period of various life stages, egg, larva and pupa was prolonged when *C. montrouzieri* was grown on *D. tomentosus* than *M. hirsutus*, indicating maximum duration lasted for 4, 18 and 11 days and 4, 14 and 10 days respectively. The survival of immature stages (l_x) from egg to adult emergence was 0.83 and 0.75 adult individual for *M. hirsutus* and *D. tomentosus* respectively (Tables 1,2). The first female mortality was observed on day 5 ($l_x=0.80$) and 2 day ($l_x=0.73$) after the emergence of adult female and increased slowly thereafter. The females of *C. montrouzieri* contributed

the highest fecundity of ($m_x=12.7$) and ($m_x=10.6$) in the life span on day 53 and 56 of pivotal age on *M. hirsutus* and *D. tomentosus* respectively. The net reproductive rate (R_0) representing the total female births was 100.65 and 57.74. Thus, the rate of increase of population of *C. montrouzieri* and *D. tomentosus* would be 100.65 and 57.74 times generation, respectively (Tables 1,2). Percentage of apparent and real mortalities for different life stages of *C. montrouzieri* were low. No mortality was recorded during adult stage. The real mortality at various stages of *C. montrouzieri* was 3.73, 1.25, 1.25, 1.25, 1.25, 2.50 and 3.75% and 4.23, 2.50, 1.25, 2.50, 2.50 and 5.00% in egg, I, II, III IV instar, prepupa and pupa on *M. hirsutus* and *D. tomentosus* respectively.

The innate capacity for increase in numbers (r_m) of *C. montrouzieri* was 0.0876 and 0.0806 females/female/day with a daily finite rate of increase (λ) of 1.0942 and 1.0833 females/female/day on *M. hirsutus* and *D. tomentosus* respectively. The mean time for completing a generation was 50.35 and 59.52 days (Table 3). The value of r_m (capacity for increase) was 0.09 and 0.08 females/female/day on *M. hirsutus* and *D. tomentosus*, respectively, which were calculated with the help of assumed values of r_m (0.07 and 0.09). The 2 values were plotted on the horizontal axis against their respective m_x on the vertical axis separately for 2 mealybugs. The 2 points were joined to give a line which intersected a vertical line drawn from the desired value ($e^{7-r_m \times m_x} = 1096.6$). The point of intersection gave the accurate r_m which represented the rate of multiplication in terms of number of females/female/day. At this rate of r_m , the doubling time required for the population of *C. montrouzieri* was 8.210 and 8.664 days and the population

Table 3 Population growth statistics of *Cryptolaemus montrouzieri* on *Maconellicoccus hirsutus* and *Dactylopius tomentosus*

Parameters	<i>M. hirsutus</i>	<i>D. tomentosus</i>
Gross reproductive rate ($\sum m_x$)	162.10	106.50
Net reproductive rate ($R_0 = \sum l_x m_x$)	100.65	57.74
Mean length of generation (days) ($T_c = \sum X l_x m_x$)	50.35	59.52
Innate capacity for increase (females/female/day) ($r_m = \log_e R_0 / T_c$)	0.0876	0.0806
Arbitrary r_m	0.07, 0.09	0.07, 0.09
Corrected $r_m = \sum e^{7-lm_x \times m_x}$ (graphically) (females/female/day)	0.09	0.08
Finite rate of increase in number (=antilog r_m) (females/female/day)	1.0942	1.0833
Doubling time ($\log_e 2 / r_m$)	8.210	8.664
Rate of weekly multiplication of population (antilog r_m) ⁷ females/female/day	1.8780	1.7507

was capable of multiplying 1.8780 and 1.7507 times/week under the specified environmental condition on *M. hirsutus* and *D. tomentosus* respectively (Table 3).

The contribution made by different stages towards stable age distribution of *C. montrouzieri* was determined and on reaching the stable age distribution, the population of *C. montrouzieri* in various stages, egg, larva, pupa and adult contributed to 38.16, 45.65, 8.75 and 7.44% and 35.01, 52.24, 6.97 and 5.79% on *M. hirsutus* and *D. tomentosus*, respectively.

The rate of multiplication indicated that under conditions of abundant space and food supply, population of *C. montrouzieri* on *M. hirsutus* and *D. tomentosus* increased with 0.0876 and 0.0806 (r_m) and 1.0942 and 1.0833 (λ) females/female/day respectively. The rate of increase of population of *C. montrouzieri* between 2 successive generations was 57.74 times when reared on *D. tomentosus* which was almost doubled (100.65 times) on *M. hirsutus*. Similarly, the mean time for completion of 1 generation was 50.35 and 59.52 days. The prolongation of life time and reduction in multiplication rate of *C. montrouzieri* on *D. tomentosus* might be due to differential preference by beetles on prey species, as mentioned by Tirumala Rao and David (1958) and Murali Baskaran *et al.* (1999) in which they reported that *C. montrouzieri* took 32.51 days from egg to pupa when reared on *D. tomentosus* compared to 26.09 days on *Planococcus citri*. Though there was an extended life-cycle for *C. montrouzieri* on *D. tomentosus*, there was no significant difference with reference to per cent real mortality in different life stages on both host mealybugs.

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SUMMARY

An experiment was conducted during November 1999 to January 2000 at $27.8 \pm 2.2^\circ\text{C}$ and $63.3 \pm 9.2\%$ relative humidity on the relative survival and multiplication of *Cryptolaemus montrouzieri* Mulsant on mealybugs, *Maconellicoccus hirsutus* (Green) and *Dactylopius tomentosus* Lam. The innate capacity for increase of population of *C. montrouzieri* (r_m)

was 0.0876 and 0.0806 with finite rate of increase (λ) of 1.0942 and 1.0833 females/female/day on *M. hirsutus* and *D. tomentosus* respectively. The population multiplied 100.65 and 57.74 times between 2 successive generations and mean time for completing a generation was 50.35 and 59.52 days on *M. hirsutus* and *D. tomentosus* respectively. On reaching the stable age distribution, the population of *C. montrouzieri* in various stages, egg, grub, pupa and adult contributed respectively 38.16, 45.65, 8.75 and 7.44% and 35.01, 52.24, 6.97, and 5.79% for *M. hirsutus* and *D. tomentosus*.

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Effect of zinc on reproductive physiology of pea (*Pisum sativum*)

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Zinc deficiency is reported from several parts of the country. Pulse crops, in general are quite sensitive to zinc deficiency. Zinc deficiency can be corrected to some extent by the application of inorganic zinc salts to the soil (Nayyar and Takkar 1980). The essential role of zinc has been established as a component of several enzymes concerned with carbohydrate and nitrogen metabolism, in addition to its involvement directly or indirectly in regulating the various physiological processes of plants (Marschner 1995). One of the zinc-containing enzymes, carbonic anhydrase is largely localized in chloroplast as well as in cytoplasm, its activity is known to reduce in zinc deficiency which in turn is responsible for decreased photosynthesis (Ohki 1978, Dell and Wilson 1989).

This paper describes the zinc deficiency effects and addition of or withdrawal of Zn on growth, metabolism and reproductive biology of pea (*Pisum sativum* L., s.l.) by growing the plants in refined sand at 2 deficient and 1 adequate levels of zinc.

In winter season of 1997–98 and 1998–99 'Oracle' pea was grown in purified sand (Agarwala and Chatterjee 1996) in polyethylene containers of 5-litre capacity. Plants were raised at 3 levels of zinc supplied as zinc sulphate: deficient (0.0065 mg/litre), subnormal (0.0325 mg/litre) and adequate (0.065 mg/litre). The composition of the nutrient solution excluding zinc was mg/litre: KNO₃, 400; Ca(NO₃)₂, 660; MgSO₄, 490; NaH₂PO₄, 230; Fe (Fe-EDTA), 5.6; Mn (MnSO₄), 0.55; Cu(CuSO₄), 0.065; B(H₃BO₃), 0.33; Cl (NaCl), 3.5; Mo(Na₂MoO₄), 0.02; Co(CoSO₄), 0.012; and Ni (NiSO₄), 0.012.

The contribution of zinc from purified sand, water and nutrient solution was not more than 0.0001 mg/litre which was taken into consideration while supplying variable levels of zinc. Initially in each treatment, there were 6 pots. At the time of emergence of flowers (day 38), plants were given additional treatments; from the deficient (0.0065 mg/litre) and subnormal level (0.0325 mg/litre) of zinc 2 pots with 4 plants in each were supplied adequate zinc (0.065 mg/litre) daily for 38 days. Similarly, at day 38, zinc was withdrawn from 2 pots previously

supplied with adequate zinc (0.065 mg Zn/litre).

On 39 day of additional treatments (after 76 days of sowing), plants were sampled from the respective treatments for dry matter, pod and seed yield and zinc in plant tissue. Plant samples drawn from each treatment were thoroughly washed with glass distilled water and dried for 48 hr at 70°C and dry weight was determined. Zinc in dried leaves and air-dried seeds was estimated by atomic absorption spectrophotometer in clear solution obtained after treating with HNO₃–HClO₄ (10 : 1) (Piper 1942). Carbonic anhydrase activity was assayed in fresh leaf extracts and protein in seeds was determined according to the methods described by Agarwala and Chatterjee (1996). All data were analysed for standard error ($\pm$ SE).

Zinc deficiency in pea depressed growth (at day 30) and induced interveinal chlorosis of middle leaves at 0.0065 mg Zn/litre. These plants appeared stunted due to shortening of internodes might be an expression of impaired auxin metabolism as zinc plays an important role in the biosynthesis of auxins (Marschner 1995). In moderate deficiency of zinc (0.0325 mg/litre) except for depression in growth of the plants, no deficiency symptoms were observed. The symptoms of Zn deficiency, chlorosis and shortening of internodes in pea are in consonance with those described for plants other than pea (Bergmann 1992). As has been suggested by Marschner (1995), pea appears to be less susceptible than cereals to zinc deficiency.

The highly reduced biomass, pod and seed yield (Table 2) in low zinc are in agreement with the results of zinc-deficient soybean (*Glycine max*) and wheat (*Triticum aestivum* L. emend. Fiori & Paol.) (Ohki 1978, Hemantaranjan 1996). The lowered biomass in zinc-deficient pea might be due to disturbed carbohydrate and protein metabolisms and reduced rate of photosynthesis, resulting in lowered supply of assimilates to be utilized for vegetative growth (Ohki 1978) under low zinc conditions.

In pea, zinc deficiency reduced the pod and seed yields more than vegetative yield. Thus lowering in reproductive yield might be due to delayed and abortive flowering and poor development of reproductive organ (Table 1). Low zinc in pea caused poor seed setting, substantiating a major role

* Short note

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Table 1 Influence of zinc deficiency on reproductive parts, pod and seed yield of pea

Zinc mg/litre	Flower number /plant	Anther size (μm) ^a	day 40			day 76	
			Pollen width (μm) ^b	Pollen length (μm) ^c	Ovary length (cm)	Pod/ plant	Seed/plant
0.0065	2	1230 $\pm$ 1.1	27.6 $\pm$ 0.25	39.1 $\pm$ 0.52	0.70 $\pm$ 0.29	4	8
0.0325	4	1239 $\pm$ 2.1	30.8 $\pm$ 0.34	42.7 $\pm$ 0.38	0.90 $\pm$ 0.23	7	15
0.065	8	1254 $\pm$ 2.3	31.6 $\pm$ 0.35	47.4 $\pm$ 0.23	0.92 $\pm$ 0.06	10	32

a, Mean values based on 20 measurements, b and c, mean values based on 25 measurements

of zinc in the development of anthers and pollen viability as has been observed in maize (*Zea mays* L.). These results might indicate that requirement of zinc is rather high for reproductive phase than for vegetative growth and establishes the involvement of high concentration of zinc in seed and pod development.

As has been reported earlier for soybean (Hemantaranjan 1996), 4.9 $\mu\text{g/g}$ dry matter zinc concentration in pea leaves exhibited foliar symptoms of zinc deficiency. At day 76, zinc content in leaves and seeds from deficient pea plants were

yield might be due to higher availability of zinc during development as reflected by increased zinc concentration in leaves and seeds after resupply of zinc to deficient plants. It appears that increase in protein content in seeds is dependent on the improved translocation of photosynthates to seeds from source as a result of resumption of zinc to deficient plants. As a consequence of which there is about 17% increase in the protein content of seeds. This ultimately accelerated the boldness of seeds. The increase in the activity of carbonic anhydrase in this treatment was more than 2 times higher from

Table 2 Influence of zinc deficiency, addition and withdrawal of zinc on biomass, seed weight, zinc concentration and carbonic anhydrase activity in leaves and concentration of protein and zinc in seeds of pea

Zinc (mg/litre)	Biomass (g/plant)	Seed weight (g/plant)	Zn(μg)/g dry weight		Carbonic anhydrase EU/mg protein	Seed protein % fresh weight
			Leaves	Seeds		
0.0065	4.45 $\pm$ 0.65	1.56 $\pm$ 0.11	4.9 $\pm$ 0.35	20.0 $\pm$ 0.21	50.3 $\pm$ 1.82	14.0 $\pm$ 0.12
0.0325	8.05 $\pm$ 1.10	2.75 $\pm$ 0.14	16.4 $\pm$ 0.21	30.9 $\pm$ 0.22	93.2 $\pm$ 2.01	18.5 $\pm$ 0.35
0.065	11.13 $\pm$ 1.21	5.59 $\pm$ 0.25	35.9 $\pm$ 0.18	42.8 $\pm$ 0.56	230.0 $\pm$ 3.22	23.0 $\pm$ 0.02
0.0065+0.065	6.6 $\pm$ 0.85	1.89 $\pm$ 0.18	31.8 $\pm$ 0.89	28.6 $\pm$ 0.12	123.0 $\pm$ 2.10	17.5 $\pm$ 0.10
0.0325+0.065	10.40 $\pm$ 1.21	4.32 $\pm$ 0.21	39.8 $\pm$ 0.31	32.6 $\pm$ 0.28	143.0 $\pm$ 4.02	19.5 $\pm$ 0.11
0.065-Zn (0.0065)	8.82 $\pm$ 0.81	4.17 $\pm$ 0.18	31.1 $\pm$ 0.02	35.0 $\pm$ 0.18	190.0 $\pm$ 3.51	13.0 $\pm$ 0.08

respectively 4.9 and 20 $\mu\text{g/g}$ dry matter (Table 2). In zinc-deficient leaves of tomato (*Lycopersicon esculentum* Miller nom. cons.) and soybean tops, Zn has been reported in the range of 0–20 $\mu\text{g/g}$ (Mengel and Kirkby 1987).

The reduction in carbonic anhydrase activity in zinc deficient leaves (Table 2) is in agreement with the findings of Dell and Wilson (1989) and Chatterjee *et al.* (1998) and can be attributed to the known role of zinc as a constituent of the enzyme which prevents the chloroplastic protein from being denatured. Zinc deficiency not only reduced the seed yield of pea but also lowered its boldness and protein content in seeds. This might be due to essential role of zinc in protein biosynthesis (Marschner 1995).

Resumption of adequate zinc through roots to deficient plants at flowering stage not only improved the growth and biomass of pea but also increased considerably the number and weight of pods and seeds. The increase in pod and seed

that of the plants without added zinc (Table 2). This might be due to higher availability of zinc for incorporation in the enzyme protein. At the same time, withdrawal of zinc from adequate plants reduced the dry matter, pod and seed yields from that obtained in adequate plants. The seed weight and protein content in seeds depressed markedly in this treatment.

The nutritional value of pea seeds is deteriorated in low zinc treatment as has been observed by Marschner (1995) because of the lowering of zinc/phytate ratio which can be improved in seeds through application of zinc fertilizers (Peck *et al.* 1980); this in turn might increase total phosphorus and protein contents of the seeds as has been obtained in pea.

These results indicate that the supply of sufficient zinc to deficient plants even at the flowering stage partially improves the economic yield of plants.

SUMMARY

An experiment was conducted during 1997–99 to study

the influence of zinc deficiency on reproductive biology of 'Oracle' pea (*Pisum sativum* L., s.l.), by growing the plants in refined sand till maturity at deficient (0.0065 mg/litre), subnormal 0.0325 mg/litre) and adequate (0.065 mg/litre) zinc. Zinc deficiency was induced on plants at 0.0065 mg Zn/litre as discoloration of middle leaves changing to interveinal chlorosis along with shortening of internodes. In pea low zinc reduced the biomass, size of pollen grains and ovaries, yield of pods, seeds, activity of carbonic anhydrase in leaves and protein content in seeds. At the initiation of flowering, resumption of adequate zinc (0.065 mg/litre) to zinc deficient (0.0065 and 0.0325 mg/litre) plants improved the growth, biomass (19%), concentration of zinc in leaf and seed, number and weight of pods and seeds and stimulated carbonic anhydrase activity in leaves considerably. At the same time withdrawal of zinc from adequate plants at the initiation of flowering significantly lowered the biomass, seed and pod yield, seed protein and specific activity of carbonic anhydrase in pea.

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THE INDIAN JOURNAL OF AGRICULTURAL SCIENCES

GUIDELINES TO AUTHORS

The Indian Journal of Agricultural Sciences is published every month. The following types of material are considered for publication on meeting the style and requirements of the journal (details in December 1996 issue).

1.1 ARTICLES ON ORIGINAL RESEARCH COMPLETED, not exceeding 4 000 words (up to 15 typed pages, including references, tables, etc) should be exclusive for the journal. They should present a connected picture of the investigation and should not be split into parts. Complete information of Ph D thesis should preferably be given in 1 article.

1.2 SHORT RESEARCH NOTES, not more than 1 300 words (total 5 typed pages), which deal with (i) research results that are complete but do not warrant comprehensive treatment, (ii) descriptions of new material or improved techniques or equipment, with supporting data, and (iii) a part of thesis or study. Such notes require no headed sections.

1.3 CRITICAL RESEARCH REVIEW ARTICLES, showing lacunae in research and suggesting possible lines of future work. These are mostly invited from eminent scientists.

1.4 The research article or note submitted for publication should have a direct bearing on agricultural production or open up new grounds for productive research. Articles on agricultural engineering, agricultural economics and Home Science are also considered. Basic type of articles and notes relating to investigation in a narrow specialized branch of a discipline may not form an appropriate material for this journal, nor do the articles of theoretical nature, or those of local importance, repetitive, based on old data, with no positive significance, or on extension education.

1.5 Author should note: (a) period (years) of conducting the experiment must be indicated, (b) article should preferably be submitted soon after completion of experiment, (c) articles on genetics and plant breeding and on plant crops should be based on data of minimum 2 years, (d) contribution involving a former or present student must clarify that it is not based/based on complete M Sc thesis, or complete or a part of the Ph D thesis, indicating its year of submission and (e) Article Certificate must be signed by all the authors.

2.1 TITLE should be short, specific and informative. It should be phrased to identify the content of the article and include the nature of the study and the technical approach, essential for key-word indexing and information retrieval.

2.2 A SHORT TITLE not exceeding 35 letters should also be provided for running headlines.

2.3 BY-LINE should contain, in addition to the names and initials of the authors, the place (organization) where research was conducted. Change of address should be given as a footnote and correspondence address separately.

3. ABSTRACT, written in complete sentences, should not have more than 150 words. It should contain a very brief account of the materials, methods, results, discussion and conclusion, so that the reader need not refer to the article except for details. It should not have references to literature, illustrations and tables.

4.1 INTRODUCTION part should be brief and limited to the statement of the problem or the aim and scope of the experiment. The review of recent literature should be pertinent to the problem. Key words of the article should be given in the beginning.

4.2 Relevant details should be given of the MATERIALS AND METHODS including experimental design and the techniques used. Where the methods are well known, citation of the standard work is sufficient. Mean results with the relevant standard errors should be presented rather than detailed data. The statistical methods used should be clearly indicated.

4.3 RESULTS AND DISCUSSION should be combined, to avoid repetition.

4.4 The results should be supported by brief but adequate tables or graphic or pictorial materials wherever necessary. Self-explanatory tables should be typed on separate sheets, with appropriate titles.

4.5 The tables should fit in the normal lay-out of the page. All weights and measurements must be in SI (metric) unit. Tables and illustrations (up to 20% of text) should not reproduce the same data.

4.6 The discussion should relate to the limitations or advantages of the author's experiment in comparison with the work of others. All recent relevant literature should be discussed critically.

4.7 Line-drawings should be clearly drawn (8.5 or 17 cm width) in black waterproof ink on smooth, tough paper. Minor points of style should be noted carefully. Photographs should be large, unmounted, glossy prints of good quality. They should be clear and relevant to the subject. Colour photographs may be sent for better identification or differentiation of different parts of the object. Line-drawings and photographs should have legends (typed). Original artwork should accompany 2 copies. Repetition in graphic and tabular matter should be avoided.

5 For citing REFERENCES a recent issue of the journal should be consulted, ensuring that the names and dates in the text and at the end correspond. Each citation should have the names of the authors, initials, year of publication, full title of the article, name of the journal (without abbreviation), volume, preferably the issue (within parentheses), and complete page-range (not merely the first page). Complete name of publisher and place of publication of books should be given. For proceedings or other publications complete details should be given.

6 All articles are sent to referees for scrutiny, and authors should meet criticism by improving the article, indicating the modifications made (in separate sheet, 2 copies).

7 Articles should be TYPEWRITTEN, and double spaced throughout (including by-line, abstract, references and tables) on white, durable bond paper of size 22 cm × 28 cm, with a 4 cm margin at the top, bottom and left. Articles should be sent in triplicate after checking typographical errors.

8 FOR WRITING, authors are requested to consult *The Council of Biology Editors Style Manual*, edn 4 (or later edition), American Institute of Biological Sciences, Washington DC. The language and spellings are followed as per British style, not American.

9 PROOF-CORRECTION should be in ink, in the margin. All queries marked in the article should be answered. Proofs are supplied for a check-up of the correctness of type-setting and facts. Excessive alterations may be charged to the author. Proofs must be returned in time

10 Contributors will receive one free copy of the issue.

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