63 (07) CODEN: IJASA3 72 (7): 377 – 442 (2002) II ISSN 0019-5022

The Indian Journal of Agricultural Sciences

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

7 *Indian J agric Sci* Vol 72 no. 7 pp 377–442 New Delhi JULY 2002

	Inland	Foreign
Single copy	Rs 75	UK £ 5, US $ 7
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THE INDIAN JOURNAL OF AGRICULTURAL SCIENCES

Previous issue : Vol 72, no.5, pp 315–376

Vol 72, no. 7 July 2002

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Indian Journal of Agricultural Sciences 72 (7) : 379–82, July 2002

Evaluation of aromatic rice cultivars in foot-hill zone of West Bengal

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Received: 20 February 2002

ABSTRACT

A field experiment was conducted during the rainy season of 1999 and 2000 at foot-hill zone of West Bengal, to study the performance of 14 aromatic rice (*Oryza sativa* L.) cultivars including a local check. In dwarf, medium-late duration group, 'Haryana Basmati', 'Karnal Local', 'PK 1505-9-2-13-1' having >2.0 tonnes/ha yield potentiality, higher nutrient assimilating power from native and fertilizer sources, >75% brown rice recovery, long-slender type kernel and strong to moderate aroma might be adopted in this zone considering both domestic as well as export purposes. However, among tall, long-duration ones, *'Seetabhog' performed well by producing >200 filled grains/* panicle, >1.8 tonnes/ha grain yield, >75% brown rice recovery, relatively higher nutrient assimilation efficiency and moderate aroma. This cultivar might, therefore, be selected as promising among short-grained ones.

Key words: Aromatic rice, *Oryza sativa*, Yield, Grain quality, Nutrient uptake

Quality of aromatic rice (*Oryza sativa* L.) is a result of interaction between genotype, soil and environmental factors. In foot-hills region of West Bengal, the rainy-season (June–October) crop experiences a temperature range of 23 to 31°C and receives 2 000–2 500 mm rainfall due to south–west monsoon. As the aromatic rice varieties require relatively cooler temperature (25°C day and 21°C night) during crop maturity for better retention of aroma (Juliano 172, Mann 1987); this zone, though a non-traditional area for aromatic rice till date, may have a great potentiality to produce a sizeable quantity of scented rice during the rainy season. Hence identification of suitable aromatic rice genotype(s) for this particular agro-climatic region is major concern of the study.

MATERIALS AND METHODS

The field experiment was conducted during the rainy season of 1999 and 2000 at Pundibari, Coochbehar, West Bengal. The soil was sandy loam, having *p*H 5.6, organic carbon 0.68% and available N and K of 210, 8.67 and 134.46 kg/ha respectively. Fourteen aromatic rice cultivars including a 'Local' check were arranged in randomized block design with 3 replications. Thirty-day-old-seedlings @ 2–3/hill were transplanted in puddled soil by adopting a 20 cm × 15 cm spacing in a plot size of 9 m^2 for each treatment. A uniform dose of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha was given to each treatment where the entire quantity of phosphate and potash were applied basal. Nitrogen was supplied through urea in 3 splits (one-fourth at transplanting, half at active tillering and rest one-fourth at panicle-initiation state). The other agronomic practices were followed as per standard recommendations for aromatic rice cultivation.

Plant height, yield components and yield were recorded at maturity. A composite sample of 3 replicates was taken for determining grain quality. After dehusking the grains by hand, the length and breadth of the kernel were measured by graph paper method. Kernel type was determined following the scale of Govindaswamy *et al.* (1985). Intensity of aroma was scored using qualitative analysis of Singh *et al.* (1986). Grain and straw samples were analysed for N, P and K contents (Piper 1966) and their uptake values were computed by multiplying with dry-matter yield. Protein percentage of grain was determined by multiplying total N with 5.95. Pooled analysis (over 2 years) of the data obtained were done following standard statistical methods (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Plant type characters, yield components and yield

Out of 14 cultivars tested, 4 were medium early (110–120 days), one medium (120–130 days), 5 medium late (130–140 days) and remaining 4 long duration (> 140 days) types (Table 1). Analysis of variance showed significant differences for all the characters among the cultivars. Plant height ranged from 80.0 cm ('Madhuri') to

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Table 1 Plant type characters, yield attributes and yield of different aromatic rice cultivars (pooled data of 2 years)

Cultivar	Duration (days)	Plant height (cm)	Panicle length (cm)	Panicles/ hill	Filled grains/ panicle	Chaffs/ panicle	1 000-grain weight (g)	Grain yield (toones/ ha)	Straw yield (tonnes/ ha)	Harvest index (%)
'Haryana Basmati'	134	86.2	25.9	10.25	65.4	43.1	22.02	2.56	4.55	36.1
'Karnal Local'	134	89.7	26.8	7.98	79.6	47.0	18.91	2.46	4.72	34.2
'PK 1505-9-2-13-1'	131	83.3	22.9	8.84	80.5	28.6	24.48	2.03	4.26	32.3
'Madhuri'	132	80.0	22.2	9.80	89.0	30.2	21.27	2.20	4.68	32.0
'Hansraj'	118	81.6	23.0	1.36	78.6	28.4	21.47	1.97	3.41	36.6
'Basmati Rajasthan'	116	114.5	25.9	9.69	71.7	28.6	20.84	1.15	2.99	27.8
'Binam'	116	132.0	24.4	8.23	61.9	22.2	17.59	1.16	2.99	28.0
'Domsiah'	116	121.11	26.8	7.68	67.1	26.9	15.77	1.11	3.12	26.2
'Basmati 370'	124	108.6	25.9	8.02	70.7	34.2	21.17	1.40	3.74	27.2
'Pusa Basmati 1'	134	94.9	29.0	7.21	89.3	45.8	21.95	1.43	4.60	23.6
'Ambemohar 159'	148	131.4	24.7	10.50	115.1	22.0	13.26	1.75	6.26	21.9
'Radhunipagal'	148	131.6	24.3	11.55	153.6	43.8	10.12	1.59	6.53	19.6
'Seetabhog'	148	119.0	26.4	11.92	209.2	108.4	13.21	1.89	5.48	25.6
'Tulsibhog' (Local check)	149	131.7	27.4	11.23	133.5	55.4	12.89	1.90	6.22	23.4
Mean	132	107.5	25.4	9.52	97.4	403	18.21	1.76	4.54	28.2
SEm±	2	1.54	0.56	0.62	3.1	1.6	0.11	0.23	0.51	
CD (P=0.05)	8	4.27	1.56	1.71	8.6	4.4	0.30	0.71	1.57	

132.0 cm ('Binam') showing 6 in dwarf to semi-dwarf and 8 in intermediate to tall group. The maximum and minimum panicle length were recorded with 'Pusa Basmati' 1 (129.0) and 'Madhuri' (22.2 cm) respectively. Number of panicles/ hill varied widely among the cultivars ranging between 7.21('Pusa Basmati 1') and 11.92 ('Seetabhog'). It was revealed that only long-duration cultivars ('Seetabhog', 'Radhunipagal', 'Tulsibhog', and 'Ambemohar 159') produced >100 filled grains/panicle; however, the number of chaffy spikelets varied within a range between 22.0 and 108.4 . Short-grained cultivars had significantly lower 1 000-grain weight and it happened to be a genetical character. The results confirm the findings of Sadhukhan and Chattopadhyay (2001), wherein the tall statured local aromatic types were longer in maturity and they had more grains/panicle, but the grain size was very small in terms

Table 2 Quality attributes of grains of different aromatic rice cultivars during kharif season (poled data of 2 years)

Cultivar	Husk (%)	Brown rice (%)	Kernel length (mm)	Kernel breadth (mm)	Length : breadth ratio	Kernel type*	Protein content (%)	Aroma**
'Haryana Basmati'	29.3	70.7	6.9	1.9	3.63	LS	9.07	3
'Karnal Local'	24.0	76.0	7.5	2.0	3.75	LS	7.80	2
'PK 1505-9-2-13-1'	23.3	76.7	7.0	2.0	3.50	LS	9.53	2
'Madhuri'	34.3	65.7	6.4	2.1	3.05	LS	9.63	2
'Hansraj'	23.0	77.0	6.9	1.9	3.63	LS	7.13	1
'Basmati Rajasthan'	24.0	76.0	6.9	1.8	3.83	LS	10.32	3
'Binam'	30.0	70.0	7.0	2.2	3.18	LS	9.43	2
'Domsiah'	30.0	70.0	7.7	1.9	4.05	LS	9.49	2
'Basmati 370'	18.7	81.3	7.2	1.9	3.79	LS	6.66	2
'Pusa Basmati 1'	26.0	74.0	7.6	2.0	3.80	LS	7.57	2
'Ambemohar 159'	32.0	68.0	5.9	1.9	3.11	SS	9.38	2
'Radhunipagal'	27.3	72.7	3.8	1.9	2.00	SB	8.40	2
'Seetbhog'	20.3	79.7	4.3	1.8	2.39	SB	7.92	2
'Tulsibhog' (Local check)	23.7	76.3	5.3	1.9	2.79	MS	9.51	2
Mean	26.1	73.9	6.5	1.9	3.32		8.70	

*LS, Long-slender; MS, medium-slender; SS, short-slender; SB, short-bold; **rated using a scale of 1–3, where 1, mild aroma; 2, moderate aroma; 3, strong aroma

of 1 000-grain weight.

Grain yield, as the end-product of interaction among the yield components, differed significantly among the cultivars. Of 14 cultivars studied, onl 5 ('Haryana Basmati', 'Karnal Local', 'Madhuri', 'PK 1505-9-2-13-1' and 'Hansraj') outyielded the local check ('Tulsibhog') and on the contrary, 3 cultivars ('Domsiah', 'Basmati Rajasthan', and 'Binam') were very low-yielding. Higher straw yield (>5 tonnes/ha) as well as lower harvest index (<26%) of long-duration traditional cultivars as observed in this study, might be due to vigorous foliage growth.

Grain quality

Seven cultivars showed >75% brown rice recovery ranging from 76.0% ('Karnal Local' and 'Basmati Rajasthan') to 81.3% ('Basmati 370') (Table 2). The length and breadth of the kernel, being genetically controlled, differed among the cultivars and all 10 cultivars except the long-duration ones belonged to long-slender group, wherein 'Domsiah', 'Pusa Basmati 1' and 'Karnal Local' recorded greater (> 7.5 mm) kernel length. 'Radhunipagal' and 'Seetabhog' were placed in short-bold, 'Ambermohar 159' in short slender and 'Tulsibhog' (local check) in medium-slender group. In this line of research, earlier workers also reported similar observations. There was wide variation in protein content of grain ranging from 6.66 ('Basmati 370') to 10.32% ('Basmati Rajasthan'). Of the cultivars tested, 2 ('Haryana Basmati' and 'Basmati Rajasthan') had strong, 11 moderate and 1 ('Hansraj') possessed mild aroma.

Nutrient uptake

Significant variations were observed in the uptake of N in rice grain and straw among the cultivars (Table 3). 'Tulsibhog' had highest efficiency in assimilating N from both soil and fertilizer sources, while 'Basmati 370' recorded the least. In case of non-aromatic rice varieties, about 73% of N was translocated to grain and the remaining in straw (Madhuswamy *et al.* 1973), but in aromatic rice cultivars these values were reasonably lower (average 47%). Efficiency of the cultivars in translocated N in grain was the highest in 'Haryana Basmati' (61%), followed by 'PK 1505-9-2-13-1' (50%) and the least in 'Tulsibhog' (37%).

Barring few exceptions, the uptake of N and P in all the cultivars was higher in straw than in grain which was in contrast with that of non-aromatic varieties (Rao *et al.* 1988). Maximum P uptake was observed in 'Hansraj' and minimum in 'Domsiah'.

Uptake of K was always higher in straw than in rice grain which was in conformity with the findings of Rao *et al.* (1988). Significant variations in K uptake in grain were observed among the cultivars. Highest K uptake in grain was found in 'Karnal Local' and the least in 'Basmati 370'. On an average, only about 5% of total K removal was translocated to grain and rest was to straw.

Based on the results, emphasis needs to be paid towards the introduction of dwarf, medium-late aromatic rice like 'Haryana Basmati', 'Karnal Local', 'PK 1505-9-12-13-1' with desirable genetic architecture towards nutrient uptake and better translocation of the same to the sink as reflected by their desirable yield potentiality (< 20 tonnes/ha), high (>75%) brown rice recovery, long-slender kernel along with moderate to strong aroma for both the domestic and export purposes. However, among short-grained, tall, long-duration cultivars, 'Seetabhog' having >200 filled grains/panicle, > 1.8 tonnes/ha grain yield, >75% brown rice recovery and moderate aroma may appear promising

Table 3 Nitrogen, phosphorus and potassium uptake by aromatic rice cultivars (pooled over 2 years)

Cultivar	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
'Haryana Basmati'	38.12	24.41	62.53	2.82	6.43	9.25	4.82	59.81	64.63
'Karnal Local'	32.09	36.23	68.32	3.35	6.99	10.35	5.60	81.48	87.08
'PK 505-9-2-13-1']	32.88	24.00	56.88	3.83	4.44	8.27	4.84	48.76	53.60
'Madhuri'	35.00	34.88	69.88	4.26	6.21	10.47	5.44	82.18	87.62
'Hansraj'	23.64	18.10	41.74	4.63	6.59	11.22	3.98	86.64	90.62
'Basmati Rajasthan'	21.14	21.33	42.47	2.77	6.44	9.21	3.00	54.33	57.33
'Binam'	18.43	23.26	41.69	1.82	5.14	6.96	2.84	55.08	57.92
'Domsiah'	17.53	22.77	40.30	1.72	4.76	6.48	2.53	44.11	46.64
'Basmati 370'	14.34	19.03	33.37	1.64	5.06	6.70	2.34	56.54	58.88
'Pusa Basmati 1'	17.92	28.92	46.84	2.49	51.7	7.66	2.90	61.37	64.26
'Ambemohar 159'	2793	39.19	67.12	3.52	4.89	8.41	4.19	95.45	99.64
'Radhunipagal'	22.35	34.51	56.86	3.48	6.38	9.85	3.44	62.45	65.89
'Seetabhog'	29.53	33.15	62.68	4.25	5.39	9.64	4.94	89.18	94.12
'Tulsibhog (Local check)	30.91	52.69	83.60	2.97	6.05	9.02	4.07	95.23	99.30
Mean	25.84	29.46	55.31	3.11	5.71	8.82	3.92	69.47	73.40
SEm±	0.80	2.39	4.01	0.72	0.64	0.81	0.52	15.31	15.07
CD (P=0.05)	2.21	7.30	12.26	NS	NS	2.47	1.58	NS	NS

in this agro-climatic zone.

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Indian Journal of Agricultural Sciences 72 (7) : 383–8, July 2002

Photosynthetic and yield performance of rice (*Oryza sativa*) genotypes under low temperature condition in hills

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Received: 11 December 2001

ABSTRACT

A field experiment with 15 genotypes of rice (*Oryza sativa* L.) was carried out during the rainy season of 1999 and 2000 to understand the photosynthetic basis of yield under low temperature in hills. Exposure of rice genotypes to low temperature conditions during reproductive phase was made by altering the dates of sowing, ie normal and 1 month late. The rate of photosynthesis (r = 0.584*) and canopy photosynthesis (r = 0.830**) estimated during grain-filling phase showed significant positive correlation with grain yield under normal planting and poor association under low temperature condition, ie late planting. Rates of canopy photosynthesis during the early phase of plant development under both plantings were found almost similar, ie no reduction in nursery bed and 2.71% at vegetative stage. A significant reduction in rates of photosynthesis (36.68%), canopy photosynthesis (44.14%), transpiration (29.30%), stomatal conductance(76.80%) and level of photosynthetic pigments (52.51%), nitrate reductase (NR) activity (51.61%) was observed at grain-filling stage under low temperature condition. Besides, a reduction in the grain-filling rate was also noted under late planting due to low temperature.Harvest index (HI) showed the significant positive association with grain yield (r = 0.772**) under low temperature condition only, which in turn indicated that the low temperature reduced the partitioning of photo-assimilates which resulted in poor yield. A significant relationship of grain sterility (r = — 0.836**), harvest index (r = 0.929**), panicle weight (r = 0.574*), NR activity (r = 567*), anthocyanins content (r = 0.561*) with cold-tolerance efficiency was observed.

Key words: Photosynthesis, Transpiration, Chlorophyll, Nitrate reductase, Cold tolerance, Low temperature, Yield, Correlation, Rice, *Oryza sativa*

Low temperature is a major constraint in rice (*Oryza sativa* L.) production in the hilly zones. In Uttaranchal hills, spring-sown rice crop faces cold stress during the germination and seedling stage while rainy-season-sown rice experiences chilling temperature during reproductive phase. Symptoms of chilling injury include poor germination, stunted growth, reduced photosynthetic capacity, discoloration and necrosis, poor panicle exertion, abnormal ripening and increased disease susceptibility which ultimately result in yield reduction. The potential yield of a crop, to a great extent, is determined by photosynthesising capacity of plant unless sink capacity is limiting (Yoshida 1972). Response of plants to biotic and abiotic stresses is also reflected in change in their photosynthetic rates (Conocono *et al.* 1998, Kumar 2000). Janardhan *et al.* (1983), Basuchaudhuri and Dasgupta (1987), Ischii (1988) and Sharma and Singh (1994) reported a wide variation in photosynthesis rate and productivity among the genotypes of rice. However, study on photosynthesis in relation to yield of rice, particularly under low temperature condition in hills is totally lacking. Therefore, an experiment was conducted to assess the fundamental relationship of photosynthesis with yield in rice under low temperature condition and to identify cold-tolerant rice genotypes for hill ecology.

MATERIALS AND METHODS

Fifteen rice genotypes, including 3 varieties (checks) and 12 advance lines, viz. 'VL Dhan 81', 'VL Dhan 206', 'Barkat', 'VL 91-1754', 'VL 91-1923', 'VL 91-1990', 'VL 91-1998', 'VL 91-2877', 'VL 91-2889', 'VL 91-3149' 'VL 94-3027', 'VL 94-3030', 'VL 94-3143', 'VL 94-3148' and 'VL 95-3336', were sown in nursery bed at 2 dates of sowing, ie normal (25 May) and 1 month late (25 June), during the rainy season of 1999 and 2000. Thereafter, 30-day-old seedlings of these genotypes were transplanted in well-puddled soil at 2 dates, ie normal (25 June), and late (25 July) to expose the reproductive phase of genotypes to low temperature condition. The experiment was laid out in factorial randomized block design with 3 replications at experimental farm, Hawalbagh (1 250 m above mean sea-level) of the VPKAS, Almora, Uttaranchal, following all

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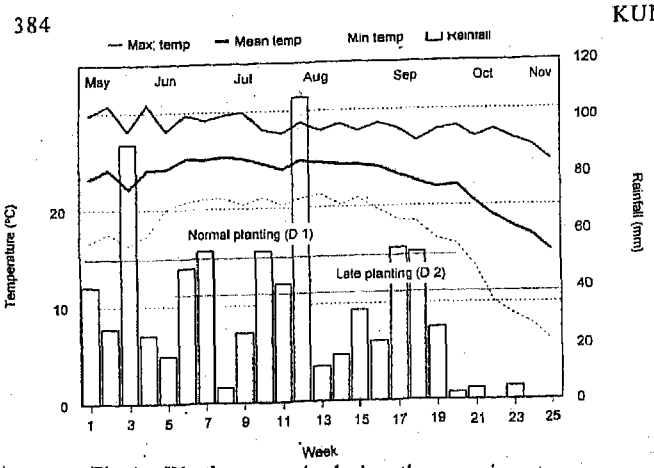

Fig 1 Weather records during the experiment

recommended package of practices for healthy crop. Weather records during the course of investigations are depicted in Fig 1.

Photosynthesis and its associated parameters were recorded during vegetative and reproductive phases. The leaf photosynthesis rate (Pn) (μ mol $CO_2/m^2/sec$), transpiration rate (TR) (m $mol/m^2/sec$) and stomatal conductance (SC) (m $mol/m^2/sec$) were measured on fully-developed second leaf from top during vegetative phase and on flag leaf during reproductive phase using portable photosynthesis system (model CIRAS-1,UK) between 10 and 12 hr in cloudless condition (photosythetically active radiation approximately 1 200μ $mol/m^2/sec$). Leaf area was measured with the help of leaf-area meter (model LI-COR 3000 A, USA). Canopy photosynthesis (CPn) was estimated by multiplying the leaf area index with photosynthesis rate. Nitrate reductase activity in vitro was determined by the method of Klepper *et al.* (1971). For chlorophyll extraction the method of Hisox and Isrelstam (1978) was followed. Total chlorophyll (Chl) and chlorophylls were calculated using Arnon's formula (Arnon 1949). Anthocyanins content was estimated following the method of Beggs and Wellmann (1985). Colorimetric absorptions were estimated with help of UV-VIS spectrophotometer. For the determination of grain-filling rate, about 20 panicles/plot were tagged at anthesis and then after each 5-day interval, 2 panicles/plot were collected and their seed number and seed weight were estimated after drying. Grain filling rate was estimated as the gain in seed weight/day. Cold-tolerance efficiency (%) was determined by multiplying with 100 to the proportion of grain yields obtained per unit area under late planting (low temperature condition) (D_2) and normal (D_1) planting. Total dry matter, yield and its attributes were recorded at harvest. Data obtained were analysed by adopting standard statistical methods.

RESULTS AND DISCUSSION

Rate of canopy photosynthesis recorded at seedling (30 days after sowing nursery), vegetative (60 days after sowing) and booting stages were found almost similar under both normal and late plantings (Fig 2). Lower rates of photosynthesis and canopy photosynthesis were obtained under late planting at anthesis and grain filling. The maximum rate of canopy photosynthesis was obtained at booting under both the conditions, thereafter it declined in later stages due to reduction in leaf area. Low temperature condition below critical level (mean temperature less than 18°C and minimum temperature less than 12°C) coincided with grain-filling phase under late planting (Fig 1) and thus a great reduction in rates of photosynthesis and canopy photosynthesis was obtained.

The significant variation in photosynthesis rates was observed amongst the genotypes which might be due to their genetic differences. The observations confirm the findings of Basuchaudhuri and Dasgupta (1987) and Sharma and Singh (1994). Reduction in rate of photosynthesis and canopy photosynthesis at grain filling stage under low temperature condition (late planting) was probably due to accumulation of soluble carbohydrates in leaves (Bruggemann *et al.*1994), because accumulation of soluble carbohydrates suppresses photosynthesis by reducing phosphate cycling and depleting ATP level in the chloroplast (Labate *et al.* 1990). Transpiration rate recorded at grain-filling stage under normal and late planting (low temperature) varied between 9.27 and 13.61 and 6.25 and 9.74 m $mol/m^2/sec$ respectively (Table 1). Stomatal conductance also showed the similar trend. Tsunodo and Fukoshima (1986) also reported genotypic variations in terms of transpiration rate and stomatal conductance in rice. Grantz (1989) also reported the reduction in photosynthesis and stomatal conductance in field-grown sugarcane under cool temperature. Reduction in stomatal conductance under low temperature probably took place due to increase in level of ABA (Chen *et al.* 1983) because

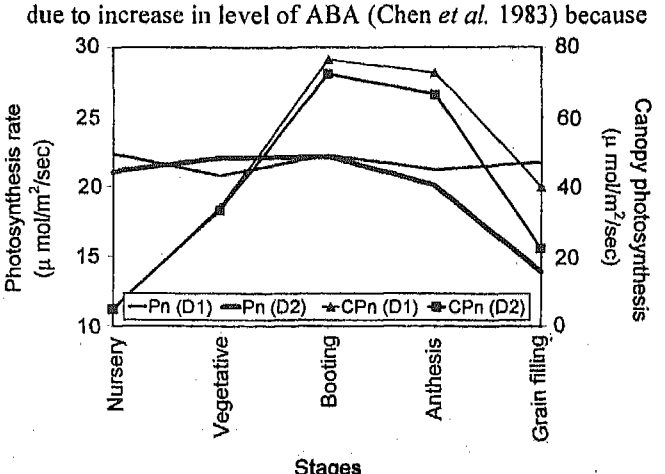

Fig 2 Rate of photosynthesis (Pn) and canopy photosynthesis (Pn) in rice at different stages under normal (D_1) and late planting (low temperature, D_2) conditions

Table 1 Rates of photosynthesis (Pn), canopy photosynthesis (CPn), transpiration (TR), stomatal conductance (SC) and nitrate reductase activity (NRA) among rice genotypes at grain filling stage under normal (D_1) and late planting (D_2) (low temperature) conditions

Genotypes	Pn (μ mol/m^2/sec)		CPn (μmol/m^2/sec)		TR (m mol/m^2/sec)		NRA (μ mol/g fresh weight/hr)	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
'VL Dhan 81'	21.62	9.55	38.39	12.45	10.46	6.25	1.16	0.52
'VL Dhan 206'	20.44	12.29	35.46	14.87	11.09	8.72	1.46	0.56
'Barkat'	22.79	22.95	28.35	23.40	12.00	9.61	1.62	1.01
'VL 91-1754'	25.42	14.88	46.87	27.89	13.27	8.65	1.77	0.55
'VL 91-1923'	19.55	10.27	24.68	13.96	10.38	7.62	1.23	0.71
'VL 91-1990'	20.00	10.75	27.34	14.64	9.27	8.20	1.99	0.97
'VL 91-1998'	21.97	13.02	45.11	26.76	11.97	8.93	1.44	0.67
'VL 91-2877'	23.30	13.32	54.20	28.30	12.38	8.30	1.33	0.60
'VL 91-2889'	22.62	13.88	55.93	32.67	12.86	7.85	1.45	0.62
'VL 91-3149'	19.93	11.74	40.84	25.01	12.32	8.58	1.33	0.56
'VL 94-3027'	19.09	14.10	27.76	19.47	11.80	8.57	1.34	0.84
'VL 94-3030'	20.00	11.62	33.12	17.09	11.71	8.59	1.65	0.94
'VL 94-3143'	23.78	15.12	45.89	22.13	13.61	8.60	2.67	1.04
'VL 94-3148'	22.43	15.97	43.01	28.08	13.22	8.88	1.13	0.68
'VL 95-3336'	22.97	16.97	50.48	27.02	13.38	9.74	1.69	1.00
Mean	21.73	13.76	39.83	22.25	11.98	8.47	1.55	0.75
CD (P=0.05)								
Treatment (T)		0.34		0.26		0.21		0.05
Genotype (G)		0.92		0.71		0.57		0.12
T × G		1.31		1.01		0.81		0.17

T_1, Normal planting (D_1) or control; T_2, late planting or low temperature (D_2)

Table 2 Photosynthetic pigments and anthocyanins content at grain filling stage among rice genotypes under normal (D_1) and late planting (D_2) (low temperature) conditions

Genotype	Photosynthetic pigments (mg/g fresh weight)						Anthocyanins (OD at 546 nm/g fresh weight)	
	Chla		Chlb		Total chl			
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
'VL Dhan 81'	1.65	0.73	0.45	0.23	2.10	0.97	3.90	1.94
'VL Dhan 206'	1.70	0.90	0.42	0.26	2.13	1.19	3.51	1.99
'Barkat'	1.75	0.99	0.49	0.28	2.24	1.27	4.21	1.97
'VL 91-1754'	1.68	0.90	0.44	0.19	2.12	1.09	3.09	1.72
'VL 91-1923'	1.40	0.97	0.44	0.23	1.84	1.20	3.99	1.97
'VL 91-1990'	2.10	0.94	0.51	0.30	2.61	1.24	3.64	2.21
'VL 91-1998'	1.41	0.47	0.43	0.15	1.84	0.63	2.94	1.24
'VL 91-2877'	1.90	0.67	0.45	0.17	2.35	0.84	4.15	2.04
'VL 91-2889'	1.84	0.69	0.42	0.20	2.26	0.90	3.66	1.55
'VL 91-3149'	1.71	0.71	0.42	0.23	2.13	0.94	3.40	2.17
'VL 94-3027'	1.49	0.80	0.37	0.24	1.86	1.01	3.02	1.92
'VL 94-3030'	1.73	0.68	0.44	0.21	2.18	0.95	4.47	1.47
'VL 94-3143'	1.91	0.81	0.48	0.25	2.14	1.07	3.77	2.14
VL-94-3148	1.90	0.84	0.60	0.24	2.51	1.05	4.44	0.24
VL-95-3336	1.95	1.03	0.54	0.26	2.50	1.30	4.46	2.57
Mean	1.74	0.81	0.46	0.23	2.19	1.04	3.78	1.93
CD (P=0.05)								
Treatment (T)		0.05		0.03		0.05		0.076
Genotype (G)		0.13		NS		0.14		0.21
T × G		0.18		NS		0.19		0.29

T_1, Normal planting or control (D_1); late planting or low temperature (D_2)

accumulated ABA adversely modulates stomatal behaviour (Jensen *et al.* 1996). Further, stomatal conductance controls the gaseous exchange in leaf thus lowering in stomatal conductance ultimately resulted in reduction in photosynthesis and transpiration rates under low temperature condition. Rate of nitrate reductase(NR) activity at grain filling stage significantly varied under both planting and lower NR activity under low temperature condition. Rice genotype 'VL-94-3143' had the highest nitrate reductase activity under both conditions. Barlaan *et al.* (1998) also reported genotypic variations in nitrate reductase activity in rice. Nitrate reductase activity showed a reduction under low temperature. Reduction in NR activity was mainly controlled by reduced rate of photosynthesis because NR activity depends on photosynthesis for reducing power and ATP (Abrol *et. al.* 1983).

The significant difference in contents of photosynthetic pigments (chl_a, chl_b, total chl) and anthocyanins measured amongst the genotypes under both normal and late planting (low temperature) and their low content under low temperature condition (Table 2). The present findings on reduced contents of photosynthetic pigments due to low temperature stress are in conformity with the report of Wang *et al.* (1986). Since photosynthetic pigments are the essential part of photosynthetic machinery, reduction in their contents also caused the lower rates of photosynthesis under low temperature condition.

The maximum grain filling rates under both normal and late planting conditions were found at 15 days after anthesis (Fig 3). However, grain-filling rate under low temperature condition reduced drastically than normal planting which in turn indicated that under low temperature translocation of photoassimilates was adversely affected.

Amongst the rice genotypes a wide variation in total dry matter, panicle weight, grain yield, 1000-grain weight, grain sterility and harvest index under both normal and late planting (Table 3). Ischii (1988) also reported significant genotypic variations among rice genotypes. A reduction

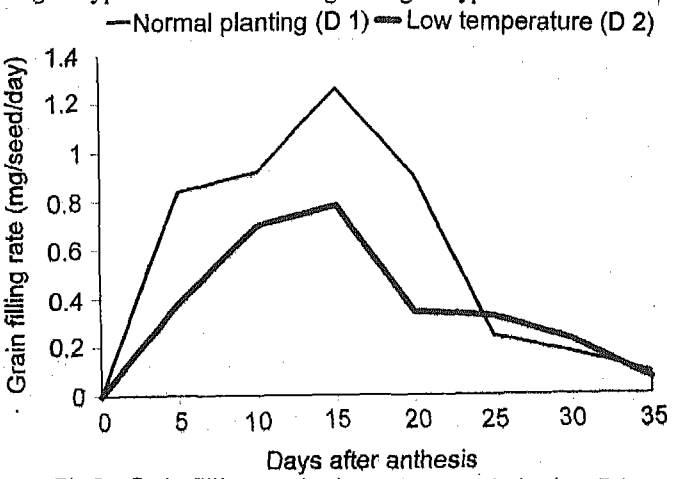

Fig 3 Grain-filling rate in rice under normal planting (D_1) and low temperature (D_2) conditions

Table 3 Total dry matter (TDM), yield and its attributes and cold tolerance efficiency (CTE) among rice genotypes under normal (D_1) and late planting (low temperature) (D_2) conditions

Genotype	TDM (tonnes/ha)		Panicle weight (g/m²)		Yield (tonnes/ha)		Test weight (g)		Grain sterility (%)		Harvest index (%)		CTE (%)	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
'VL Dhan 81'	9.62	9.13	537.99	370.35	4.60	2.99	27.88	22.66	11.00	33.33	47.78	32.75		65.03
'VL Dhan 206'	8.91	8.24	422.73	322.54	3.87	2.67	26.23	23.08	7.97	25.82	43.41	32.38		68.96
'Barkat'	8.64	8.04	446.81	350.17	4.01	3.22	25.31	22.89	12.54	23.32	46.46	40.04		80.19
'VL 91-1754'	11.34	10.68	510.38	372.05	5.34	3.11	25.22	23.19	15.05	30.50	47.06	29.14		58.31
'VL 91-1923'	8.89	9.27	450.75	393.41	4.05	3.55	25.23	22.31	8.41	22.54	45.58	38.27		87.52
'VL 91-1990'	9.74	9.92	509.78	440.86	4.56	3.77	24.05	22.42	11.57	24.86	46.79	37.97		82.69
'VL 91-1998'	11.26	9.77	582.57	418.86	5.15	3.35	25.07	22.09	10.79	32.74	45.74	34.27		65.03
'VL 91-2877'	11.46	11.12	585.06	517.74	5.29	4.17	25.85	23.93	16.04	27.08	46.14	37.53		78.96
'VL 91-2889'	11.84	11.84	601.71	344.30	5.61	2.59	25.25	23.14	14.01	37.30	47.39	21.86		46.12
'VL 91-3149'	11.50	10.67	512.91	398.49	4.85	3.08	26.50	24.53	14.86	35.80	42.17	28.89		63.57
'VL 94-3027'	11.17	10.84	513.99	459.58	4.67	3.90	26.80	25.37	10.20	24.13	41.77	35.95		83.52
'VL 94-3030'	10.54	9.77	510.30	389.22	4.68	3.23	26.4	24.44	14.06	37.05	44.42	33.04		68.92
'VL 94-3143'	11.17	10.54	558.17	472.59	5.37	4.34	31.26	27.80	10.35	22.57	48.07	41.11		80.74
'VL 94-3148'	10.69	10.19	542.61	448.50	4.67	3.80	28.67	24.65	11.84	26.89	43.73	37.33		81.36
'VL 95-3336'	11.89	10.85	549.19	473.90	5.11	4.13	28.35	25.16	6.75	26.11	42.99	38.07		80.85
Mean	10.58	10.06	522.33	411.50	4.79	3.46	26.54	23.84	11.70	28.67	45.30	34.57		72.78
CD (P=0.05)														
Treatment (T)		0.28		7.41		0.13		0.26		0.27		1.33		
Genotype (G)		0.76		20.30		0.35		0.71		0.73		3.64		
T × G		NS		28.70		0.49		1.00		1.03		5.14		

T_1, Normal planting (D_1) or control; T_2, late planting or low temperature (D_2)

in yield and its attributes was noted under late planting (low temperature) condition. Cold-tolerance efficiency (%) among rice genotypes was 46.12–87.52 (%). Six genotypes among the advance lines, viz 'VL 91-1923', 'VL 91-1990', 'VL 94-3027', 'VL 94-3143', 'VL 94-3148' and 'VL 95-3336' proved their cold-tolerance efficiency over 80% and were identified promising cold tolerant.

Correlation analysis among traits (Table 4) revealed that leaf photosynthesis rate recorded at anthesis and grain filling stages and canopy photosynthesis estimated at booting anthesis and grain filling stages showed the significant association with grain yield under normal planting. The results confirm the reports of Sharma and Singh (1994). However, under late planting (low temperature) condition, rates of leaf photosynthesis and canopy photosynthesis measured at different stages exhibited the poor association with grain yield. Further, harvest index had a significant positive association with grain yield under low temperature condition only which in turn indicated that under low temperature partitioning of photosynthates was slow or limited and probably due that partitioning coeffcient exhibited strong relationship with yield. In contrast, under normal planting partitioning of photo-assimilates was not a limiting factor, so that photosynthesis recorded during grain-filling phase had significant positive association with grain yield (Yoshida 1972). Furthermore, significant positive associations of grain yield with total dry matter under normal planting and their poor association under low temperature condition strengthened this fact. Similarly, 100-grain weight had significant positive association with grain yield under low temperature condition but not so under normal planting. Panicle weight exhibited significant positive correlation with grain yield under both normal and late planting conditions. The stomatal conductance, which is a component of photosynthesis had significant positive association with photosynthesis rate under both conditions. It also showed positive association with transpiration rate, which in turn indicated the role of stomatal conductance in regulation of rates of photosynthesis and transpiration.

Further, cold-tolerance efficiency exhibited the significant positive association with harvest index (r = 0.928**), panicle weight (r = 0.574*), nitrate reductase activity (r = 0.567*) and anthocyanins content (r = 561*). A significant association of anthocyanins content with frost resistance in sugarcane was also reported by Singh and Kanwar (1989). Chlorophylls contents though showed positive associations with cold tolerance, but these were not statistically significant. Cold tolerance efficiency had a highly significant negative relationship with grain sterility (r = —0.836**). Present findings indicated that grain sterility, harvest index, panicle weight, NR activity, anthocyanins content and levels of photosynthetic pigments may be taken as the criteria to select the cold-tolerant rice genotypes for hill ecology.

Table 4 Relationship among grain yield and physiological traits in rice under normal (D_1) and late planting (low temperature) (D_2) conditions

Trait	Correlation coefficient (r) under	
	Normal planting (D_1)	Low temperature (D_2)
TDM vs grain yield	0.904**	0.306
Panicle weight vs grain yield	0.891**	0.934**
HI vs. grain yield	0.291	0.772**
1000-grain weight vs grain yield	0.214	0.587*
Pn (30 DAS) vs grain yield	—0.335	—0.404
Pn (60 DAS) vs grain yield	—0.252	—0.497
Pn (booting) vs grain yield	0.344	0.0802
Pn (anthesis) vs grain yield	0.544*	0.144
Pn (grain-filling) vs grain yield	0.584*	0.178
CPn (30 DAS) vs grain yield	0.047	—0.132
CPn (60 DAS) vs grain yield	0.481	0.335
CPn (booting) vs grain yield	0.684**	0.218
CPn (anthesis) vs grain yield	0.749**	—0.024
CPn (grain-filling) vs grain yield	0.830**	0.080
Pn (grain-filling) vs SC	0.839**	0.850**
Pn (grain-filling) vs TR	0.683**	0.726**
SC(grain-filling) vs TR	0.643**	0.545*

TDM, Total dry matter; HI, harvest index; Pn, photosynthesis rate; CPn, canopy photosynthesis; TR, transpiration rate; SC, stomatal conductance

* P=0.05 (r= >0.531); ** P=0.01 (r= >0.641)

ACKNOWLEDGEMENT

I am grateful to Director, VPKAS, Almora, for providing facilities during investigation and Mr J K Arya for field technical assistance in the conduct of experiment.

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Indian Journal of Agricultural Sciences 72 (7) : 389–92, July 2002

Comparative efficacy of different composts in 'S_1' mulberry (*Morus alba*) under rainfed condition

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Received: 17 December 2001

ABSTRACT

A field experiment was conducted during 1998–2000 to study the efficacy of different composts on growth, leaf yield and qualitative parameters of 'S_1' mulberry (*Morus alba* L.) under rainfed, alluvial soil conditions of Gangetic plain. The *p*H of the soil was 6.89 and soil moisture in dry season (November–April) was 15.95%. Analysis of pooled data for 8 seasons revealed that all the composts in combination with N, P and K improved plant growth characters, leaf yield and quality in comparison with any compost alone or only with N, P and K application. Out of 4 types of composts, vermicompost in combination with 150, 50, 50 kg N, P and K/ha/year resulted in the maximum plant height (92.76 cm), leaves/plant (243.84), leaf yield (16.26 tonnes/ha/year) and K uptake by leaves (87.80 kg/ha/year). Besides, branches/plant (13.63), leaf area (42.63 cm^2), uptake of N (113.36 kg/ha/year) and P (19.72 kg/ha/year) by leaves were also significantly increased over the control. However, total soluble protein was found to be at par and total soluble sugar was almost similar with the other treatments. Among others, vermicompost was found more efficient in overall improvement in quantity and quality characters of mulberry.

Key words: Vermicompost, Weed compost, Rearing waste compost, Farmyard manure, Mulberry, *Morus alba*, Rainfed package

Potentiality of using organic manure along with balanced fertilizers is well established in increasing crop yield and sustained crop production (Nambiar and Abrol 1992). Presently vermicompost has been advocated as a good organic manure for use in field crops which could combat the ill-effect of chemical fertilizer (Kale 1996). Chowdappa *et al.* (1999) reported that vermicompost could also be prepared from the organic waste of arecanut (*Areca catechu* L.) and cocoa (*Theobroma cacao* L.) within 3 months contained higher quantity of N, P, K, Cu, Zn, Fe and Mn than ordinary compost. Application of lower dose of vermicompost alone or in combination with 25% reduced dose of chemical fertilizer increases wheat (*Triticum aestivum* L. emend. Fiori & Paol.), guinea grass (*Panicum maximum* L.) and ridgegourd [*Luffa acutangula* (L.) Roxb.] productivity over full or reduced dose of farmyard manure (FYM) alone or in combination with chemical fertilizer (Ranwa and Singh 1999, George and Pillai 2000, Sreenivas *et al.* 2000). Venkateswarlu (1995) reported the importance of using vermicompost in different crop plants particularly in mulberry (*Morus alba* L.) and standardized the method of composting the organic waste through earthworm. Other reports revealed that the application of vermicompost increased the leaf quality, sprouting, survival rate and growth in mulberry (Ravignanam and Gunathilagaraj 1996).

Farmyard manure made with cowdung is generally used as a major source of organic manure in field crops and its limited availability particularly for mulberry garden, low quality and high price have become a major constrain to the sericulturists. It has also been observed that huge quantity of biomass of mulberry farm and rearing refuses remain unutilized and become waste due to lack of proper utilization in the form of organic manure through recycling. It is thus proposed to test the efficacy of weed compost, rearing waste compost, purchased farmyard manure (cowdung) and vermicompost separately under rainfed condition as 65–70% mulberry garden belongs to this category. Keeping this in view, a study was undertaken to compare the efficacy of different composts on growth characters, leaf yield and quality of 'S_1' mulberry, a popular high-yielding variety of eastern and north-eastern regions under rainfed, alluvial soil conditions of Gangetic plain of West Bengal with an attempt to search for a suitable alternative of cowdung manure.

MATERIALS AND METHODS

The experiment was conducted at the Institute,

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Berhampore, during 1998–2000 under rainfed, alluvial soil conditions of Gangetic plain. Organic carbon, *p*H, moisture-holding capacity were estimated (Black 1965). Weed compost and rearing waste compost were prepared as per the method of Hajra *et al.* (1992) while vermicompost was prepared following the method of Venkateswarlu (1995). Nutrient status of soil and different composts and nitrogen, phosphorus and potassium uptake by leaves were determined by the method of Jackson (1973). Leaf moisture was determined by oven drying method and leaf area was estimated by following the method of Satpathy *et al.* (1992). Total soluble protein in leaf was determined by Lowry *et al.* (1951) and total soluble sugar in leaf was estimated by the method of Morris (1948). Atmospheric outdoor temperature was measured by maximum–minimum thermometer and soil moisture during dry seasons (November–April) was determined by gravimetric method.

Six years old 'S_1' mulberry variety at 60 cm × 60 cm spacing was used in the experiment which was kept fallow for 1 year before experimentation. The experiment was initiated with a ground-level pruning and was laid out in completely randomized block design with 10 treatments having 3 replicates in each treatment combination. Recommended cultural practices for rainfed mulberry and application of different composts @ 10 tonnes/ha/year, N, P and K @ 150, 50 and 50 kg/ha/year were followed (Ullal and Narasimhanna 1987). Above dose of farmyard manure (cowdung) along with N, P and K was treated as the control. No fertilization was treated as blank. Data on growth characters, leaf yield, leaf area, moisture content and NPK uptake by leaves were obtained during 4 seasons, ie May, August, November and February. Analysis of variance was done on the data of 2 consecutive years. The overall mean of each of the 10 treatments and critical difference value (P=0.05) were calculated.

The experimental soil was mild acidic (*p*H 6.89) with an optimum level of water-holding capacity (41.8%) and organic carbon content (0.76%). Available N (246 kg/ha), P (57 kg/ha) and K (320 kg/ha) were found at moderate level.

Two years month-wise average data indicated that atmospheric outdoor temperature ranged widely, low during winter (26.15°C in January) and high during summer (37.86°C in April). Soil moisture at 30cm depth was also found varying during dry season (November to April) from 13.63% during April to 18.3% during February under rainfed condition, while light or heavy rain in rest of the months and soil moisture was recorded from 50–80%.

The total nitrogen (1.96%) and phosphorus contents (0.751%) were high in rearing waste compost followed by vermicompost 1.008% N and 0.739% P, while high potash (1.42%) content was observed in farmyard manure (cowdung), followed by weed compost (1.34% K).

RESULTS AND DISCUSSION

Effect of different composts on growth, leaf yield and quality of mulberry

Analysis of variance revealed significant difference among the treatments (P<0.05) for 11 parameters except total soluble protein. Interaction between season and treatment was also found significant at 5% level for all the parameters except total soluble protein and total soluble sugar.

Efficacy of composts on growth characters

Plant height and leaves/plant were found significantly higher under the application of vermicompost @ 10 tonnes/ha/year in combination with $N_{150} : P_{50} : K_{50}$ kg/ha/year than the control, while branches/plant were maximum under rearing waste compost, followed by vermicompost in combination with the same dose of fertilizer (Table 1). The result corroborated the findings of George and Pillai (2000) in the growth of guinea grass and Ravignanam and Gunathilagaraj (1996) in mulberry with vermicompost application.

Efficacy of composts on leaf yield

Leaf yield was variable in different treatments with or without chemical fertilizer. Vermicompost @ 10 tonnes/ha/year in combination with NPK N_{150} P_{50} K_{50} kg/ha/year application resulted in significantly higher leaf yield over the control (farmyard manure) under rainfed condition (Table 1). Though rearing waste compost contains high N and K and its application alone outyielded 10.96 tonnes/

Table 1 Effect of different composts on growth characters and leaf yield of mulberry

Treatment	Plant height (cm)	Branches /plant	Leaves /plant (cm^2)	Leaf area	Leaf yield (tonnes/ ha/year)
Blank (no fertilization)	64.55	8.87	183.63	31.39	7.96
Farmyard manure (cowdung)	68.96	10.65	208.75	30.89	8.88
Weed compost	75.30	11.84	211.79	35.08	9.88
Vermicompost	70.05	11.11	211.71	32.13	9.60
Rearing waste compost	75.87	11.96	241.69	33.40	10.96
NPK	89.36	12.78	227.08	41.51	15.00
FYM (cowdung) + NPK (cont)	91.66	13.21	241.08	42.48	15.96
Weed compost + NPK	87.05	11.85	215.76	41.31	13.80
Vermicompost + NPK	92.76	13.63	243.84	42.63	16.16
Rearing waste compost + NPK	92.14	14.46	241.84	42.79	15.96
CD (*P*=0.05)	3.25	1.17	16,30	2.59	0.278
SE (158 df)	1.16	0.42	5.82	0.92	0.099

Dose: Manure/compost @10 tonnes/ha/year; N, P and K @150, 50 and 50 kg/ha/year; FYM, farmyard manure

ha/year mulberry leaf, in combination with chemical fertilizer the leaf yield increased by 45.62%. However, in comparison with vermicompost, the leaf yield was found to be little reduced in rearing waste compost application which was found similar with control (farmyard manure). Seasonal influence on different treatments was also found significant for leaf yield. The findings confirm the observations of Kale (1996), Ranwa and Singh (1999) and Sreenivas *et al.* (2000).

Leaf area was the highest in rearing waste compost application which was almost similar with vermicompost application combined with chemical fertilizer (Table 1). The application of only compost without chemical fertilizer registered lower leaf area.

Efficacy of composts on leaf quality

With regard to leaf moisture, significant difference was found among the treatments in different composts application combined with chemical fertilizer, while it was significantly reduced under different composts application alone (Table 2). However, maximum leaf moisture was recorded in farmyard manure treatment combined with chemical fertilizer, followed by rearing waste compost application but it was found significantly lower under vermicompost and weed compost application.

Total soluble protein content in leaf was not significant under different treatments, ranging from 16.42 mg/g fresh weight to 17.86 mg/g fresh weight and was found at par with control and treatments (Table 2).

Among the treatments, total soluble sugar content in leaf was significantly higher under most of the treatments including vermicompost and rearing waste compost with the application of chemical fertilizer over the control. Although highest sugar content in leaf was recorded in farmyard manure application alone without chemical fertilizer (Table 2).

Highest N and P uptake by leaves were recorded under rearing waste compost with NPK application, followed by vermicompost combined with NPK application and both the treatments being significantly higher than control (Table 2). However, K uptake by leaves was found maximum in vermicompost combined with NPK application, followed by rearing waste compost with NPK over control. Composts without chemical fertilizer application showed lower quantity of N, P and K uptake by leaves.

Improvement of all the qualitative parameters with the application of vermicompost confirm the findings of Kale (1996), Chowdappa *et al.* (1999), Ravignanam and Gunathilagaraj (1996) and Sreenivas *et al.* (2000).

Though there was high N content (1.96%) in rearing waste compost, vermicompost with NPK performed better or similar in most of the economic parameters (plant height, leaves/plant, leaf yield, leaf area, total soluble protein and sugar, N, P and K uptake by leaves) compared with other treatments and the control in 'S_1' mulberry under rainfed condition. It might be owing to availability of balanced nutrition and increasing in protein, potassium and other nutrient content resulted better growth, yield and quality (Kale 1996, Chowdappa *et al.* 1999, Ravignanam and Gunathilagaraj 1996). However, the dose of manure @ 10 tonnes/ha/year for rainfed mulberry garden was followed as per recommendation of Ullal and Narasimhanna (1987). Because of perennial nature of mulberry and to encourage the application of proper dose of organic manure at farmers' level, the dose was not reduced. However a separate attempt was made on reduction of the dose of vermicompost/fertilizer application in mulberry.

Thus application of recommended dose of organic manure in the form of vermicompost along with NPK is highly effective and increases leaf yield and quality of

Table 2 Effect on different composts on leaf quality of mulberry

Treatment	Leaf moisture (%)	Total soluble protein (mg/g fresh weight)	Total soluble sugar (mg/g fresh weight)	Total nutrient uptake by leaves (kg/ha/year) N	P	K
Blank(no fertilization)	75.33	16.42	40.06	53.92	10.60	37.92
Farmyard manure (cowdung)	75.63	17.23	41.15	63.40	12.20	44.76
Weed compost	75.25	17.83	37.50	65.12	13.08	48.32
Vermicompost	74.28	16.45	38.02	64.84	13.08	46.60
Rearing waste compost	75.90	16.86	40.59	68.64	14.56	52.20
NPK	75.67	17.86	40.59	103.40	18.52	81.76
FYM (cowdung) + NPK (cont)	76.89	17.64	38.10	106.28	18.28	84.00
Weed compost + NPK	76.10	17.31	39.58	92.88	17.24	74.60
Vermicompost + NPK	76.13	17.35	40.40	113.36	19.72	87.80
Rearing waste compost + NPK	76.56	16.97	41.11	115.68	20.84	87.36
CD (P=0.05)	0.71	NS	1.73	8.92	1.76	7.40
SE (158 df)	0.25	0.44	0.71	3.19	0.63	2.64

Dose: Manure/compost @10 tonnes/ha/year; N,P and K @150, 50 and 50 kg/ha/year
FYM, Farmyard manure

mulberry over the other composts even under rainfed condition. And vermicompost proved as an alternative to cowdung manure which can be prepared with the use of organic wastes by the help of earthworm within a short period. Hence vermicompost may be recommended as an organic manure for the application in mulberry garden in view of getting better production of quality leaf and maintenance of soil health.

ACKNOWLEDGEMENT

We are grateful to Dr G N Chattopadhyay, Reader, Department of Soil Microbiology, ASEPAN, Palli Siksha Bhawan, Sriniketan, Visva-Bharati (WB), for supplying primary culture of earthworm (*Eisenia fetida*)

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Indian Journal of Agricultural Sciences 72 (7) : 393–5, July 2002

Evaluation of guava germplasm under Sabour (Bihar) conditions*

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Received: 20 February 2002

Key words: Germplasm, Winter season, Rainy season, TSS, Total sugar, Reducing sugar, Vitamin C and Pectin

Guava (*Psidium guajava* L.) flowers are always borne on newly emerging vegetative shoots irrespective of the time of year (Rathore and Singh 1974, Singh *et al.* 2000). Consequently, flowering and fruit set can be very erratic, depending on the environmental conditions (Singh *et al.* 2000). In northern India, 3 distinct flowering seasons, ie summer, rainy and autumn, with corresponding harvesting periods in rainy, winter and spring have been observed by Rathore (1972), Dwivedi *et al.* (1990) and Singh (2000) under Delhi, Uttar Pradesh and Bihar conditions respectively. The ripening and quality of guava fruits is greatly influenced by the prevailing atmospheric temperature and humidity conditions. Precise knowledge of flowering and fruiting behaviour help the orchardists in selecting suitable cultivars according to the market demand and to adjust the cultural practices like time of irrigation, manuring, and crop regulation etc. since no report on this aspect in different guava germplasm is available under Bihar conditions, screening of guava germplasm for their flowering, fruiting and fruit quality attributes to select new varieties for Sabour region was undertaken.

Eight years old plants of gauva spaced 6 m × 6 m apart in Horticultural Garden of Department of Horticulture, Sabour, during 1998 and 1999 were selected. Single plant/unit was replicated 4 times in randomized block desin with 10 collections, viz. 'Safed Jam' (V_1), 'Kohir Safeda' (V_2), 'Hybrid 1' (V_3), 'Selection 8' (V_4), R_4p_5 (V_5), R_5p_3 (V_6), R_5p_8 (V_7), R_8p_5 (V_8), $R_{10}p_5$ (V_9), and 'Allahabad Safeda' (V_{10}), (check cultivar). The observations were recorded on flowering, fruiting and physico-chemical quality of fruits. For physico-chemical characters, the fruits were collected from all the sides of the plants at the right stage of ripening and observations were recorded based on 10 random selected fruits. Total soluble solids, titratable acidity and sugars were determined by standard methods. Ascrobic acid content was determined by titrating freshly extracted juice against 2,6-dichlorophenol indophenol dye (AOAC 1984). Pectin content was analysed as per the method of Ranganna (1977) and was expressed as calcium pectate.

Maximum flowers/tree were borne in 'Allahabad Safeda' in rainy and winter seasons, followed by 'Safed Jam'. Least flowers/tree in both the seasons were recorded in 'Kohir Safeda'. Rate of flowering in guava is governed by the seasons and the cropping pattern (Dwivedi *et al.* 1990). Both the factors are likely to affect the food reserves of the plant. Since flowering and vegetative growth during winter season is almost negligible, the plants accumulate sufficient food reserves, which is responsible for the initiation of new growth in the following spring. Due to heavy flowering in March–April and fruiting in the rainy season, the food reserves were exhausted, therefore the rainy-season flowering (July–August) for winter season cropping (November–December fruiting) were less than with flowering in March–April (Dwivedi *et al.* 1990). There was a significant variation in fruit set (%) in different guava germplasm. Maximum fruit set (%) in both the seasons was found in 'Allahabad Safeda' and it was on par with 'Safed Jam'. 'Kohir Safeda' showed the minimum fruit set (%) during both the cropping seasons. The variation in fruit set (%) among different germplasm was perhaps due to variations in pollen germination (Srivastava 1974). In general, fruits set (%) was higher during winter season than that during rainy season. The hot summer appears to be the main cause of poor fruit set for rainy-season crop. The result confirms the findings of Dwivedi *et al.* (1990) and Singh *et al.* (2999) in guava. Maximum numbers of days were required for maturity of 'Allahabad Safeda' during both the seasons, while it was least in 'Kohir Safeda'. The days required for fruit set to maturity were more in winter than that required in rainy season, due to prevailing low temperature during the period of fruit growth in winter, while high temperature accompanied with high humidity in summer accelerated fruit growth and maturity during rainy season. Our results confirm those of Kundu and Mitra (1994) under West Bengal conditions. The maximum fruit weight was recorded in 'Allabhabad Safeda', followed by 'Safed Jam' during both the seasons (Table 1). Least fruit weight was found in 'Kohir Safeda'.

* Short note

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Table 1 Reproductive and yield attributes of different guava germplasm (pooled data of 2 years)

Germplasm	Average no. of flowers/tree		Fruit set (%)		Days taken for maturity		Average fruit weight (g)		Yield/plant (kg)	
	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season
V_1	710.00	375.00	56.90	66.00	118.00	136.00	163.90	220.00	68.74	38.14
V_2	561.00	230.00	48.00	58.30	105.00	123.00	105.00	120.00	31.92	12.76
V_3	589.00	280.00	52.91	62.90	108.00	128.00	126.30	149.00	35.28	20.54
V_4	620.00	290.00	54.00	64.18	109.00	127.00	136.90	168.00	40.93	24.94
V_5	626.00	266.00	53.81	63.00	111.00	130.00	140.40	190.00	42.56	27.00
V_6	649.00	272.00	52.41	64.50	100.00	128.00	145.17	215.90	47.12	30.64
V_7	586.00	248.00	51.29	62.89	113.00	130.00	132.49	180.00	67.88	24.20
V_8	667.00	296.00	53.18	63.09	114.00	132.00	140.98	191.00	44.80	30.49
V_9	688.00	278.00	53.99	63.18	112.00	131.00	128.00	181.00	40.57	27.28
V_{10}	812.00	390.00	58.90	69.00	120.00	138.00	165.30	224.10	72.14	42.18
CD (P=0.05)	35.00	26.00	3.87	4.11			5.89	8.14	4.89	5.69

Details of germplasm is given in text

Rainy-season fruits had less fruit weight than of winter season in all the germplasm. Since restricted fruit : leaf ratio and limited exposure of light due to cloudy weather, probably less photosynthates were available for fruit growth in rainy season; hence medium to smaller size fruits were obtained. However, during the winter season, fruits received more organic metabolites and thus gained more weight because of higher leaf : fruit ratio and better exposure to light. These observations confirm the results of Dwivedi *et al.* (1990) in 'Sardar' guava. 'Allahabad Safeda' was found superior to other germplasm, having 72.14 kg and 42.18 kg fruit during rainy and winter season, respectively, followed by 'Safed Jam'. Least fruit yield/ plant during both the seasons was recorded in 'Kohir Safeda'. The rainy-season crop recorded more fruit yield than winter season one. Higher yield in the rainy season may be owing to higher number of flowers obtained in summer flowering. While due to exhaustion of the food reserves by the rainy-season crop, less number of flowers and fruits were produced on the tree during winter season. Similar results were obtained by Dwivedi *et al.* (190) in 'Sardar' gauva. The maximum total soluble solids, total sugar, reducing sugar, Vitamin C and pectin content were found in 'Allahabad Safeda' (check cultivar) being on a par with 'Safed Jam' during both the seasons (Table 2). Best-quality fruits were obtained during the winter season. These results are in conformity with the findings of Dwivedi *et al.* (190). Rathore (1972) reported that low temperature during the ripening period of winter season crop in guava retarded the excessive loss of respiratory substrates and also increased translocation of photosynthates from leaves to fruits. Another important factor, which may contribute to the better-quality fruits during the winter, is the coincidence of low temperature with phase III (last stage of fruit growth between 90 and 120 days from the date of fruit set) of fruit growth. On the basis of yield and fruit quality attributes it may be concluded that 'Safed Jam' may be recommended in

Table 2 Fruit quality attributes of different guava germplasm (pooled data of 2 years)

Germplasm	TSS (%)		Actidity (%)		Total sugar (%)		Reducing sugar (%)		Vitamin C (mg/100 g)		Pectin (%)	
	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season
V_1	9.35	11.89	0.30	0.42	7.00	9.00	3.59	5.11	130.00	250.00	0.89	1.36
V_2	9.08	10.93	0.29	0.43	6.75	7.56	3.00	4.20	105.20	201.00	0.61	1.04
V_3	9.12	11.00	0.32	0.41	6.81	8.71	3.31	4.67	110.30	210.00	0.67	1.05
V_4	9.33	11.32	0.31	0.44	6.34	8.34	3.41	4.66	119.49	218.39	0.69	1.14
V_5	9.18	11.28	0.33	0.45	6.24	8.21	3.24	4.54	120.00	232.00	0.73	1.30
V_6	9.35	11.19	0.28	0.46	6.13	8.10	3.45	4.34	122.29	234.00	0.81	1.31
V_7	9.31	11.00	0.32	0.45	6.95	7.98	3.33	4.59	124.95	240.00	0.65	1.29
V_8	9.24	11.14	0.31	0.44	6.45	8.40	3.10	4.29	125.00	224.91	0.63	1.26
V_9	9.38	11.00	0.29	0.43	6.14	8.10	3.20	4.34	126.00	205.00	0.75	1.24
V_{10}	9.89	12.00	0.28	0.41	7.13	9.13	3.67	5.69	139.00	260.95	0.92	1.42
CD (P=0.05)	0.41	0.48	0.02	0.03	0.87	1.09	0.41	0.62	13.95	21.59	0.06	0.11

Details of germplasm is given in text

addition to 'Allahabad Safeda' for commercial cultivation under Bihar conditions.

SUMMARY

Ten guava (*Psidium guajava* L) germplasm, viz 'Safed Jam' (V_1), 'Kohir Safeda' (V_2), 'Hybrid 1' (V_3), 'Selection 8' (V_4), R_4p_5 (V_5), R_5p_3 (V_6), R_5p_8 (V_7), R_8p_5 (V_8), $R_{10}p_5$ (V_9), and 'Allahabad Safeda' (V_{10}) (check cultivar) were evaluated during rainy and winter seasons of 1998 and 1999 for their flowering, fruiting and fruit quality attributes. 'Allahabad Safeda' was found superior to others in respect of yield (42.18 kg/plant during winter season and fruit-quality attributes (12.00% TSS, 260.95 mg/100 g vitamin C during winter season) and it was on a par with 'Safed Jam'. Average number of flowers/tree was higher (812–561) during summer flowering (April–May) than that in rainy season flowering (July–August) in all germplasms, while fruit set (%) was better (69.00–58.30) during the rainy-season flowering compared with summer season flowering. Highest yield/plant (72.14–31.92 kg) was obtained in rainy season, followed by winter season (42.18–12.76 kg). However, maximum TSS (12.00–190.93%), total sugar (9.13–7.56), reducing sugar (5.69–4.20), vitamin C (260.95–201.00 mg/100 g) and pectin content (1.42–1.04%) were found in the winter season cropping, followed by rainy season in all germplasms. Based on the yield and fruit quality attributes 'Safed Jam' proved superior in addition to 'Allahabad Safeda' to others under Bihar conditions.

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Indian Journal of Agricultural Sciences 72 (7) : 396–9, July 2002

Impact of fly ash application on consumptive and water use efficiency in wheat (*Triticum aestivum*) under different soils*

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Received: 24 December 2001

Key words: Fly ash, Water-use efficiency, Wheat, *Triticum aestivum*, Yield, Root growth, Evaporation

A huge quantity of fly ash is being produced everyday all over the world by several coal-fired thermal power plants. For the want of disposal of fly ash it is simply dumped in useful land adjacent to the thermal plant. This disposal not only converts useful land to unproductive one but also poses a threat to the quality of environment (Kumar 1996). Hence there is a great need to evolve a suitable solution for useful disposal of fly ash.

Fly ash possesses variable sizes of dark colour particles, high water-retention capacity, low bulk density, and modulus of rupture and medium to high hydraulic conductivity and low status of plant nutrients, and alkaline *p*H (Page *et al.*1979, Carlson and Adriano 1993). These features indicate that fly ash may serve as soil conditioner for improving water-holding capacity of light-textured soils and retard evaporation losses and act as temperature insulator when applied as a layer on soil surface.

Fly ash produced by thermal power plant, located at Panipat in Haryana (India), was found to possess all these properties. Therefore, an attempt was made to study the impact of fly ash application to 3 different soils, viz sandy soil, sandy loam and loam, on performance of wheat (*Triticum aestivum* L. emend. Fiori & Paol.).

A field experiment (lysimeter) with wheat was carried out at Hisar, Haryana, during the winter season of 1995–96 and 1996–97. The study was conducted on 3 types of soil loam (calcareous mixed hypothermic typic camborthids), sandy loam (Typic camborthids) and sandy (Typic ustipsamments), collected from and around the experimental farm of Department of Soil Science of the University, representing arid climate with annual average rainfall of 402 mm against potential evapotranspiration of 1 470 mm. The soils were air dried and analysed for physico-chemical properties. Bulk fly ash was collected from the dumping site of thermal power plant (Panipat) and analysed (Table 1).

All the soils filled at 1.5 Mg/m^3 bulk density in metallic lysimeters of diameter 50 cm and depth 95 cm were placed in pit spaced equally. The base of the pit was covered with a 200-gauge polyethylene sheet over which a 5 cm thick layer of sand was placed to avoid any water contribution from subsurface flow to the experimental crop. Fly ash was mixed with each of the experimental soils in top 15 cm layer @ 0.0, 2.5, 5.0 and 10.0% (w/w). Also a 2.5 cm fly ash layer was applied on to soil surface of each of the 3 soils.

The soils in the lysimeter were stabilized for a month by intermittent wetting and drying under an average environmental evaporativity of 10.4 mm/day. After applying 10.0 cm irrigation to each lysimeter, soil moisture was monitored for 52 days to determine the evaporation loss

Table 1 Physico-chemical properties of experimental soils and fly ash

Property	Fly ash	Soil		
		Sandy	Sandy loam	Loam
Sand (%)	93.4	92.0	68.0	55.9
Silt (%)	3.4	3.8	10.5	20.0
Clay (%)	3.2	4.2	21.5	24.1
Bulk density (Mg/m^3)	1.2	1.50	1.39	1.31
Hydraulic conductivity (cm/hr)	7.25	3.69	2.77	1.52
Water-holding capacity (%, v/v)	52.2	41.0	44.6	50.9
Modulus of rupture (Pa)			67.2	56.1
*p*H (1:2)	8.8	8.6	8.3	6.9
EC (1:2) (dS/m)	1.1	0.17	0.84	0.44
Organic carbon (%)	0.07	0.07	0.12	0.64
Available N (ppm)	6.3	15.9	28.9	54.6
Available P (ppm)	7.0	0.8	5.0	19.7
Available K (ppm)	15.7	155.0	90.0	422.5

*Short note

A part of Ph D thesis of the first author submitted to Chaudhary Charan Singh Haryana Agricultural University, Hisar, in 1997 (unpublished)

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of water from the bare soil of each lysimeter. To quantify the role of various fly ash treatments on soil evaporation, empirical equations between square root of time and cumulative evaporation were established (Table 3).

After applying 5.0 cm irrigation to each lysimeter, 'WH 542' wheat was sown on 14 November 1995 and 12 November 1996 and harvested on 4 April 996 and 7 April 1997 respectively. At harvest straw and grain yields were recorded during both the growing seasons. Soil moisture from all the soil profile at 0–15, 15–30, 30–60 and 60–75 cm depth was determined at different stages of crop growth by thermo-gravimetric method. Total profile moisture was determined by totalling the soil-moisture contents of different depths.

The consumptive use of the crop under different treatments of fly ash was calculated by summing up the moisture depletion from the soil profile during different periods of crop growth. The rainfall received during the period was also taken into account. The following relationship was used for computing the consumptive use of the crop :

$$Cu = \frac{\Sigma u}{N}$$

$$\text{and } u = ER + \sum_{i=1} \frac{M1i - M2i}{100} \times Ai \times Di \quad \ldots\ldots (1)$$

where Cu, the seasonal consumptive use of crop (cm); u, the water use from the root zone from successive sampling periods (cm); ER, the effective rainfall (cm); N, the number of soil layers sampled in the root zone depth D; M_{1i}, the soil moisture (%) at the time of first sampling in the i layer; M_{2i}, the soil moisture (%) at the time of second sampling in the i layer; Ai, the bulk density (Mg/m^3) and D_i, the depth of i layer (cm).

In computing the consumptive use, the capillary contribution of water across the bottom of the root zone (75 cm) of the crops was considered negligible because of the artificial barrier provided by lining with polyethylene sheet and sand layer below the root zone.

$$\text{WUE (g/lysimeter-cm)} = \frac{\text{Grain yield (g/lysimeter)}}{\text{Consumptive use (cm)}} \quad \ldots(2)$$

The water-use efficiency (WUE) of the crop under different fly ash treatments was calculated as:

For root studies, soil core (8.4 cm internal diameter and height 15 cm) samples were taken from the entire root zone in all treatments after crop harvest. The samples were washed with water on a fine sieve to make them free from soil. Each root sample was pressed between the filter papers to remove extraneous water and then cleared of any foreign material present. The samples were dried at 65°C in an electric oven. The weight of each sample was recorded with a precision balance (0.0001 g accuracy) and the root-weight density (root weight per unit soil volume) was calculated.

Application of 2.5 cm fly ash layer on soil surface resulted in the highest grain yield irrespective of soil type (Table 2). Improvement in the average yield under this treatment was 31.0, 29.0 and 33.4% over the control yield of 168.0, 138.8 and 108.4 g/lysimeter in loam, sandy loam and sandy soils respectively. Addition of 10.0, 5.0 and 2.5 % fly ash to the soil also improved the grain yield by 23.7, 18.3 and 8.7% in loam, 19.8, 11.1 and 6.3% in sandy loam; and 23.1, 16.5 and 7.0% in sandy soil over their respective controls. The type of soils also significantly influenced the grain yield. The highest yield was obtained in loam, followed by sandy loam and sandy soil (Table 2). The interaction between fly ash and soil was also found to be significant.

The superior performance of 2.5 cm fly ash layering is attributed to its mulching action which helped the soil to maintain favourable hydro-thermal regime in the soil

Table 2 Effect of fly ash on average consumptive use, water-use efficiency, grain and straw yield of wheat under different soils

Treatment	Soil				Soil				Soil				Soil			
	Loam	Sandy	Sand	Mean	Loam	Sandy	Sand	Mean	Loam	Sandy	Sand	Mean	Loam	Sandy	Sand	Mean
	Grain yield (g/lysimeter)				Straw yield (g/lysimeter)				Consumptive use (cm)				WUE (g/lysimeter-cm)			
Control	168.0	138.8	108.4	138.4	221.5	173.4	130.3	175.1	35.6	33.6	32.1	33.8	4.74	4.13	3.39	4.09
Soil + 2.5% FA	182.6	147.5	116.0	148.7	231.5	186.9	139.2	185.9	35.2	33.4	32.0	33.5	5.21	4.42	3.65	4.43
Soil + 5.0% FA	198.7	154.2	126.3	159.7	249.4	203.5	153.3	202.1	35.0	33.2	31.6	33.2	5.71	4.65	4.03	4.80
Soil + 10.0% FA	207.8	166.3	133.4	169.2	269.1	214.4	162.1	215.2	34.4	32.9	31.3	32.9	6.03	5.06	4.29	5.13
2.5 cm FA layer	292.8	179.1	143.5	180.9	292.8	234.2	190.0	239.0	32.9	31.8	31.1	31.9	6.72	5.64	4.65	5.67
Mean	195.4	157.2	125.5		252.9	202.5	155.0		34.6	33.0	31.6		5.68	4.78	4.00	
LSD (P=0.05)																
FA	2.91	S			2.26	Y			1.84	FA × S			5.04	FA × Y		4.12
S × Y	3.19	FA × S × Y		7.13	FA			3.79	S			2.94	Y			2.40
FA × S	6.56	FA × Y		5.36	S × Y			4.15	FA × S × Y			9.28	FA		0.09	S
0.07	Y		0.06	FA × S		0.15	FA × Y		0.13	\S × Y			0.10	FA × S × Y		NS

FA, Fly ash; S, soil; Y, year; WUE, water-use efficiency

which in turn helped in efficient utilization of moisture and nutrient by the crop and better crop growth and grain and straw yields.

The straw yield (Table 2) also improved following application of fly ash to different soils. The highest mean straw yield was obtained with application of 2.5 cm fly ash layer compared with the control yield of 221.5, 173.4 and 130.3 g/lysimeter in loam, sandy loam and sandy soil (Table 2). The straw yield improved over the control by 4.5, 12.6, 21.5 and 32.2% in loam; 7.8, 17.4, 23.6 and 35.1% in sandy loam; and 6.8, 17.7, 24.4, 45.8% in sandy soil with incorporation of 2.5, 5.0 and 10.0% fly ash and application of 2.5 cm fly ash layer. Like grain more straw yield was noticed in loam, followed by sandy loam and sandy soil. Tiwari *et al.* (1992), Waramhe *et al.* (1992) and Raman *et al.* (1996) also reported beneficial effects of fly ash on crop yield improvement.

The response of crop in terms of grain and straw yields was linear up to 5.0% level of fly ash and declined with further increase in the dose of fly ash application. Among different soils, response was highest in loam, followed by sandy soil and sandy loam for wheat grain. However, for wheat straw lowest response was observed in loam, followed by sandy and sandy loam, which were identical. Application of fly ash as a 2.5 cm layer (equivalent to 13.3 %) appeared to be more advantageous over the corresponding application as a mix in all the soils.

Table 3 Relationship between cumulative evaporation and square root of time as influenced by different fly ash treatments for various soils

Treatment	Equation	r^2 value
	Loam	
Control	CE = 0.672+0.916 Öt	(r^2=0.99**)
Soil + 2.5% FA	CE = 0.124+0.855 Öt	(r^2=0.99**)
Soil + 5.0% FA	CE = 0.399+0.700 Öt	(r^2=0.99**)
Soil + 10.0% FA	CE = 0.460+0.615 Öt	(r^2 =0.99**)
2.5 cm FA Layer	CE = 0.504+0.556 Öt	(r^2=0.99**)
	Sandy loam	
Control	CE = 0.199+0.647 Öt	(r^2=0.93*)
Soil + 2.5% FA	CE = 0.017+0.607 Öt	(r^2=0.92*)
Soil + 5.0% FA	CE = 0.123+0.534 Öt	(r^2=0.94*)
Soil + 10.0% FA	CE = 0.032+0.502 Öt	(r^2=0.96*)
2.5 cm FA Layer	CE = 0.115+0.455 Öt	(r^2=0.95*)
	Sandy	
Control	CE = —0.016+1.105 Öt	(r^2=0.99**)
Soil + 2.5% FA	CE = —0.713+1.099 Öt	(r^2=0.99**)
Soil + 5.0% FA	CE = —0.842+1.058 Öt	(r^2=0.99**)
Soil + 10.0% FA	CE = —0.832+1.039 Öt	(r^2 =0.99**)
2.5 cm FA Layer	CE = —1.002+1.022 Öt	(r^2=0.99**)

FA, Fly ash; CE, cumulative evaporation in cm; t, time in days
*P = 0.05; ** P = 0.01

The evaporation from bare soil reduced significantly from the control with increasing level of fly ash mixing up to 5.0% in sandy and up to 10.0% in sandy-loam and loam soils. Maximum reduction in evaporation was however observed under 2.5 cm fly ash layer (13.3%) in all the soils due to its mulching action.

The application of fly ash, in general, reduced evaporation of water from all the soils; however, the maximum reduction was noticed in loam, followed by sandy-loam and sandy soils. In sandy soil appreciable reduction in evaporation was noticed only under 2.5 cm fly ash layer. Incorporation of fly ash even up to 10.0% in sandy soil did not help much to reduce water loss during second stage of evaporation, as is evident from the value of coefficient of Ötime (Table 3). However, the first stage of evaporation was influenced a little by the incorporation of fly ash. This may be due to limitation in monitoring of soil moisture which commenced only from 72 hr after irrigation. This is reflected in the intercept of the equations. In case of loam, fly ash application reduced evaporation during second stage substantially. While it had a little impact on evaporation during the first stage of drying. In sandy-loam soil, fly ash application had less impact on evaporation reduction than loam but it was more than sandy soil. A net saving of 27.0, 17.0 and 15.0 mm in soil water was recorded in loam, sandy loam and sandy soil, respectively, after 52 days where fly ash was applied on the surface.

Though reduction in evaporation due to application of sand soil mulch of varying thickness (0.6–10.0 cm) have been reported by number of workers but the reduction in evaporation due to fly ash application could be speculated by Carlson and Adriano (1993).

Wheat crop, on an average, consumed 346, 330 and 316 mm water as evapo-transpiration to complete its life-cycle, respectively, in loam, sandy loam and sandy soils (Table 2). Application of fly ash lowered the consumptive use of crop marginally. Fly ash application as a layer lowered the consumptive use of crop by 27 mm in loam, 18 mm in sandy loam and 10 mm in sandy soil. Reduction in consumptive use was also reflected in increased quantum of water left out in the soil profile at the harvest of each crop.

The water-use efficiency of crop under differentially treated fly ash soils showed that the trend in improvement of water-use efficiency was similar to that of grain yield (Table 2), ie it significantly improved with increasing rate of fly ash application to different soils. Application of 2.5 cm fly ash layer resulted in the highest water-use efficiency compared to control value in loam, sandy loam and sandy soil. Addition of 2.5, 5.0 and 10.0% fly ash also recorded higher water-use efficiency of the crop over the control. The mean water-use efficiency improved by 9.9, 20.5 and 27.2 in loam; 7.0, 12.6 and 22.5 in sandy loam and 7.7, 18.9 and 26.5 in sandy soil with incorporation of 2.5, 5.0 and

10.0 % fly ash, respectively over their respective controls. Among the soils, the highest water-use efficiency of the crop was observed in loam and lowest in sandy soil. The interaction effect of fly ash and soil was also found to be significant.

As a consequence of highest improvement in grain yield with a little change in consumptive use, the water-use efficiency of the crop improved to the maximum extent of 41.8, 36.6 and 37.2% over their control in loam, sandy loam and sandy soil, respectively, with 2.5 cm fly ash layering. Mixing of fly ash also improved the water-use efficiency, which increased with increasing quantity of fly ash application. This could be attributed to better physical conditioning of the fly ash amended soils (Plank *et al.* 1975).

The root density improved with increasing rate of application of fly ash and attained highest value in 2.5 cm fly ash layer in all the soils over their respective controls. The root density of wheat in 0-15 cm layer was 291.3, 384.2, 423.4, 535.1 and 604.8 mg/cm^3 in sandy, 373.5, 462.7, 491.9, 579.0 and 630.9 mg/cm^3 in sandy loam and 456.5, 492.8, 558.2, 631.0 and 681.4 mg/cm^3 in loam under fly ash application at 0.0, 2.5, 5.0 and 10.0% and 2.5 cm fly ash layering, respectively. Maximum root density was observed in 0–15 cm layer (about 80%), under all the treatments and it decreased with increase in soil depth. The trend of root density under all the treatments in lower layers was similar as observed in case of 0–15 cm layer. In general, crop root growth was better in loam than the other two soils. Application of fly ash to the soil improved root density substantially. Even mixing of a small quantity of fly ash @ 2.5% in the plough layer helped improve the root density 18.5%. The improvement in root density with 2.5 cm fly ash layer treatment was 52.3, 68.1 and 64.1% over the control in loam, sandy loam and sandy soils, respectively. Taylor and Schuman (1988) and Carlson Adriano (1993) also reported improvement in root biomass and its distribution. This observation clearly show that application of fly ash to soil invariably improved root biomass which in turn may be useful in absorption of soil water and nutrients by plants.

SUMMARY

A lysimetric study was conducted during 1995–97 under arid tropical environment, to assess the effect of fly ash application on performance of wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crop on 3 texturally different soils, viz sandy, sandy loam and loam. The treatments consisted of 0.0, 2.5, 5.0 and 10.0% fly ash (w/w) mixed in the plough layer and application of 2.5 cm thick fly ash layer on soil surface. The grain and straw yields significantly increased with increasing rate of fly ash application in different soils. The consumptive use by crop remained almost unaltered but the evaporation under bare soil reduced 27, 17 and 15 mm in 52 days under loam, sandy-loam and sandy soils with applications of fly ash as a layer. Due to dark colour and high water holding capacity, fly ash helped modify soil thermal regime and improving water-holding capacity. The advantages of fly ash were reflected in the improvement improvement of 60.8, 30.8, 37.7 and 38.5% respectively was recorded under 2.5 cm fly ash of root density, grain and straw yields and water-use efficiency of wheat; the highest layer. Among the 3 soils, highest crop yield (220 g/lysimeter) was obtained in loam followed by sandy loam, (179.1 g/lysimeter) and sandy soils (143.5 g/lysimeter). Among the treatments of fly ash mixed in the plough layer (0–15 cm), the advantages declined with reducing quantity of fly ash. The improvement in terms of grain, straw and root biomass per unit quantity of fly ash mixed in the soil was maximum at 5% level (112 tonnes/ha).

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Indian Journal of Agricultural Sciences 72 (7) : 400–3, July 2002

Effect of rice (*Oryza sativa*)-based intercropping systems on vesicular-arbuscular mycorrhizal colonization, P uptake and yield*

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Received: 13 March 2002

Key words: Legumes, P uptake, Rainfed-upland ecosystem, Rice, *Oryza sativa*, Rice based intercropping systems, Vesicular arbuscular mycorrhiza

Upland rice (*Oryza sativa* L.) is grown under direct sown, aerobic to semi-aerobic soil conditions. Poor phosphorus (P) nutrition is one of the major constraints of low productivity in rainfed upland rice due to inefficient P acquisition by plants (Fageria *et al.* 1982). Importance of vesicular-arbuscular mycorrhizal (VAM) fungi, particularly in phosphorus uptake of plants, is well recognized (Chandra 1992). Soil inoculation of vesicular-arbuscular mycorrhizal fungi (VAMF) does not appear to be a pragmatic approach in seasonal crops like upland rice because soil population crashes during off-season and frequent additions of inoculum is expensive. Moreover, there is greater propensity of the natural soil micro-flora including native vesicular-arbuscular mycorrhizal fungi to reject the intruders (Vierheilig and Gareia Garrido 2000). However, sufficient native vesicular-arbuscular mycorrhizal fungi population (predominantly *Glomus*) is present in the soil planted to upland rice and its colonization enhances when rice is intercropped with legumes (Maiti *et al.* 1995). The present work was initiated to identify suitable upland rice-based intercropping system that would inherently support better native vesicular-arbuscular mycorrhizal association in upland rice for efficient P acquisition and higher, sustained productivity.

The field experiment was conducted during the wet seasons of 1998 and 1999 at the research farm of the Central Rainfed Upland Rice Research Station, Hazaribag. The rice-based intercropping systems tested comprised T_1, rice sole (R); T_2, rice + pigeonpea [*Cajanus cajan* (L.) Millsp.] in 4:1 row ratio (R+PP); T_3, rice + groundnut (*Arachis hypogaea* L.) in 4 : 2 row ratio (R+GN); T_4, rice + blackgram (*Phaseolus mungo* L.) in 4 : 1 row ratio (R+BG); T_5, rice + greengram (*P. radiatus* L.) in 4 : 1 row ratio (R+GG). Row ratios under the intercropping systems were followed as per standard recommendations. The crop varieties used were 'Vandana' (rice), 'Birsa Arhar' (pigeonpea), 'BG 3-6' (groundnut), 'Pant U 19' (blackgram) and 'Sunayana' (greengram). The crops were sown on 1 July in 1998 and 28 June in 1999. Rice was harvested on 12 and 8 October respectively in 1998 and 1999.

The experiment was laid out in complete randomized block design with 3 replications. Rice and intercrops were sown directly in lines 20 cm apart. The seed rates were 100 kg/ha (rice), 20 kg/ha (pigeonpea and greengram), 15 kg/ha (blackgram) and 110 kg/ha (groundnut). Uniform, basal application of P and K @ 13 kg P/ha and 16.6 kg K/ha was done through single superphosphate and muriate of potash respectively. Nitrogen was applied @ 40 kg/ha in 2 splits in rice and 20 kg /ha basal in pulses as starter dose through urea.

Plant samples (shoot and root) were taken 60 days after rice emergence for biomass yield, P uptake and root colonization (%) by vesicular-arbuscular mycorrhizal fungi. Leaf-area index at 60 days after rice emergence, tiller number and panicle number at maturity were recorded. Grain yield of rice and intercrops were recorded after sun drying for 1 week. Rice-equivalent yields of the intercrops were calculated on the basis of their support prices.

Roots were cut into pieces of about 1 cm length and fixed in formalin 5 ml: acetic acid 5 ml: 70% alcohol 90 ml solution for 48 hr. The fixed roots were cleared using KOH solution and stained by Trypan blue following the method of Kormanik *et al.* 1980. The stained roots were observed under stereo-zoom microscope and root colonization (%) was assessed using systematic gridline-intersect method (Giovennetti and Mosse 1980). Shoot and roots of rice from adjacent (row 1) and second rows (row 2) to the intercrops were sampled and analysed separately. Average data for both the parameters are presented.

Soil samples were collected before seeding and after

*Short note

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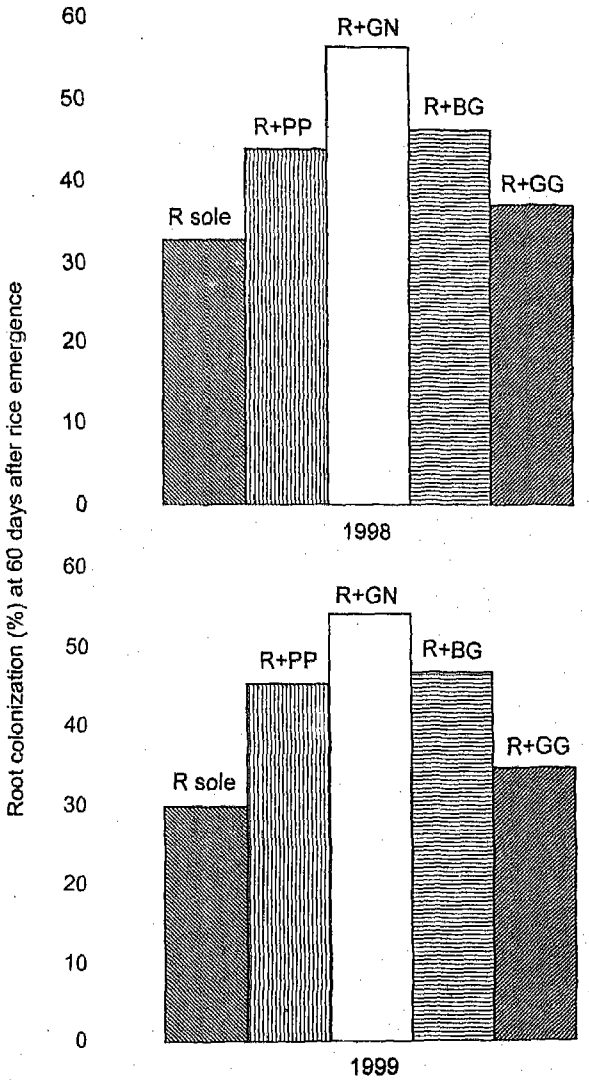

Fig 1 Influence of upland rice-based intercropping systems on native VAMF association in rice. R, Rice; PP, pigeonpea; GN, groundnut; BG, blackgram; GG, greengram

harvesting from each plot. Five subsamples (0–20 cm) from each plot were pooled and final samples of 500 g were stored for P analysis. The Mehlich 1 P was estimated calorimetrically using blue colour ascorbic acid method.

Root colonization by native vesicular-arbuscular mycorrhizal fungi in rice at 60 days after rice emergence ranged from 30.9% in rice sole to 54.7% when rice intercropped with groundnut (GN). Rice grown with groundnut, resulted in the highest root colonization in both the years (Fig. 1), whereas percent root colonization was at par in rice + blackgram and rice + pigeonpea, followed by rice + greengram. Higher colonization in rice under intercropping systems could be due to increased root density per volume of soil in intercropping systems which favoured the spread of the symbiotic fungi (Harinikumar and Bagyaraj 1988, Maiti *et al.* 2002).

Both, P concentration and uptake in rice straw at 60 days after rice emergence were influenced by the intercrops (Table 1). But the differences were statistically significant only with P uptake by intercropped rice over rice sole. At maturity also P uptake in intercropping systems was more but did not differ significantly. Higher P uptake by rice in intercropping systems was due to higher P acquisition

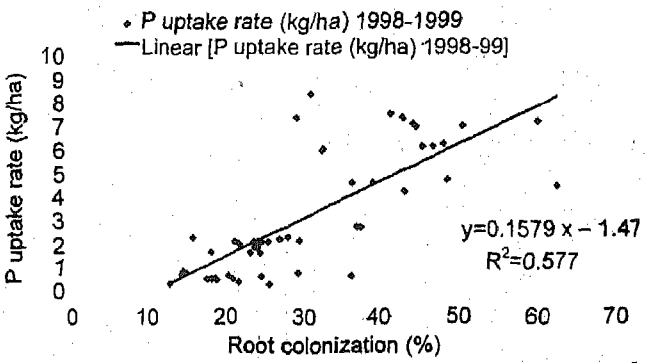

Fig 2 *Correlation between root colonization (%) by native* VAMF and P uptake in upland rice during 1998–99, wet seasons

Table 1 Effect of upland rice based intercropping systems on P uptake

Inter-cropping system	P concentration in plant (mg/g) and uptake (kg/ha)							
	1998				1999			
	60 days*			Maturity	60 days*			Maturity
	Concentration in rice	Uptake by rice	Uptake by intercrop	Uptake by rice	Concentration in rice	Uptake by rice	Uptake by intercrop	Uptake by rice
R sole	1.94 b	2.93 b		6.74 a	1.80 a	3.81 b		6.95 a
R + PP	2.33 ab	5.78 a	3.49	7.38 a	1.99 a	7.06 a	9.68	8.51 a
R + GN	2.31 ab	6.03 a	13.94	8.00 a	1.99 a	7.48 a	24.50	8.45 a
R + BG	2.62 a	6.08 a	2.62	7.77 a	1.99 a	6.41 a	16.15	7 96 a
R + GG	2.30 ab	6.09 a	1.72	8.54 a	2.02 a	8.09 a	4.98	9.45 a

Initial soil available P content 12.7–15.1 (1998), 9.0–14.5 (1999) kg/ha + 13.1 kg/ha added
In a column, means followed by a common letter are not significantly different at the 5% level by DMRT
R, Rice; PP, pigeonpea; GN, groundnut; BG, blackgram; GG, greengram; *days, days after rice emergence

mediated through higher vesicular-arbuscular mycorrhizal colonization, as evident by the significant, positive correlation between root colonization (%) and P uptake (Fig 2). This might be due to intimate interactions between roots of rice and intercrops via hyphal interconnections of VAM fungi as reported by Pasolon and Hirata (1993).

The competition for P by the intercrops was highest in groundnut, followed by blackgram, pigeonpea and least by greengram 60 days after rice emergence. This might have resulted in marginally higher P uptake by rice at maturity, in the rice + greengram system despite having lower vesicular-arbuscular mycorrhizal fungal colonization than other intercropping systems. Though the groundnut had higher P demand, rice + groundnut system maintained higher P uptake by rice. This again indicated role of vesicular-arbuscular mycorrhizal association in efficient P acquisition from the labile P pool of soil.

Intercropping systems, in general, increased yield-attributing characters (leaf-area index 60 days after rice emergence, tiller number and panicle number) of rice (Table 2). In 1998, the tiller number and panicle number were significantly higher in intercropping systems than rice sole, but in 1999, only leaf-area index was higher. Solaiman and Hirata (1997) reported influence of vesicular-arbuscular mycorrhizal association in enhancing leaf-area index or biomass.

Grain yield of rice and intercrops, in general, was higher in 1999 over 1998 except in groundnut (Table 2). In 1999, rainfall was higher (921.9 mm) and well distributed than in 1998 (768.3 mm), during growing period (sowing to harvest) of rice. In 1998, the crops received 2 drought spells of 6 days (22–27 July) and 14 days (15–28 September) of continuous non rainy days. These drought spells coincided with tillering and grain-formation stages of rice respectively. However, there was no drought spells of more than 4 days (1–4 July) in 1999. Better rainfall in 1999, on the other hand, led to higher soil moisture, persisted continuously after peg formation (August) which reduced groundnut yield. Higher (statistically not significant) grain yield of rice in all intercropping systems except in rice + groundnut system was obtained over rice sole in the first year (1998). In 1999, however, the rice yields in the intercropping systems were lower than rice sole with similar trend among intercropping systems. This was due to higher competition by the intercrops in the second year reflected by higher yield. Total productivity of rice + pigeonpea was significantly and consistently higher than other cropping systems in 2 years but was on par with that of rice + groundnut system in 1998 (Table 2). Higher productivity in rice + pigeonpea can be attributed to the higher yield of pigeonpea coupled with higher rice yield mediated through higher native VAM association. The results indicated that under rainfed upland ecosystem, rice + pigeonpea appears to be most appropriate intercropping system for achieving optimum and sustainable productivity through exploiting natural beneficial agent like vesicular-arbuscular mycorrhiza.

Table 2 Influence of upland rice based intercropping systems on plant characters of rice and productivity

Inter cropping system	Plant characters of rice						Grain yield of rice (tonnes/ha)		Grain yield of intercrops (tonnes/ha)		Rice + rice equivalent grain yield (tonnes/ha)	
	Leaf area index (60 days*)		Tillers/m²		Panicles/m²							
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
R sole	1.07 ab	1.11 b	257.1 b	352.1 a	231.7 b	306.8 a	0.809 a	1.750 a			0.809 b	1.750 c
R+PP	1.16 a	1.71 a	318.4 a	362.9 a	311.7 a	323.8 a	0.988 a	1.529 ab	0.621	0.936	2.285 a	3.467 a
R+GN	1.20 a	1.82 a	313.2 a	339.6 a	272.1 ab	314.8 a	0.603 a	1.057 b	0.813	0.584	2.449 a	2.382 b
R+BG	0.95 b	1.73 a	348.8 a	350.0 a	281.3 ab	311.7 a	0.895 a	1.367 ab	0.121	0.169	1.115 b	1.717 c
R+GG	1.01 ab	1.87 a	295.0 ab	392.1 a	268.4 ab	329.2 a	0.818 a	1.705 a	0.119	0.174	1.065 b	2.066 bc

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

SUMMARY

Role of augmented native vesicular-arbuscular mycorrhizal fungal (VAMF) colonization through rice (*Oryza sativa* L.) based intercropping systems on enhancing P uptake in upland rice was monitored in a field experiment conducted during 1998–99 at the Central Rainfed Upland Rice Research Station, Hazaribag, Jharkhand. Among the intercropping systems tested, upland rice variety 'Vandana' intercropped with groundnut (*Arachys hypogaea* L.) induced the highest colonization by native VAMF in rice (77% more over rice sole). This was followed by rice + blackgram (*Phaseolus mungo* L.) and rice + pigeonpea [*Cajanus cajan* (L.) Millsp.] by 48.9% and 42.7% higher colonization over rice sole respectively. Concomitant increase of P uptake (92%) was observed in the 3 intercropping systems over rice sole. Among the 3 systems, however, highest average rice yield (1.26 tonnes/ha) and total productivity in terms of rice (2.88 tonnes/ha) were obtained in rice + pigeonpea intercropping system.

ACKNOWLEDGEMENT

We are thankful to the ICAR for providing fund (AP

Cess Fund) and other facilities to pursue the investigation.

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Indian Journal of Agricultural Sciences 72 (7) : 404–7, July 2002

Morpho-physiological changes associated with waterlogging in rice (*Oryza sativa*)*

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Received: 13 February 2002

Key words: Rice, *Oryza sativa*, Waterlogging, Bronzing, Physiological disorder, Iron toxicity, Variety

Environmental factors like high rainfall consistently depress rice (*Oryza sativa* L.) yield during monsoon (*kharif*) season in Upper Brahmaputra valley zone of Assam. Waterlogging is common in poorly drained soils of the areas with high rainfall. It is established that genotypic differences exist for tolerance to waterlogging in cereal crops. Low redox potential and *p*H in waterlogged soil cause increased availability of reduced iron, which is normally toxic to the plant. Being a flood-prone area, iron toxicity is one of the major problems in the rice fields of Assam. Selection of suitable variety with proper management may be one of the economically feasible solutions for sustainable rice production under flooded condition during rainy season. Therefore, in the present

* Short note

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Table 1 Effect of waterlogging on culm height at flowering, tiller number, chlorophyll and iron content at 45 days after transplanting

Variety	Height (cm)		Tillers/ m^2		Leaf chlorophyll (mg/g fresh weight)		Shoot iron (ppm)	
	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal
'IET 11271'	123	111	96	136	1.66	2.14	526	431
'Bogabordhan'	113	112	180	178	2.44	2.68	487	375
'IET 10016'	90	88	186	184	2.51	2.65	511	408
'IET 10021'	92	87	169	189	2.48	2.70	488	391
'IET 11188'	109	99	95	142	1.25	2.12	675	454
'Utkalprova'	111	104	128	150	2.01	2.35	509	395
'IET 11187'	89	83	76	135	1.18	2.04	684	405
'Kushal'	89	84	158	167	2.50	2.65	481	377
'Sobita'	114	110	148	165	2.14	2.43	499	386
'Neeraja'	100	92	135	158	2.11	2.41	527	384
'Moniram'	85	87	166	172	2.38	2.58	487	384
'IET 11195'	112	112	118	139	1.79	2.18	581	497
'IET 13119'	119	115	152	163	1.92	2.15	545	362
'IET 10543'	109	103	132	168	2.14	2.34	496	417
'IET 11910'	119	112	112	152	1.55	2.02	610	400
Mean	105.6	100.6	138	161	2.01	2.37	538	404
Source	*SEd* ±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*	*SEd* ±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*
Depth of water 'w'	0.528	2.273	5.393	0.023	0.236	1.006	4.199	18.072
Varieties 'v'	2.357	4.619	3.269	0.064	2.491	4.881	19.492	38.205
Between 2 'v' Mean at the same level of 'w'	3.333	NS	4.624	0.090	3.522	6.903	27.566	54.030
Between 2 'w' mean at the same level of 'v'	0.528	NS	5.393	0.023	0.233	1.006	4.199	18.072

NS, Non-significant

study we sought to explore the relationship between physiological disorder in terms of bronzing intensity and reduction in grain yield when rice cultivars were subjected to continuous waterlogging stress.

The field experiment was conducted during the rainy season of 1999 at Jorhat in split-plot design. Rice varieties selected were 'IET 11271', 'Bogabordhan', 'IET 10016', 'IET 10021', 'IET 11188', 'Utkalprova', 'IET 11187', 'Kushal', 'Sobita', 'Neeraja', 'Moniram', 'IET 11195', 'IET 13119', 'IET11272', 'IET 10543' and 'IET 11910'. The sandy-loam soil had organic carbon 0.58%, coarse sand 11.30%, fine sand 58.92%, silt 16.25%, clay 12.64%, available N 264 kg/ha, P 14.08 kg/ha and K 240 kg/ha. Fertilizers were applied in the field @ 40, 8.8 and 16.6 kg N, P and K/ha. Thirty-day old-seedlings were transplanted at a distance of (15 cm × 20 cm). Two levels of water depth (10 ± 5 cm and 50 ± 5 cm) were maintained 2 weeks after transplanting when seedlings have established properly in the field. Waterlogged condition (50 ± 5 cm) was maintained in the field throughout the experimental period up to flowering and in the control plot, the water was drained out as and when needed. Soil *p*H was determined with Elico model glass electrode *p*H meter. Soil Fe^{++} was determined colorimetrically by orthophenanthroline method after extracting the soil with neutral normal ammonium acetate (Jackson 1973). Iron content in the shoots of rice plant was determined colorimetrically by orthophenanthroline method after extracting with triacid mixture. Leaf chlorophyll was estimated by double beam spectrophotometric method (Anderson and Boardman 1964). Nitrogen, phosphorous and potassium contents were determined by standard methods of Jackson (1973). Culm height at flowering and harvesting was measured and the number of tillers/m^2 at 45 days after transplanting was recorded. Percentage of yellow leaf was calculated in each observation in terms of total leaves .The yellow and green leaves of 5 individual plants in each plot were counted at 45 days after transplanting. Yield and other yield-attributing parameters were estimated by standard methods.

Table 2 Effect of waterlogging on N, P and K content in shoots of rice after harvest

Variety	N%		P%		K%	
	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal
'IET 11271'	1.60	1.68	0.22	0.30	1.38	1.53
'Bogabordhan'	2.09	1.90	0.32	0.37	1.69	1.74
'IET 10016'	2.12	1.84	0.30	0.33	1.61	1.74
'IET 10021'	2.07	1.80	0.33	0.35	1.58	1.65
'IET 11188'	1.52	1.57	0.17	0.31	1.13	1.45
'Utkalprova'	1.72	1.60	0.28	0.30	1.37	1.58
'IET 11187'	1.50	1.61	0.17	0.28	1.00	1.41
'Kushal'	1.83	1.78	0.29	0.32	1.52	1.57
'Sobita'	1.64	1.66	0.24	0.30	1.45	1.64
'Neeraja'	1.70	1.63	0.21	0.27	1.41	1.46
'Moniram'	1.82	1.65	0.27	0.29	1.52	1.61
'IET 11195'	1.65	1.60	0.20	0.29	1.28	1.45
'IET 13119'	1.84	1.77	0.28	0.36	1.50	1.71
'IET 10543'	1.62	1.48	0.21	0.29	1.37	1.57
'IET 11910'	1.58	1.75	0.19	0.27	1.20	1.46
Mean	1.75	1.69	0.24	0.30	1.40	1.56
Source *SEd* ±			*SEd*±		*SEd*±	
	CD (P=0.05)		*CD (P=0.05)*		*CD (P=0.05)*	
Depth of water 'w'	1.019	0.043	2.012	0.008	1.030	0.044
Varieties 'v'	5.434	0.106	2.074	0.040	4.065	0.079
Between 2 'v'mean at the same level of 'w'	0.076	0.150	2.934	NS	5.750	0.112
Between 2 'w'mean at thesame level 'of v'	1. 019	0.043	2.012	NS	1.030	0.044

NS, Non-significant

There was significant reduction in tiller number in 7 varieties due to waterlogging. 'IET 10021' and 'Bogabordhan' produced relatively higher number of tillers (Table 1). Under waterlogged condition, culm height was maximum in 'IET 11910', 'IET 112 72', 'IET 11271', 'IET 13119' and 'IET 11195'. Waterlgging causes reduction in plant growth at their early stages along with lower number of functional leaves due to inundation (Venkateswarlu 1978). At the initial stage of waterlogging, the drop in soil *p*H (4.8) was due to accumulation of organic acid and CO_2 and thereafter the subsequent increase in *p*H (5.45) is associated with soil reduction. Increased uptake of iron by the plants was observed under waterlogged condition. 'IET 10016', 'IET 11188', 'IET11187' and 'IET 11910' possessed more tissue iron content than 'Bogabordhan', 'IET 10021', 'Kushal' and 'Moniram' under waterlogged condition (Table 1). These findings confirm those of Baruah and Nath (1997).

Under waterlogged condition, nitrogen content increased with the decrease in phosphorous and potassium content (Table 2). Decrease in phosphorous content is due to conversion of a part of water-soluble P to insoluble ferric phosphate with the increase in the concentration of iron under waterlogged condition (Singh and Singh 1976). 'Bogabordhan', 'IET 10016' and 'IET 10021' recorded a higher level of phosphorus under waterlogged condition than 'IET 11188' and 'IET11187'. The cultivars 'IET 10016', 'Bogabordhan' and 'IET 10021' recorded higher N content in the shoot compared to the other varieties. Higher K content in the tissue may prevent intrusion of Fe^{++} to the shoot and this may be one of the reasons for better performance of some of the varieties at waterlogged situation. Higher concentration of tissue iron was found in 'IET 11187', 'IET 11188', 'IET11195', 'IET 11910' and ' Neerja' than the other varieties. Higher concentration of

Table 3 Effect of waterlogging on dry matter content (leaf + stem), number of panicles/m^2, filled grain (%) and yield (tonnes/ha) at harvest

Variety	Dry matter (g/m^2)		Panicle		Filled grain (%)		Yield (tonnes/ha)	
	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal
'IET 11271'	556	612	133	127	76	81	1.69	2.79
Bogabordhan'	680	683	201	217	97	96	4.32	4.39
'IET 10016'	718	712	187	203	92	94	4.74	4.81
'IET 10021'	702	690	191	199	92	95	4.49	4.63
'IET 11188'	536	634	95	120	73	86	1.36	2.82
'Utkalprova'	583	647	147	160	79	89	2.25	3.70
'IET 11187'	512	638	78	118	72	79	1.10	2.64
'Kushal'	615	672	173	179	90	92	4.20	4.49
'Sobita'	598	685	116	127	83	89	2.84	3.22
'Neeraja'	592	643	150	161	86	88	3.17	4.00
'Moniram'	610	652	162	190	90	92	4.09	4.50
'IET 11195'	598	634	120	127	82	84	1.68	3.11
'IET 13119'	605	683	165	173	91	95	4.01	4.08
'IET 11272'	647	669	137	150	84	91	2.37	3.55
'IET 10543'	596	678	117	98	80	92	2.01	3.92
'IET 11910'	588	684	107	113	70	83	1.24	3.72
Mean	608	664	142	154	83.5	89.1	2.85	3.77
Source	*SEd*±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*
Depth of water 'w'	0.754	3.247	1.930	8.307	0.218	0.940	0.0127	0.0548
Varieties 'v'	4.630	9.075	5.876	11.518	0.816	1.599	0.0440	0.0862
Between 2 'v" mean at the same level of 'w	6.548	12.834	8.310	16.289	1.154	2.262	0.0622	0.1220
Between 2 'W' mean at the same level of 'v'	0.754	3.247	1.930	8.307	0.218	0.940	0.0127	0.0548

tissue iron was reported to be the cause of yellowing in rice under waterlogged condition and less intensity of bronzed leaves in the resistant varieties is due to the root oxidizing ability of these varieties leading to less metabolically active Fe absorption mechanism (Ottow *et al.* 1982). Waterlogging causes reduction in total chlorophyll content (Table 1). But the variety 'Bogabordhan', 'IET 10016', 'IET 10021', 'Kushal' and 'Moniram' maintained higher level of chlorophyll compared with the other tested varieties. Adakand and Das Gupta (2000) reported similar type of results and stated that chlorophyll content reduces proportionately with increase in submergence period and more so in susceptible varieties due to inhibition of RUBP carboxylase activity. Panicles/m^2 and dry matter in leaves decreased under waterlogged condition (Table 3). 'Bogabordhan', 'IET 10016' and 'IET 10021' performed better than the other varieties. The results confirm the findings of Chaudhary and Das Gupta (1985). Under waterlogged condition percentage of filled grain, grain yield and harvest index were reduced significantly due to reduction in functionally active leaves and panicles. Appearance of bronzing due to higher concentration of soluble Fe^{++} may be one of the factors of reduction in grain yield under waterlogged condition as reported by Verma (1991). 'IET 10016' followed by 'IET 10021', 'Bogabordhan', 'Kushal', 'Moniram' and 'IET 13119' recorded higher grain yield than the other varieties (Table 3).

SUMMARY

A field experiment was conducted to investigate the physiology of waterlogging tolerance and associated physiological disorder in 16 varieties of rice (*Oryza sativa* L.) during the rainy season of 1999. Two water depths (10 ± 5 and 50 ± 5 cm) were maintained continuously up to the flowering stage of the crop. Occurrence of bronzing was observed in plants grown under waterlogged condition. 'IET 11187', 'IET 11188' and 'IET 11910' recorded higher number of bronzed leaves. Intensity of bronzing was less in 'Bogabordhan', 'IET 10016', 'IET 10021' and 'Kushal'. Significant reductions in chlorophyll content (1.18 mg/g fresh weight) of leaves were observed. Panicles (78/m^2), dry matter production (512 g/m^2), grain filling (70%) were significantly reduced under waterlogged condition, resulting in yield less (1.10 tonnnes/ha). 'Bogabordhan', 'IET 10016', 'IET 10021'and 'Kushal'performed relatively better than the tested varieties under waterlogged condition in terms of bronzing and yield potential. 'IET 11187', 'IET

11188' and 'IET 11910' were very sensitive to waterlogged condition.

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Indian Journal of Agricultural Sciences 72 (7) : 408–10, July 2002

Quality characteristics of non-aromatic and aromatic rice (*Oryza sativa*) varieties of Punjab*

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Received: 18 September 2001

Key words: Rice, *Oryza sativa*, Physico-chemical characteristics, Milling, Cooking quality

Grain quality of rice (*Oryza sativa* L.) is getting prominence in breeding programmes in the states, self-sufficient in its production. Consumers judge the quality of rice mostly on its appearance, particularly the colour, size and shape and on its elongation during cooking. Millers and traders, on the other hand, prefer a variety capable of giving high total and head rice recovery. Since information on milling, physico-chemical and cooking characteristics of commercially grown rice varieties of Punjab is limited, the present study was undertaken.

Fourteen samples of various non-aromatic and aromatic varieties grown during the rainy season of 2000 were collected from Rice Research Station, Kapurthala. The samples were 5-month-old at the time of analysis. Weighed samples (in triplicate) of clean husked rice (moisture content 13–14%) were dehusked in a Satake rubber roll laboratory sheller and the shelled rice samples were milled. The time of polishing was adjusted to obtain a 6% degree of polish in all the samples. Percentages of brown rice, milled rice and head rice were determined following the mathematical calculations. Length and breadth of brown rice were recorded using a dial thickness gauge. Standard analytical methods were used for estimating amylose alkali-digestion value water uptake (Bhattacharya and Sowbhagya 1971) and kernel elongation (Azeez and Shafi 1966). Gel consistency was determined using 100 mg milled rice powder dispersed in 2 ml 0.2 N KOH with little modification of Cagampang *et al.* (1973) in test-tubes of 12 mm × 100 mm (diameter × length). Cooking time was noted according

Table 1 Milling and physical characteristics of grain

Variety	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length (mm)	Kernel bread (mm)	Length: breadth	1 000-kernel weight (g) Husked rice	Brown rice	Milled rice
Non-aromatic									
'IR 8'	79.09	71.71	47.87	6.55	2.50	2.62	27.13	22.14	20.55
'Jaya'	80.93	74.44	51.60	6.39	2.45	2.60	27.03	22.74	20.80
'PR 113'	78.81	71.24	43.58	6.59	2.53	2.60	28.49	23.72	21.05
'PR 103'	76.01	67.44	43.82	6.82	2.13	3.20	23.48	19.00	17.55
'PR 106'	77.90	68.68	46.74	6.73	2.01	3.34	20.89	17.45	15.75
'PR 108'	78.82	69.62	51.56	6.79	2.13	3.19	22.96	19.60	17.61
'PR 111'	76.86	67.16	40.52	7.15	1.83	3.90	20.44	16.48	14.82
'PR 114'	77.36	67.90	55.48	7.33	1.95	3.75	23.33	18.68	16.88
'PR 115'	77.13	66.68	44.48	6.86	2.03	3.37	23.05	19.06	17.17
'PR 116'	79.48	70.48	55.49	6.91	2.12	3.25	24.75	20.76	19.37
Aromatic									
'Basmati 370'	77.54	68.53	55.31	6.97	1.91	3.64	19.65	16.59	15.20
'Basmati 385'	78.19	68.30	46.44	7.06	1.86	3.79	20.36	16.43	15.31
'Basmati 386'	75.97	67.60	50.93	7.49	1.88	3.98	22.02	17.83	16.69
'Pusa Basmati No.1'	74.44	65.15	44.52	7.99	1.83	4.36	21.53	17.09	16.13
Mean	77.75	68.92	48.45	6.97	2.08	3.40	23.22	19.11	17.49
SEm±	1.60	2.30	4.77	0.42	0.24	0.52	2.65	2.32	2.06
CV (%)	2.05	3.34	9.84	6.02	11.53	15.29	11.41	12.14	11.78

* Short note

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to the method of Chakrabarthy *et al.* (1972). Hundred kernels, each of husked rice, brown rice and milled rice were weighed in triplicate and the mean weight was multiplied by 10 to represent 1 000-kernel weight.

The varieties did not differ much in hulling and milling recovery (Table 1). The highest hulling and milling recovery was in 'Jaya', and the lowest was in 'Pusa Basmati No. 1'. 'PR 116' gave the highest head rice recovery (55.49%) (Table 1). Milling yield and head rice recovery are the most important criteria of rice quality, especially from marketing point of view. Rice in international market contains 98% head rice and there is consistent demand for good head rice in the internal market also (Juliano 1990). Hence greater emphasis on head rice recovery will be very useful in the breeding programmes.

A significant difference among varieties existed for length : breadth ratio of brown rice (Table 1). Length : breadth ratio of aromatic cultivars was higher than that of the non-aromatic cultivars. Hence, all the aromatic varieties were slender while the non-aromatic ones ranged from medium-slender in shape. 'Pusa Basmati No. 1' recorded the longest kernel length, while the smallest was that of the non-aromatic variety 'Jaya'. The non-aromatic varieties could thus be classified long–medium while the aromatic ones long–extra long on the basis of kernel length. Khush *et al.* (1979) reported that varieties having medium-long, slender and translucent grains give the best head rice yields. The varieties differed significantly for 1 000-kernel weight of husked rice, brown rice and milled rice (Table 1). The highest 1 000-kernel weight of husked rice, brown rice and milled rice was recorded for 'PR 113'. Among the various varieties, lowest 1000-kernel weight for brown rice and milled rice was recorded for 'Basmati 385' and 'PR 111' respectively. Thus the varieties could be classified as small and big on the basis of weight of milled rice (Bhattacharya *et al.* 1980). Singh *et al.* (1998) recorded a significant difference among varieties of Himachal Pradesh for 1 000-kernel weight of husked rice, brown rice and milled rice.

Large variation was observed in alkali value and water uptake ratio of the varieties. The varieties recorded low to intermediate gelatinization temperature and amylose content (Table 2). Amylose content and gelatinization temperature are the prime determinants for excellent cooking qualities. Preference in the international market is for rices that possess intermediate to slightly high amylose content with intermediate gelatinization temperature (Bhattacharya 1989, Jennings *et al.* 1979). Water uptake was 23.95–72.15% (Table 2). Water uptake by rice during cooking is primarily related to the surface area of rice, and is generally unrelated to its other physico-chemical characteristics (Bhattacharya and Sowbhagya 1971). Hence small and slender grains tend to absorb more water on cooking for a definite time than large, round grains. All the varieties had soft gel consistency (gel length > 60 mm, Table 2). Rice with soft gel consistency cook tender and remain soft even after cooking. Rice with soft to medium gel consistency is preferred by most rice consumers (Sarkar *et al.* 1994).

Table 2 Chemical characteristics and cooking quality of rice

Variety	Alkali spreading and clearing value	Water uptake (%)	Gel consistency (mm)	Amylose (%)	Cooking time (min)	Kernel after cooking (mm)		Elongation ratio
						Length	Breadth	
Non-aromatic								
'IR 8'	6.5 , 5.0	36.76	95	23.50	16.43	10.30	3.10	1.37
'Jaya'	6.5 , 5.0	40.85	93	24.12	16.41	10.30	3.00	1.41
'PR 113'	6.5 , 5.0	72.12	100	25.69	16.40	10.60	3.20	1.45
'PR 103'	3.5 , 2.0	49.09	97	15.98	15.38	10.10	2.90	1.42
'PR 106'	7.0, 5.5	44.27	90	24.75	15.17	10.00	2.70	1.44
'PR 108'	7.0 , 7.0	55.83	100	23.81	17.16	10.20	2.70	1.43
'PR 111'	3.0 , 1.5	24.61	95	24.75	16.23	10.50	2.50	1.47
'PR 114'	7.0 , 5.5	65.89	94	22.84	15.43	10.80	2.80	1.45
'PR 115'	4.0 , 2.0	51.90	95	13.14	17.30	10.20	2.70	1.39
'PR 116'	7.0 , 5.5	54.26	98	21.59	18.02	10.50	2.80	1.45
Aromatic								
'Basmati 370'	3.5 , 2.0	23.95	100	17.84	18.19	12.40	2.30	1.70
'Basmati 385'	3.5 , 2.0	20.92	100	19.09	16.06	12.60	2.40	1.70
'Basmati 386'	4.0 , 2.0	23.31	100	19.40	17.31	12.50	2.20	1.60
'Pusa Basmati No.1'	7.0, 5.5	35.39	100	20.97	16.02	14.10	2.40	1.86
Mean	5.42,3.96	42.79	96.92	21.24	16.53	11.07	2.60	1.51
SEm±	1.62,1.83	15.71	3.17	3.54	0.91	1.22	0.29	0.14
CV (%)	29.88,46.21	36.71	3.27	16.85	5.50	11.02	11.15	9.27

Cooking time varied from15.17 to 18.19 min (Table 2). With the increasing cost and decreasing availability of fuel for cooking, an important breeding objective could be the reduction of cooking time for milled rice (Juliano 1990). Elongation ratio was in the range of 1.37–1.86 (Table 2). Some varieties expand more in size than others upon cooking. Length-wise expansion without increase in width is considered a highly desirable trait (Dela Cruz and Khush 2000).

Thus the varieties studied had good-milling quality. The length of grains ranged from medium to extra long while the shape was found to be medium to slender. Amylose content and gelatinization temperature were in the range of low to intermediate and gel consistency was soft. There is still scope for improvement of certain quality parameters like head rice recovery and elongation ratio to sustain a constant demand by the consumers and to get a remunerative price for the farmers' produce.

ACKNOWLEDGEMENTS

I am grateful to Dr G L Raina and Dr P S Gill for facilities and Dr T S Bharaj, for providing the rice samples.

SUMMARY

An experiment was conducted during 2000 to study physico-chemical characteristics of 10 non-aromatic and 4 aromatic varieties of rice (*Oryza sativa* L.) grown in Punjab. Highest head rice recovery was recorded for PR '114' and 'PR 116' (55.48%) among the non-aromatic and for 'Basmati 370' (55.31%) among the aromatic varieties. Kernel length was 6.39–7.33mm (medium-long) among non-scented and 6.97–7.99 mm (long-extra long) among the scented varieties. Only 3 non-aromatic varieties, 'PR 113', 'Jaya' and 'IR 8' were medium in shape, while the length : breadth ratio of all others was > 3.0 and hence were classified as slender. Amylose content and gelatinization temperature were in the range of low–intermediate and gel consistency was soft for all the varieties. On the basis of physical appearance, amylose content, alkali value, gel consistency, water uptake, kernel length and breadth after cooking 'PR114' and 'PR 116' among the non-aromatic and 'Pusa Basmati No. 1' among the aromatic varieties were found to be superior to others.

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Indian Journal of Agricultural Sciences 72 (7) : 411–5, July 2002

Effect of submergence on phosphorus status and transformations in rice (*Oryza sativa*) soils*

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Received: 8 April 2002

Key words: Inorganic P transformations, P availability indices, Plant-growth parameters, Rice soil

Several extractants have been tried for rapid assessment of available phosphorus status of rice (*Oryza sativa* L.) soils, but no single extractant was found universally acceptable. However, the P ratings are being determined in air-dried soils in the soil-testing laboratories and the submergence effect on P availability is not being taken into account. Increase of P in some soils owing to submergence is quite sufficient to meet the P requirement of rice, whereas in other soils the increase is negligible and require phosphate fertilization (Mandal 1979). Therefore, the effect of submergence on P availability needs to be quantified while making fertilizer P recommendations to rice. An ideal P test is one, which extracts the fraction of P, and has a direct bearing on P nutrition of rice. With this in view, the present investigation was undertaken to study the transformation of inorganic P under submergence and to determine most suitable soil-test method for estimation of available P for routine analysis.

Thirty two composite soil samples were collected at a depth of 0.3 m from intensively rice-growing soils, from 8 districts of Andhra Pradesh, India, viz West Godavari (6), East Godavari (5), Krishna (3), Guntur (3), Srikakulam (5), Rangareddy (3), Nalgonda (4) and Nellore (3). The soils had a wide range of texture (sandy clay loam to clay and belong to Vertisols, Alfisols, Entisols and Inceptisols), neutral to slightly alkaline (*p*H 6.35–8.22), non-saline (0.14–2.23 dS/m), low to high in organic C (0.46–1.17%), low to medium in available N (98–187 mg/kg) and P (3.74–8.34 mg/kg) and medium to high in available K (51.0–159.2 mg/kg).

Soil samples (200 g each) were submerged separately in plastic containers and the water level was maintained at 2.5 cm above the soil surface throughout the incubation period by periodic additions of distilled water. The redox potential (Eh) was measured by using a calomel electrode and a platinum electrode in a digital *p*H meter at the beginning and at the end of 7, 14, 21, 28, 35, 42, 49, 56, 63 and 70 days after incubation. After attaining the maximum reduction (70 days after incubation), the wet soil samples were collected by taking moisture content of the samples into consideration and determined the inorganic P fractions and the available P status by different extractants.

Inorganic P fractions [Fe-P, Al-P, Ca-P, saloid-P (S-P) and reductant soluble-P (RS-P)] in both air-dry soils (collected from the processed bulk soil samples) and submerged soils (collected at 70 days after incubation) were determined sequentially (Jackson 1973). The available P content in air-dried and submerged soils was determined by 4 extractants, viz 0.5M $NaHCO_3$, *p*H 8.5 (Olsen *et al.* 1954), 0.5M $NaHCO_3$ + 0.01M EDTA, *p*H 8.5 (Ananthanarayana *et al.* 1989), 0.5M NH_4HCO_3, *p*H 7.8 (Datta and Khera 1969) and 1.0M NH_4HCO_3 + 0.005 M DTPA, *p*H 7.6 (Soltanpour and Schwab 1977).

Three kg of each soil was potted, soaked with water and kept under submergence. An uniform dose of N at 67 mg/kg was applied in 3 equal doses, ie before transplanting, 15 and 30 days after transplanting (DAT); K at 18.6 mg/kg and 2 levels of phosphorus at 0 and 19.5 mg/kg (P_0 and P_1) were applied before transplanting. The P treatments were replicated thrice in completely randomized block design. The soil was thoroughly mixed with fertilizer solutions and rice (cv 'Tellahamsa') seedlings, 21 days old, were transplanted @ 3 hills/pot at equal spacing. The crop was harvested 60 days after transplanting, washed thoroughly, oven-dried and dry-matter yield was recorded. Plant samples were ground, digested with a mixture of conc. HNO_3 and $HClO_4$ (7:3 ratio) and total P was determined by vanadomolybdophosphoric acid yellow colour method (Jackson 1973). The uptake of P was computed based on dry-matter yield and P concentration in the plant samples.

Simple linear correlation coefficients between P availability indices and inorganic P fractions in air-dried and submerged soils with plant-growth parameters were

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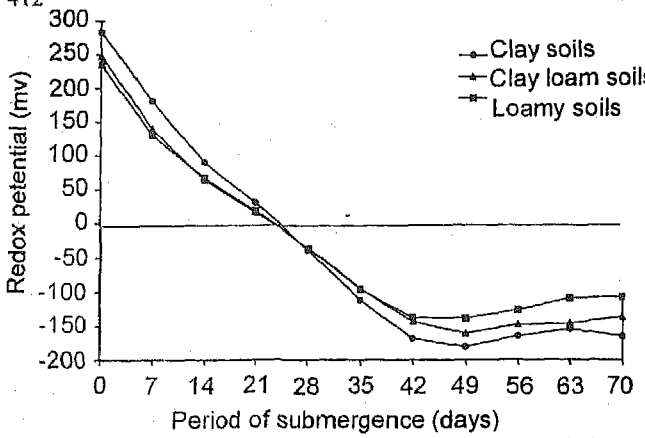

Fig 1 Changes in redox potential (Eh) at different periods of submergence

determined to establish the relationship. Step-wise regression analyses were done to assess the relative contribution of various inorganic P fractions to the available P and contribution of P fractions to the P uptake by rice.

The dry-matter yield varied from 7.3 to 21.0 g/pot and an increase of 22.7 % in dry-matter yield was evident owing to the application of P with a wide variation in yield response (7.0 to 60.0%) in different soils (Table 2). Total P uptake varied from 6.5 to 23.6 mg/pot, with an increase of 64% in P uptake by rice was observed across all the soils due to application of 19.5 mg P/kg. The individual effect of soils, P levels and interaction effect between soils and phosphorus on dry-matter yield and P uptake was found significant. Ramakrishna Reddy *et al.* (1986) also reported similar response to P application in rice soils of Andhra Pradesh.

The mean Eh values at weekly intervals were 261, 154, 75, 22, —37, —102, —154, —165, —152, —145 and —144 mV at the beginning and at the end of 7, 14, 21, 28, 35, 42, 49, 56, 63 and 70 days after submergence. The redox became negative 28 days after submergence (—37 mV), attained the lowest value by 49 days after submergence (—165 mV), and remained almost constant up to 70 days after submergence. The fall of redox was mainly dependent on soil type, clay content and organic matter status of the soil. The Eh values in clay soils (13) were 284, 180, 90, 30, —39, —112, —169, —181, —165, —155 and —166 mV, whereas in clay loam soils (14) these were 248, 139, 64, 16, —35, —95, —144, —161, —148, —147 and —137 mV, respectively, at the start and at the end of 7, 14, 21, 28, 35, 42, 49, 56, 63 and 70 days after submergence (Fig 1). However, the changes in redox potential in loamy soils (5) were found to be 235, 130, 67, 18, —36, —96, —138, —139, —127, —110 and —108 mV at the same intervals.

Across all soils, the occurrence of different inorganic P fractions (mg/kg) in air-dried soils (Table 1) was in the order of Ca-P (78.9) > Al-P (38.9) > Fe-P (33.4) > reductant soluble-P (27.4) > saloid-P (4.5), whereas in submerged soils the sequence was found to be Ca-P (87.2) > Fe-P (40.1) > Al-P (39.0) > reductant soluble-P (33.1) > saloid-P (4.5). The results showed that the Ca-P was found to be appreciably high in the soils might be due to continuous application of higher doses of P fertilizers in the form of superphosphate or diammonium phosphate. An increase of higher proportion of Fe-P than the other P fractions in submerged soils might be due to transformation of insoluble ferric phosphate to more soluble ferrous phosphate caused by changes in soil *p*H (Islam and Islam 1973). Increase of Ca-P in submerged soils might be due to conversion of insoluble tricalcium phosphate to more soluble mono or dicalcium phosphate and mineralization of organic P under submerged conditions (Raghupathy and Raj 1973). The increase of reductant-soluble P fraction on waterlogging might be due to an increase of soil *p*H which increases the rate of mineralization of organic P and decreased sorption of organic P compounds by hydrous oxides. These findings corroborate with those reported by

Table 1 Inorganic P fractions and available P in air-dry and submerged soils

Location/ district	Inorganic P fraction (mg/kg)										P availability index (mg/kg)							
	Air-dried soils					Submerged soils					Air-dried soils				Submerged soils			
	Fe-P	Al-P	Ca-P	S-P	RS-P	Fe-P	Al-P	Ca-P	S-P	RS-P	Olsen's-P	Modified Olsen's-P	AB P	AB DTPA-P	Olsen's-P	Modified Olsen's-P	AB-P	AB-DTPA-P
West Godavari	33.0	34.8	78.1	5.2	31.1	40.3	36.1	85.4	4.9	35.0	5.45	6.01	4.26	4.61	6.09	6.25	4.36	5.05
East Godavari	38.4	44.4	115.6	6.6	31.6	46.3	43.2	125.2	6.0	37.4	7.19	8.16	5.08	5.64	7.97	8.37	5.77	6.06
Krishna	35.9	40.6	93.2	4.3	29.0	41.5	42.6	101.2	4.3	34.1	5.49	6.53	4.12	4.49	6.57	6.68	4.81	5.25
Guntur	33.6	36.2	76.0	4.1	24.6	39.8	37.1	85.7	4.2	31.2	5.72	6.96	4.22	4.72	6.86	7.30	4.86	5.2
Srikakulam	29.2	41.8	57.6	3.0	23.0	35.2	41.1	65.7	3.4	29.4	5.25	6.09	3.89	4.35	6.11	6.34	4.55	4.80
Rangareddy	29.5	34.4	69.4	3.2	24.6	35.9	32.8	78.3	3.5	31.2	5.41	6.14	4.41	4.90	6.33	6.54	5.21	5.52
Nalgonda	32.8	37.6	62.4	3.4	23.4	38.2	36.0	69.2	3.8	29.2	5.06	6.28	3.29	3.97	6.46	6.56	4.45	4.58
Nellore	34.8	40.3	74.6	5.3	29.7	43.0	42.6	84.0	5.8	36.7	5.85	6.62	4.27	4.91	6.91	7.30	5.32	5.46
Mean	33.4	38.9	78.9	4.5	27.4	40.1	39.0	87.2	4.5	33.1	5.71	6.61	4.21	4.70	6.65	6.88	4.89	5.22

Table 2 Effect of phosphorus on dry matter yield and P uptake by rice

Location/ district	No. of soil samples	Dry matter yield (g/pot) P0	Dry matter yield (g/pot) P1	Per cent yield response	P uptake (mg/pot) P0	P uptake (mg/pot) P1	Per cent uptake response
West Godavari	6	9.2–15.6 (12.2)	14.2–21.0 (16.0)	11.7–60.3 (37.1)	8.0–13.6 (10.5)	15.8–13.6 (18.1)	55.3–96.5 (73.8)
East Godavari	5	8.5–16.0 (13.0)	10.1–18.9 (16.0)	6.8–29.4 (16.6)	6.7–12.9 (11.0)	11.1–21.1 (16.6)	33.4–66.9 (52.2)
Krishna	3	7.3–13.8 (9.9)	10.8–15.9 (12.6)	14.2–56.4 (38.0)	6.5–11.1 (8.2)	12.5–17.8 (14.4)	60.6–98.9 (78.7)
Guntur	3	11.0–13.1 (12.0)	13.6–15.6 (14.2)	15.7–26.1 (20.2)	8.8–10.9 (9.7)	14.8–16.8 (15.6)	53.3–68.5 (61.7)
Srikakulam	5	11.5–15.4 (13.6)	15.2–18.7 (16.8)	13.2–52.1 (25.6)	9.9–12.5 (11.0)	15.8–20.7 (18.2)	55.7–76.0 (65.2)
Rangareddy	3	11.0–16.2 (14.2)	14.9–19.4 (17.7)	14.2–36.1 (25.9)	9.2–12.6 (11.4)	15.1-21.7 (19.0)	63.5–71.7 (66.5)
Nalgonda	4	8.4–13.2 (11.3)	10.3–15.8 (13.4)	14.9-23.2 (19.2)	7.1–10.4 (9.3)	11.6-16.0 (14.4)	50.8–63.8 (55.6)
Nellore	3	9.8–16.5 (14.2)	10.6–20.4 (17.0)	8.0–24.8 (18.3)	7.9–12.7 (11.1)	12.1–22.5 (18.6)	52.3–77.5 (65.1)
Mean		12.6	15.4	43.7	10.4	17.0	63.8
LSD (P=0.05)							
Soils	2.52		2.49				
Phosphorus	0.63		0.62				
Interaction (S × P)		3.57		3.52			

Figures in parentheses indicate mean values
P0, 0 mg P/kg; P1, 19.5 mg P/kg

Verma and Tripathi (1982).

The available P (mg/kg) extracted by different reagents in air-dry soils was in the order of modified Olsen's-P (6.61) > Olsen's-P (5.71) > ammonium bicarbonate + DTPA-P (4.70) > ammonium bicarbonate-P (4.21) (Table 1). Similar trend of extraction of available P by different reagents was also observed in submerged soils. A marginal increase of 16, 4, 11 and 17% of available P was noticed with the extraction of Olsen's, modified Olsen's, ammonium bicarbonate + DTPA and ammonium bicarbonate methods, respectively, in submerged soils. Modified Olsen's reagent extracted more available P than Olsen's reagent might be due to inclusion of EDTA which might have partly complexes Al and Fe thus releasing some inorganic P. Similar findings were reported by Alexander and Robertson (1972). Addition of DTPA to ammonium bicarbonate reagent releases more P due to chelating action of Ca, Fe and Al, similar to the findings of Chandra Sekhara Rao and Bajaj (1994). Under submerged conditions, Olsen's reagent extracts relatively higher available P than the other extractants. The increase in available P under submergence might be due to relative transformation of different inorganic P fractions, release of occluded P, increase in solubility of $FePO_4.2H_2O$ and $AlPO_4.2H_2O$ caused by an increase in pH of slightly acidic soils. These results confirm the findings of Islam and Islam (1973).

Table 3 Matrix of correlation coefficients (r) between P fractions and P availability indices

P availability index	Fe-P	Al-P	Ca-P	Saloid-P	Reductant soluble-P
Air-dry soils					
Olsen's-P	0.59**	0.44*	0.72**	0.50**	0.50**
Modified Olsen's-P	0.66**	0.47**	0.73**	0.50**	0.46**
Ammonium bicarbonate-P	0.48**	0.42*	0.67**	0.50**	0.60**
Ammonium bicarbonate-DTPA-P	0.59**	0.47**	0.70**	0.38*	0.57**
Submerged soils					
Olsen's-P	0.79**	0.61**	0.63**	0.42*	0.66**
Modified Olsen's-P	0.79**	0.57**	0.63**	0.42*	0.66**
Ammonium bicarbonate-P	0.64**	0.52**	0.67**	0.45**	0.66**
Ammonium bicarbonate-DTPA-P	0.75**	0.51**	0.69**	0.42*	0.69**

* & **, Significant at 5 and 1 per cent level, respectively

All the P availability indices in air-dry soils showed highly significant relationship with Ca-P, followed by Fe-P and reductant soluble P (Table 3). However, in submerged

soils, all the P availability indices showed highly significant correlations with Fe-P, followed by reductant soluble P and Ca-P. The Fe-P in submerged soils had significant relationship with relative yield, relative P uptake and control P uptake followed by Al-P and reductant soluble P, whereas in air-dried soils, Fe-P showed significant relation with relative P uptake and control P uptake followed by Ca-P (Table 4). Thus the results indicated that Fe-P was the most important inorganic P fraction, contributing to P nutrition of rice followed by Ca-P and Al-P. The Olsen's extractable P in submerged soils and modified Olsen's extractable P in air-dried soils showed highly significant correlations with plant-growth parameters in comparison to other methods. In calibration of soil-test methods, considering nutrient uptake is more reliable than yield because of nutrient uptake was less influenced by the factors other than availability of added nutrients and it also reveals the extraction pattern of the plant throughout the growing season. As such in the present study, Olsen's extractable P showed highly significant correlations with P uptake under both the soil conditions and considered it as superior than other extractants.

It was found that Ca-P fraction alone contributed 52, 49 and 45% variation to the available P in air-dried soils as extracted by Olsen's, ammonium bicarbonate + DTPA and ammonium bicarbonate reagents respectively. The relative contribution of different P fractions towards the P uptake by rice indicated that 40% of variation was accounted by Fe-P, saloid P and reductant soluble P with a greater contribution from Fe-P fraction to the available P pool of the plants. In submerged soils, the Fe-P and Al-P accounted for 77, 74 and 69% of the observed variation to the available P as extracted by Olsen's, modified Olsen's and ammonium bicarbonate + DTPA methods, respectively, whereas Fe-P fraction only accounted for 23% variation towards the P uptake by rice. The results indicated that the proportion of contribution towards the available P pool was greater with Fe-P than Al-P. The variability in the relative contribution of inorganic P fractions to the available P pool may be attributed to the physico-chemical regime of waterlogged soil and differential solubility and transformation of inorganic P fractions. These results are in accordance with the findings of Mandal (1979). The contribution of inorganic P fractions towards the P uptake is moderate, probably mineralization of organic P might have contributed the P uptake by rice plants under submerged soil conditions and the availability of soil phosphate to the plant may be a function of solubility and amounts of all or certain forms of P present in the soil (Verma and Tripathi 1982).

Table 4 Linear correlation matrix (r) between P fractions and P availability indices with plant growth parameters

Inorganic fraction/P availability index	Air-dried soils			Submerged soils		
	Relative yield	Relative P uptake	Puptake (control)	Relative yield	Relative P uptake	Puptake (control)
Inorganic P fraction						
Fe-P	0.47**	0.44*	0.36*	0.58**	0.48**	0.36*
Al-P	0.55**	0.30	0.09	0.54**	0.32	0.24
Ca-P	0.54**	0.40*	0.20	0.47**	0.35*	-0.03
Saloid-P	0.23	0.29	0.01	0.32	0.34	-0.04
Reductant soluble-P	0.32	0.14	0.18	0.52**	0.25	0.21
P availability index						
Olsen's-P	0.75**	0.58**	0.55**	0.82**	0.57**	0.46**
Modified Olsen's-P	0.79**	0.66**	0.39*	0.81**	0.54**	0.38*
Ammonium bicarbonate-P	0.58**	0.33	0.30	0.81**	0.50**	0.22
Ammonium bicarbonate-DTPA-P	0.69**	0.52**	0.40*	0.74**	0.45**	0.35*

*P = 0.05; **P = 0.01

As regard the suitability of P soil-test method, Olsen's extractable P showed highly significant relationship with all the P fractions and plant-growth parameters in comparison to other P availability indices. It was observed that all the plant growth parameters were significantly correlated with Fe-P and Al-P fractions in submerged soils than the other P fractions. Since these 2 fractions (Fe-P and Al-P) mainly contributed to the Olsen's extractable P in submerged soils, it is possible to measure the P status of rice soils at submergence by Olsen's method is more reliable than the other extraction methods. Submergence influenced the available P status of the soil and it may not be possible to subject the soils to submergence in laboratory conditions as it takes 3 to 4 weeks, a regression equation was developed between Olsen's extractable P under air-dry and submerged soil conditions as

$$Y = 4.64 + 1.01 X$$

where Y is the available P under submerged conditions and X is the available P determined in air-dry soils.

Using this equation, the available P status of rice soils could be assessed for submerged conditions and used for fertilizer adjustments. Therefore, it is necessary to consider the submergence effect for fertilizer P recommendations by the soil testing laboratories because the soils low in available P also did not respond to P fertilization under submerged conditions. Similar findings were also reported by Mandal (1979).

Thus submergence caused an increase of Fe-P, Ca-P and reductant-soluble P fractions, with a major contribution of Fe-P and Al-P to the available P pool and P uptake by rice. Since Olsen's method extracted Fe-P and Al-P in submerged soils, which are also the main source for the plant P uptake, the determination of available P status at submergence by Olsen's method may be a better index for recommending P fertilizer doses to rice. As the soils were

neutral to slightly alkaline, Olsen's method of extraction was found to be more reliable than the other methods. However, the submergence effect has to be taken into consideration while making fertilizer P recommendations to rice to enhance the P-use efficiency and to minimize the expenditure on costly P fertilizers.

SUMMARY

Available P status and transformation of different inorganic P fractions in intensively rice (*Oryza sativa* L.) -growing soils of Andhra Pradesh was studied during 1996–97 under air-dried and submerged soil conditions and their relationship with plant-growth parameters was determined. The relative abundance of inorganic P fractions (mg/kg) was in order of Ca-P (78.9) > Al-P (38.9) > Fe-P (33.4) > reductant soluble-P (27.4) > saloid-P (4.5) in air-dry soils and Ca-P (87.2) > Fe-P (40.1) > Al-P (39.0) > reductant soluble-P (33.1) > saloid-P (4.5) under submerged soil conditions. Relative concentration of available P determined by different extractants in both air-dried and submerged soils was in the order of modified Olsen's > Olsen's > ammonium bicarbonate + DTPA > ammonium bicarbonate. Iron-bound phosphate was found to be the most important inorganic P fraction, contributing to phosphate nutrition of rice, followed by Al-P fraction. Olsen's method proved superior to other methods, as it showed significant correlations with all plant growth parameters.

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Indian Journal of Agricultural Sciences 72 (7) : 416–7, July 2002

Effect of tillage practices, organics and nitrogen levels on yield and economics of foxtail millet (*Setaria italica*) during rainy season*

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Received: 21 June 2001

Key words: Tillage practices, Organics, Nitrogen levels, Foxtail millet

In Karnataka, millets are cultivated on an area of 1.25 million ha, producing 1.54 million tonnes with a productivity of 1 230 kg/ha (AICSMIP 1997). Foxtail millet (*Setaria italica* L.) is widely grown in Dharwad, Haveri and Belgaum districts of northern transitional zone of Karnataka (Zone 8). Tillage is very much essential to incorporate the soil organic sources as well as to mix the fertilizers in the soil. Owing to this, the loss of nutrients are prevented by removing the weeds particularly the deep-rooted ones. In recent years, much emphasis has been given for use of organics to produce adequate amount of high-quality food. Such integrated nutrient supply system (INSS) helps for maintenance and possibly improvement of soil fertility for sustaining crop productivity on long-term basis (Babalad 1999). The use of bio-fertilizers is effective and improves the yield and other soil parameters. In the present paper we discussed effect of improved tillage practices with integrated nutrient system on yield of foxtail millet.

The field experiment was conducted during rainy season 1997 and 1998 on shallow Alfisols (*p*H 7.0) at Agricultural Research Station, Hanumanamatti. There were 4 main plots (tillage practices), viz M_1, shallow tillage (5 cm) with flat bed sowing; M_2, shallow tillage (5 cm) with ridging; M_3, medium tillage (15 cm) with flat bed sowing; and M_4, medium tillage (15 cm) with ridging; and 4 subplots (organics), viz S_1, enriched farmyard manure @ 2.5 tonnes/ha; S_2, enriched farmyard manure @ 2.5 tonnes/ha + *Azospirillum* @ 10 kg/ha; S_3, *Glyricidia* green-manuring @ 5.0 tonnes/ha; and S_4, control (without organics) and 3 sub-subplots (nitrogen levels), viz 0, 30 and 60 kg N/ha, making 48 treatment combinations. The experiment was laid out in split split-plot desgin with 3 replications.

After tillage treatments, 1 week before sowing the land was harrowed and soil was brought to a fine tilth. Nitrogen was applied as per treatments and recommended dose of P and K was applied common to all the treatments at the time of sowing. Fertilizer was applied in furrows open manually at 30 cm rows to the sowing furrows and covered manually. 'SIA 2642' foxtail millet cultivar was used. Required plant population was maintained by thinning the plants at 20 days after sowing. The intercultural operations were carried out first at 20–25 days after sowing and second at 30–35 days after sowing. Ridges were made as per treatment in the main plots. Hand-weeding was carried out once for complete removal of weeds.

Foxtail millet recorded significantly higher grain yield in medium tillage and ridging with enriched FYM + *Azospirillum* + 60 kg N/ha over the other treatment combinations. The next best treatment combination was found to be medium tillage and ridging with *Glyricidia* green manuring (Table 1). The same trend was also observed for straw yield. The improved tillage practices with integrated nutrient system favourably influenced the growth and development of foxtail millet. The greater dry-matter accumulation and superior yield attributes resulted in higher yield performances (Sharma *et al.* 1998).

There was significant differences due to interaction effects of tillage practices, organics and nitrogen levels for net returns (Table 1). Medium tillage and ridging with enriched farmyard manure + *Azospirillum* + 60 kg/ha reflected in significantly higher net returns and next in order was medium tillage and ridging with *Gliricidia* green-manuring + 60 kg/ha over shallow tillage flat bed sowing + control + 0 kg N/ha. These results corroborate the findings of Murthi *et al.* (1986) and Alwar *et al.* (1995).

SUMMARY

An experiment was conducted during the rainy season of 1997 and 1998 to study response of foxtail millet (*Setaria italica* L.) to tillage practices, organics and nitrogen. Foxtail millet recorded significantly higher grain yield (2 044 kg/ha) and net returns (7 312 Rs/ha) in medium tillage and

* Short note

A part of the Ph D thesis submitted by first author submitted in 2000 to University of Agricultural Sciences, Dharwad, Karnataka (unpublished)

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Table 1 Grain yield, straw yield and net returns in foxtail millet as influenced by tillage practices, organics and nitrogen levels during rainy season (data of 2 years)

Treatment	Organics	Grain yield (kg /ha) at				Straw yield (kg/ha) at				Net returns (Rs/ ha) at			
		N_0	N_{30}	N_{60}	Mean	N_0	N_{30}	N_{60}	Mean	N_0	N_{30}	N_{60}	Mean
ST–FS	E FYM	810	1 077	1 208	1 032	1 717	2 406	2 784	2 302	1 706	3 071	3 881	2 886
	E.FYM+Azo	904	1 305	1 496	1 235	2 013	2 568	3 047	2 543	1 876	4 448	5 266	3 863
	Gly	845	1 291	1 449	1 195	1 776	2 508	2 867	2 384	1 193	4 143	4 767	3 367
	Control	529	652	742	640	1 178	1 481	1 701	1 453	1 090	1 385	2 106	1 527
	Mean	772	1 081	1 223	1 026	1 671	2 241	2 600	2 171	1 466	3 262	4 004	2 911
ST–R	E FYM	872	1 776	1 327	1 126	1 867	2 638	3 047	2 517	2 035	3 367	4 386	3 262
	E.FYM+Azo	1 007	1 381	1 579	1 322	2 327	2 747	3 292	2 788	2 571	4 931	5 619	4 374
	Gly	926	1 391	1 553	1 290	1 967	2 768	3 009	2 581	2 222	4 669	5 165	4 018
	Control	611	719	837	723	1 110	1 680	1 790	1 500	1 455	1 954	2 740	2 050
	Mean	855	1 167	1 324	1 115	1 818	2 439	2 784	2 347	2 070	3 730	4 477	3 426
MT–FS	E FYM	928	1 233	1 423	1 195	1 931	2 783	2 998	2 570	2 138	3 758	4 541	3 479
	E.FYM+Azo	1 060	1 490	1 776	1 442	2 316	2 986	3 303	2 868	2 748	4 963	6 463	4 725
	Gly	955	1 473	1 748	1 392	2 137	2 884	3 229	2 750	2 251	5 049	6 236	4 512
	Control	*687*	*799*	*934*	*807*	*1 356*	*1 781*	*1 936*	*1 691*	*1 701*	*2 393*	*2 923*	*2 338*
	Mean	908	1 249	1 470	1 209	1 935	2 609	2 688	2 470	2 209	4 041	5 041	3 764
MT–R	E FYM	981	1 294	1 498	1 257	2 101	2 871	3 213	2 728	2 008	3 955	5 039	3 667
	E.FYM + Azo	1 118	1 587	2 044	1 582	2 491	3116	3 524	3 043	3 486	5 381	7 312	5 393
	Gly	1 008	1 636	1 869	1 507	2 412	2 991	3 276	2 892	2 647	5 891	6 863	5 133
	Control	758	865	1 024	883	1 576	1 916	2 184	1 875	1 889	2 875	3 269	2 677
	Mean	966	1 345	1 609	1 307	2 133	2 723	3 049	2 635	2 507	4 526	5 621	4 218
Mean	E FYM	898	1 195	1 364	1 152	1 904	2 675	3 010	2 530	1 971	3 538	4 461	3 323
	Azo	1 022	1 441	1 724	1 395	2 287	2 854	3 291	2 811	2 670	4 931	6 165	4 589
	Gly	933	1 448	1 655	1 345	2 073	2 788	3 095	2 652	2 078	4 938	5 758	4 259
	Control	647	759	884	763	1 293	1 694	1 903	1 630	1 514	2 152	2 759	2 148
	Mean	875	1 211	1 407		1889	2 503	2 825		2 063	3 889	4 786	
For comparison of means		*CD (P=0.05)*				*CD (P=0.05)*				*CD (P=0.05)*			
Tillage practice (TP)		37				91				38			
Organics (O)		32				66				38			
Nitrogen levels (N)		27				57				30			
Interactions													
TP × O		63				131				75			
TP × N		53				114				60			
O × N		53				114				60			
TP × O × N		106				228				128			

ST-FS, Shallow tillage-flat sowing; MT-FS, medium tillage-flat sowing; E. FYM, enriched FYM @ 2.5 tonnes/ha; Gly, *Glyricidia* green manuring @ 5.0 tonnes/ha; ST-R, shallow tillage and ridging; MT-R, medium tillage and ridging; Azo., *Azospirillum* @ 10.0 kg/ha; control, without organics

ridging with enriched farmyard manure + *Azospirillum* + 60 kg N/ha over other treatment combinations. The next best treatment combination was medium tillage and ridging with *Glyricidia* green manuring @ 5.0 tonnes/ha + 60 kg N/ha.

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Indian Journal of Agricultural Sciences 72 (7) : 418–20, July 2002

Response of greengram (*Phaseolus radiatus*) to irrigation schedule and fertilizer level*

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Received: 21 January 2002

Key words: Greengram, *Phaseolus radiatus*, Irrigation, Fertilizer, Yield

In India greengram (*Phaseolus radiatus* L.) is mainly cultivated as a dryland crop, mostly in the rainy season. Among the various factors responsible for maximizing the yield of crop, irrigation and fertilizers are the most important ones. Physiological stages of crop growth are critical in their demand of water. For maximization of crop yield, it is essential that crop should not suffer due to soil-moisture stress at any stage and balanced mineral nutrition specially nitrogen, phosphorus and potassium. Since fertilizers are scarce and costly, it is necessary to use them judiciously and economically. In this regard, the targeted yield approach based on the crop needs and available nutrients in soil seems to be better (Ramamoorthy *et al.* 1967). Hence an experiment was conducted on this aspect.

A field experiment was carried out during the rainy season of 2000 at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. The experiment was laid out in split-plot design, replicated thrice. The treatments comprised 4 irrigation schedules as main plot treatments, viz I_1, irrigation schedule at initial, flowering and pod-development stages; I_2, initial and flowering stages; I_3, initial and pod-development stages; and I_4, flowering and pod-development stages; and 5 fertilizer levels as subplot treatments, viz F_1, recommended dose (25, 22, 0 kg N, P and K/ha); F_2, fertilizer required as per soil test (31, 27.3, 0 kg N, P and K/ha) F_3, fertilizers required for 1.0 tonne/ha targeted yield (13, 11.9, 10.0 kg N, P, K/ha) ; F_4, fertilizers required for 1.2 tonne/ha targeted yield (22, 22.9, 8.3 kg N, P and K/ha); and F_5, fertilizers required for 1.4 tonne/ha targeted yield (31, 33.9, 21.6 kg N, P and K/ha). The soil was clay in texture, low in available nitrogen (178 kg/ha), phosphorus (12.8 kg/ha) and rich in available potassium (459 kg/ha). The bulk density of the experimental field was 1.30 Mg/m^3. Field capacity and permanent wilting point were 32.0 and 16.5 % respectively. The total available moisture was 15.5 %. The nutrients nitrogen, phosphorus and potassium were applied through urea, single superphosphate and muriate of potash respectively. The fertilizers required for the targeted yields were calculated by the following fertilizer prescription equation developed by soil test crop response correlation scheme, MPKV, Rahuri (MPKV 1993):

$$FN = 4.56\ T - 0.18\ SN$$
$$FP_2O_5 = 12.51\ T - 7.61\ SP$$
$$FK_2O = 3.53\ T - 0.05\ SK$$

where T, target in q/ha (100 kg/ha), SN, SP and SK, available soil N, P and K respectively.

The crop was sown by dibbling on 1 July 2002 at optimum moisture conditions with a spacing of 30 cm × 10 cm. Irrigations were applied as per the critical stages of crop from sowing to harvest. Irrigation water was measured through 90°V notch and time required to irrigate each unit was measured and depth of irrigation at each irrigation was calculated by the standard formula developed by Michael and Hukkeri (1977).

The irrigation regimes did not significantly influence the growth and yield attributes measured in terms of plant height, number of functional leaves, leaf area, dry-matter accumulation, pods/plant, seeds/pod and seed weight/plant (Table 1). However, growth attributes were maximum when irrigations were scheduled at initial and pod-development stages (I3). This might be owing to availability of sufficient moisture during vegetative and reproductive stages. These results confirmed the findings by Selvaraju (1999).

All the yield attributes showed higher magnitude due to scheduling of irrigation at initial, flowering and pod-development stages compared with only 2 irrigations (Table 1). However, the differences between the treatments were not observed. The seed yield due to various irrigation schedules did not differ significantly, indicating that only 2 irrigations at critical growth stages were sufficient for greengram either at initial and flowering or initial and pod development or flowering and pod development stages. During the rainy season effective rainfall received during the crop growth period might have helped to reduce the number of irrigations. It also indicated that among the 3 critical growth stages any 2 critical growth stages were found effective in keeping the yield levels at par with that

* Short note

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Table 1 Growth and yield of mungbean as influenced by irrigation schedules and fertilizer levels

Treatment	Plant height (cm)	Leaves /plant	Leaf area/ (dm^2)	Dry matter/ plant (g)	Pods/ plant	Seeds /plant	Seed weight /plant(g)	Seed yield (tonnes/ha)	Straw yield (tonnes/ha)	Protein yield (tonnes/ha)
Irrigation schedule										
I_1, Initial, flowering and pod development stage	58.68	48.40	54.14	23.65	38.82	10.19	11.52	1.09	2.45	0.19
I_2, Initial and flowering stage	59.10	48.04	53.93	23.47	38.85	9.55	11.41	1.07	2.40	0.19
I_3, Initial and pod development stage	59.13	49.74	54.17	22.79	38.27	10.07	11.11	1.03	2.37	0.18
I_4, Flowering and pod-development stage	59.19	48.47	55.21	22.61	38.28	9.89	11.31	1.00	2.34	0.18
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertilizer (N:P:K kg/ha)										
F1, 25:22:0 (recommended dose)	58.45	46.08	54.51	20.05	36.92	9.04	10.99	1.00	2.31	0.16
F2, 31:27.3:0 (as per soil test)	59.38	47.38	52.77	21.96	37.69	9.42	11.02	0.97	2.35	0.17
F_3, 13.11.9: 10.0 (targeted yield, 1 tonne/ha)	59.42	48.38	53.48	23.50	38.75	9.74	11.05	1.05	2.37	0.19
F_4, 22:22.9:8.3 (targeted yield, 1.2 tonne/ha)	59.22	49.79	55.43	24.51	39.65	10.29	11.56	1.10	2.50	0.20
F_5, 31:33.9:21.6 (targeted yield, 1.4 tonnes/ha)	58.89	51.72	55.62	25.63	39.77	11.15	12.05	1.01	2.42	0.20
CD (P=0.05)	0.66	NS	NS	0.73	1.28	0.74	0.71	0.007	0.059	0.018
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

of 3 critical growth stages. Similar trend was noticed for straw yield/ha.

The protein yield/ha did not differ significantly due to different irrigation regimes; however, it was maximum when irrigations were scheduled at initial, flowering and pod-development stages. Uptake of N, P and K was found to

Table 2 Uptake of nutrients, irrigation water applied, depletion of water, effective rainfall, consumptive use and water-use efficiency as influenced by different treatments

Treatment	Uptake (kg/ha)			Irrigation water applied (mm)	Depletion of moisture (mm)	Effective rainfall (mm)	Consumptive use (mm)	Yield (kg/ha)	Water-use efficiency (kg/ha-mm)
	N	P	K						
Irrigation schedule									
I_1, Initial, flowering and pod development stage	99.92	31.79	78.73	280.0	257.4	10.3	267.7	1086	4.05
I_2, Initial and flowering stage	98.56	31.56	89.87	210.0	191.2	10.3	201.5	1068	5.30
I_3, Initial and pod-development stage	96.18	31.93	80.74	210.0	189.7	43.8	233.5	1033	4.42
I_4, Flowering and pod-develo- stage	89.83	29.02	82.70	210.0	187.3	13.8	201.8	1004	4.97
CD (P=0.05)	7.68	1.28	3.97						
Fertilizer (N:P:K kg/ha)									
F_1, 25:22:0 (recommended dose)	7.56	24.72	69.51	227.5	206.4	19.5	225.9	998	4.41
F_2, 31:27.3:0 (as per soil test)	90.21	27.28	67.59	227.5	206.4	19.5	225.9	925	4.31
F_3, 13:11.9:0 (targeted yield, 1 tonne/ha)	95.02	30.83	84.63	227.5	206.4	19.5	225.9	1050	4.64
F_4, 22:22.9:8.3 (targeted yield, 1.2 tonne/ha)	104.25	33.38	92.83	227.5	206.4	19.5	225.9	1100	4.86
F_5, 33.33.9:21.6 (targeted yield, 1.4 tonne/ha)	112.39	37.97	100.50	227.5	206.4	19.5	225.9	1107	4.90
CD (P=0.05)	6.93	2.21	2.35						
Interaction	NS	NS	NS						

be significant. The maximum uptake of N was observed due to scheduling of irrigation at initial, flowering and pod-development stages, and it was significantly superior to those observed in rest of the treatments. The P uptake was higher when irrigations were applied at initial and pod-development stages, and significantly maximum K uptake was recorded when irrigations were scheduled at flowering and pod-development stages.

The irrigations scheduled at initial, flowering and pod-development stages (I_1) recorded the highest consumptive use of water, being highest when irrigations were scheduled at initial and flowering stages (I_2).

The values of growth attributes increased with the increase in fertilizer levels throughout the crop-growth period except plant height at harvest. The dry-matter accumulation due to treatment F_5 was significantly higher than that recorded in rest of the levels. This might be due to the higher levels of fertilizer which helped in synthesizing more photosynthates resulting in higher dry-matter accumulation. These results are in conformity with those of Parmar *et al.* (1999), Sharma and Upadhyay (2000) and Chowdhary (2000). The pods/plant, seeds/pod and seed weight/plant were significantly increased with highest level of fertilizers F_5, followed by F_4. The seed yield was maximum under treatment F_5 which was significantly superior to yields obtained in rest of the fertilizer levels except F_4 which was at par with that of F_5. The 1.0 tonne/ha yield target was achieved easily but yield decrease was observed up to 8.33 and 21.42 % in 1.2 and 1.4 tonnes/ha targeted yield respectively. These results are in agreement with those obtained by Patil *et al.* (1995).

The protein yield/ha was maximum at fertilizer level F_5 and was significantly superior to the protein yield produced by rest of the fertilizers levels. The total uptake of N, P and K (Table 2) increased significantly with the increase in the level of fertilizer and it was maximum in fertilizer level F_5. These results confirm the findings of Basu and Bandyopadhyay (1990).

The consumptive use of water with fertilizer levels was 225.9 mm. The water-use efficiency ranged between 4.31 and 4.90 kg/ha-mm for different fertilizer levels.

SUMMARY

Application of irrigation at any 2 critical growth stages and fertilizer application for 1.0 and 1.2 tonnes/ha targeted yields of greengram were found better than those observed in other treatments. The maximum consumption use (267.7 mm) was obtained when irrigations were scheduled at initial, flowering and pod development stages. The water-use efficiency was the highest (5.30 kg/ha-mm) when irrigations were scheduled at initial and flowering stages.

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Indian Journal of Agricultural Sciences 72 (7) : 421–3, July 2002

Effect of rhizospheric micro-organisms on growth and yield of greengram (*Phaseolus radiatus*)*

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Received: 30 August 2001

Key words: Phosphate-solubilizing micro-organisms, Greengram, *Phaseolus radiatus*, N_2 fixers

Phosphorus occurs in both organic and inorganic forms in soil and is a vital nutrient for plants and micro-organisms. Most of the soil phosphorus is in unavailable form, which is converted to readily available form by different soil micro-organisms (Rokade and Patil 1992). The efficient P solubilizers posses the ability to solubilize inorganic phosphate and also can mineralize organic phosphatic compounds. The effect of combined inoculations with N_2 fixers and P-solubilizers on yield, nitrogen and phosphorus accumulation in plants has been found to be more significant than the effect of either organism used alone. The present work deals with the synergistic interactions of N_2-fixing organisms with phosphate-solubilizing microorganisms and their effect on greengram (*Phaseolus radiatus* L.).

The phosphate-solubilizing micro-organisms, and N_2 fixers were isolated from the rhizosperic soils of greengram, tomato (*Lycopersicon esculentum* Miller nom. cons.), garlic (*Allium sativum* L.) and onion (*A. cepa* L.) grown in garden soil of Rafi Ahmad Kidwai Institute of Agricultural Sciences, AMU, Aligarh. *Bradyrhizobium* sp and *Azotobacter chroococcum* Beijerinck were isolated using yest-extract mannitol agar (YMA) and Ashby's agar medium respectively. Phosphate-solubilizing micro-organisms were isolated by enrichment culture technique using Pikovskaya's broth (Pikovskaya 1948). *Proteus vulgaris* was procured from the IARI, New Delhi.

The P-solubilizing efficiency of the isolated strains was investigated using tricalcium phosphate (TCP) at different incubation periods. The amonut of phosphate solubilized was estimated by colorimetric method of King (1932). The bacterial and fungal strains showing better solubilization were selected for crop inoculation experiments.

Surface-sterilized seeds of 'T 44' greengram were soaked in 4 days old cultures (@ 10^8 cells/ml) for 1hr. Seeds were sown in nutrient agar plates and germination (%) and root and shoot length were recorded after 4 days of incubation. Surface-sterilized seeds of greengram coated with 10^8 cells/ml were also sown in pots containing 5 kg sterilized soils. Uninoculated control was also kept. Each treatment was replicated 3 times. Nodules were collected after 45 days after sowing. The crop was harvested at 55 days and P and N uptake was estimated after harvest.

In the present study, the rhizospheres of tomato, greengram, garlic and onion harboured nearly identical number of P-solubilizer and N_2 fixer. Nine bacterial and 6 fungal strains were isolated from the rhizospheric soils. Isolate O_3 (*Bacillus* sp) and Mf_2 (*Aspergillus* sp) were found better solubilizer than other isolates. The incidence of phosphate-solubilizing micro-organisms in these rhizosphere may be attributed to the favourable influence exerted by root exudates of the crops. The incidences of phosphate-solubilizing micro-organisms and in different rhizospheres have also been reported by number of workers (Sattar and Gaur 1989). In liquid medium, the release of soluble P increased progressively till day 10 of incubation. The highest amount of phosphate solubilized was observed when *Bacillus* sp and *Aspergillus* sp were inoculated together (498.2 mg/ml) with decrease in *p*H from 5 to 4.8. However, the lowest solubilization was recorded when *Bacillus* sp, *P. vulgaris* and *Bradyrhizobium* sp were incubated together (59.4 µg/ml). In general, all the isolates solubilized phosphates, but their efficiency differed considerably. The increase in P-solubilization could be due to different mechanism of generating acidity by cultures (Illmer and Schinner 1995). *Bacillus* sp, *Aspergillus* sp, *P. vulgaris*, *A. chroococcum* and *Bradyrhizobium* sp were grown together and no antagonistic behaviour of one organism towards another was noticed, indicating the feasibility of using all the 5 strains together as microbial inoculant. The co-existence of N_2 fixer and P-solubilizer could be explained by the fact that nitrogenous substances and growth-promoting

*Short note

Based on complete information of M Sc thesis of the first author, who submitted it to Aligarh Muslim University, Aligarh, in 2000 (unpublished)

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substances synthesized by N_2 fixer could be utilized by P-solubilizers, whereas growth of N_2 fixer was stimulated owing to the presence of available P in the medium. The result also indicated an inverse correlation between P-solubilization and *p*H of the medium.

The seed germination was 100% recorded when inoculated with *Bradyrhizobium* sp and *P. vulgaris* alone. The dual inoculation of *Bacillus* sp + *Aspergillus* sp or *Bacillus* sp + *Bradyrhizobium* sp and triple inoculations of *Bacillus* sp + *Aspergillus* sp + *P. vulgaris* also exhibited the enhanced effect compared with the other single inoculation treatments. Maximum shoot length (14.1 cm) and root length (9.46 cm) were observed when seeds were treated with *Bradyrhizobium* sp alone. The single inoculation with *A. chroococcum* and triple inoculation of *Bacillus* sp + *P. vulgaris* + *Aspergillus* sp also enhanced root length significantly. *Bacillus* sp + *P. vulgaris* + *Bradyrhizobium* sp however, adversely affected the health of greengram crop.

Maximum seed germination (100%) in pot culture was recorded when seeds were inoculated with *Aspergillus* sp alone or *Aspergillus* sp + *Bacillus* sp + *P. radiatus* + *Bradyrhizobium* sp + *A. chroococcum*. *Bacillus* sp + *A. chroococcum* treatment significantly improved the shoot length (25.6 cm) compared with the other treatments or the control. The 5 cultures used together performed significantly better than single, dual or triple inoculations. The *Bradyrhizobium* sp inoculation alone significantly improved the root length (9.83 cm) compared with other treatments. Seeds coated with *A. chroococcum* alone augmented the shoot dry weight (2.06 gm/plant). Maximum root dry weight (0.37 g/plant) and grain yield (6.6 g/plant) were observed with *Bradyrhizobium* sp alone. The mixed inoculum of all 5 cultures also improved the yield (5.9 g/plant) compared with other single, dual or triple inoculations (Table 1). The associative effect of *A. chroococcum* and *Bacillus* sp resulting in better plant health was probably owing to the release of growth-promoting substances. The beneficial effect of *Azotobacter* is not only due to its ability to fix nitrogen but also due to its ability to secrete growth-promoting substances and its capacity to produce antifungal antibiotics which improves plant health by inhibiting root pathogens (Kothari and Saraf 1990). Among all the treatments, nodule number and nodule dry weight varied considerably. The possible reason for low number of nodules may be due to the presence of competitive indigenous rhizobia in the rhizospheres, which might be delaying the nodulation. Significant improvement in nodulation was observed when all the five microbial cultures were used together. Single inoculation with *Bradyrhizobium* sp as well as all the 5 strains applied together exhibited a high degree of nodule rating. Highest phosphorus (0.39%) and N_2 (2.96%) uptake was found in plants treated with double inoculation of

Table 1 Effect of rhizospheric microorganisms on growth, nodulation, yield and nutrient uptake of greengram

Treatment	Length/plant (cm)		Weight/plant (g)		Nodules			Yield/ plant (g)	Nutrient uptake		
	Root	Shoot	Root	Shoot	Number/ plant	Weight/ (g/plant)	Rating		N (%)	P (%)	K (ppm)
Bacillus sp	6.03	16.0	0.21	1.15	8.0	0.11	3.0	2.25	2.31	0.36	14.0
Aspergillus sp	7.0	8.0	0.22	1.43	9.0	0.12	5.25	2.66	1.65	0.34	10.0
P. vulgaris	7.67	18.17	0.24	1.15	20.0	0.24	6.0	3.1	1.70	0.26	8.0
A.chroococcum	7.0	20.17	0.29	2.06	11.0	0.14	7.0	5.2	1.80	0.35	11.0
Bradyrhizobium sp	9.83	19.17	0.37	1.91	33.0	0.28	8.5	6.6	1.83	0.10	12.0
Bacillus sp + *Bradyrhizobium* sp	6.50	20.33	0.28	1.49	15.0	0.24	4.2	3.8	1.73	0.37	9.0
Bacillus sp + *A. chroococcum*	8.50	25.6	0.26	1.92	11.0	0.14	5.4	3.1	2.32	0.38	9.0
Bacillus sp + *P. vulgaris*	8.0	16.3	0.16	1.09	9.0	0.14	6.4	3.1	2.96	0.39	10.0
Aspergillus sp + *P. vulgaris*	7.67	23.83	0.15	0.62	12.0	0.15	6.1	2.1	2.56	0.19	21.0
Aspergillus sp + *A. chroococcum* + *Bradyrhizobium* sp	9.50	18.60	0.28	1.37	14.0	0.14	6.3	4.1	1.69	0.32	10.0
Aspergillus sp + *P. vulgaris* + *Bradyrhizobium* sp	8.67	21.33	0.32	0.5	16.0	0.2	7.75	4.6	2.46	0.05	14.0
Bacillus sp + *P. vulgaris* + *Bradyrhizobium* sp	8.17	20.83	0.33	1.47	17.0	0.2	8.0	4.3	2.59	0.06	12.0
Bacillus sp + *P. vulgaris* + *Bradyrhizobium* sp + *A. chroococcum* + *Aspergillus* sp	10.0	24.33	0.23	1.45	23.0	0.26	10.0	5.9	2.45	0.16	11.0
Control	5.07	18.17	0.11	0.62	8.0	0.11	4.0	1.3	2.11	0.1	10.0
CD (P=0.05)	4.7	5.7	0.07	0.6	3.0	0.02		0.2			

Bacillus sp + *P. vulgaris* while highest potassium content was observed in plants treated with *Aspergillus* sp + *P. vulgaris* (21 ppm). The phosphate-solubilizing micro-organisms and N_2 fixers may supply both of these nutrients to the crop if the 2 groups interact with each other. The associative effect of 2 groups of beneficial organisms such as N_2 fixers and P-solubilizers (Belimove *et al.* 1995) and *Azotobacter* and phosphate solubilizing bacteria are well documented (Sattar and Gaur 1989, Singh 1994). The present finding indicates that the synergistic interactions of all 5 microbial strains and increased P-solubilization may prove beneficial for developing mixed inoculants for increasing crop productivity.

SUMMARY

Phosphate-solubilizing micro-organisms isolated from rhizospheric soils of garlic (*Allium sativum* L.), greengram (*Phaseolus radiatus* L.), onion (*A. cepa* L.) and tomato (*Lycopersicon esculentum* Miller nom. cons.) were evaluated for their P-solubilizing efficiency. *Bacillus* sp and *Aspergillus* sp when grown together were found potential P-solubilizer. *Bacillus* sp, *Aspergillus*, *P. vulgaris*, *A. chroococcum* and *Bradyrhizobium* sp grown together showed no antagonistic behaviour of one organism towards another organism. An inverse correlation between P-solubilization and *p*H of the medium was noticed. The P-solubilizing and N_2-fixing organisms improved the seed germination, plant health, nodulation and grain yield of greengram (*Phaseolus vulgaris* L.) var 'T 44'. The dual or triple inoculations in general, augmented the N uptake, whereas all the cultures except *A. chroococcum* + *P. vulgaris* + *Bradyrhizobium* improved the P content. *Aspergillus* + *P. vulgaris* significantly improved the potassium content compared with other treatments.

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Indian Journal of Agricultural Sciences 72 (7) : 424–7, July 2002

Effects of sowing time and irrigation on phenology and growing degree days of spring sunflower (*Helianthus annuus*)

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Received: 21 September 2001

Key words: Sunflower, *Helianthus annuus*, Sowing time, Irrigation, Phenology, Growing degree-days

Among oilseed crops, cultivation of spring sunflower (*Helianthus annuus* L.) is becoming popular in north-west India as it fits well in various cropping systems. Sunflower is photo-thermo-insensitive, short-duration crop and has high production potential, and can be grown successfully in all the seasons. However, it takes more time when grown in winter season in North-Western Zone (Giri 2001). Variation in temperature during growing season is documented to modify the plant activities and growth process to a large extent. Photo-periodic variation also causes differences in dates of budding, flowering and maturity. To set up the production and realize maximum benefits in a short period, it is imperative to schedule need-based irrigation. High yield can be obtained when irrigation is applied at proper time (Vivek *et al.* 1994). Since information on optimum time of sowing and irrigation schedulding on physiological growth stages for spring sunflower is not available in foot-hills tract of Uttranchal, present investigation on spring sunflower was carried out.

The field experiment was conducted during the spring season of 1998 and 1999 at University Crop Research Centre, Pantnagar (29^{0}N, 79.3^{0}E, 245.83^{0}m above mean sea-level). The soil was sandy loam (Mollisols), high in organic carbon (0.69%) and available phosphorus (31.93 kg/ha) and medium in available potassium (236.40 kg/ha), having bulk density 1.58 g/cm^3, field capacity 23.4 and permanent wilting point 10.4%, with soil *p*H 7.2.

The parental lines ('234 A' and '35 R') in 3:1 ratio at 20 cm × 60 cm planting distance were sown at rate of 8 kg seed/ha on 3 dates [5 February (D_1), 20 February (D_2) and 7 March (D_3)] under 4 levels of irrigation [irrigation applied at all growth stages (I_1), 1 irrigation missed at pre-flowering (I_2), 1 irrigation missed at flowering (I_3), and 1 irrigation missed at grain filling (I_4)]. The trials were laid out in split-plot design, allocating dates of sowing in main plots and irrigation in subplots, replicated 4 times. The plot size was 5 m × 5.4 m (net 3 m × 4 m). The full dose of P (40 kg/ha) and half dose of recommended N (100 kg/ha) applied at sowing time and remaining N was top-dressed after first irrigation. The thining and gap-filling were done 15 days after sowing. No potassium fertilizer was applied to the crop. All the other recommended practices were followed for raising the crop. Five rows were selected in each plot for phenological observations. The days taken to these stages were counted from the date of sowing. Heat units were computed, which show relationship between growth duration and temperature. Temperature of 7^{0}C was used as base temperature for sunflower. Heat units were calculated for each phenological stage. Mathematically it can be expressed as :

$$GDD = \Sigma^{n}_{i=1} [(T_{max} + T_{min}) — T_b/2]$$

T_{max}, maximum temperature of the day; T_{min}, minimum temperature of the day; and T_b, lowest temperature below which there is no growth also called base temperature.

During growing seasons mean minimum 4.6^{0}C–26.3^{0}C and maximum 19.6^{0}C–39.8^{0}C temperatures were recorded. The difference between average temperature and base temperature was calculated and multiplied with number of days required to reach to a particular stage of the crop. Temperature during February–May was 5.5–25^{0}C (minimum) and 21–39^{0}C (maximum). The base temperature 7^{0}C was used for heat units computation. Humidity varied from 32.5% to 73.7%. The rainfall received during the crop growing seasons was 149.0 mm and 172.6 mm in 1998 and 1999 respectively. Other weather conditions were favourable to the crop.

The phenological stages of sunflower were significantly influenced by date of sowing.

There was fast seedling emergence as date of sowing was advanced. The maximum days to seedling emergence were recorded when planting was done on 5 February,

Article is based on a part of the Ph D thesis of first author who submitted it to the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, in 2000 (unpublished).

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Table 1 Effect of date of sowing and level of irrigation on occurrence (days after sowing) of phenological stages on growing degree-days for phenological stages of sunflower (pooled data of 1998 and 1999)

Treatment	50% seedling emergence	50% button initiation	50% flowering	50% Harvesting grain filling	Up to 50% seedling emergence (from soil temperature)	50% seed emergence to 50% button initiation	50% button initiation to 50% flowering	50% grain flowering to 50% grain filling	50% filling to harvesting	Total seedling to harvesting (1+2+3+4+5)
Sowing date										
5 February	13.95	55.75	67.65	77.50	102.30	186.55	477.20	195.20	202.70	547.75	1 619.55
20 February	11.20	53.65	63.80	72.20	96.30	157.50	589.25	202.40	180.95	531.10	1 661.35
7 March	8.00	50.75	57.55	64.25	90.55	133.45	726.95	154.20	164.40	601.55	1 779.75
SEm±	0.31	0.24	0.25	0.26	0.27	5.18	6.76	6.72	5.71	6.26	11.86
CD (P=0.05)	0.75	0.57	0.59	0.63	0.66	12.68	16.55	16.43	13.97	16.22	29.03
Irrigation level										
Irrigation at all growth stages (I_1)	11.00	53.25	62.65	72.10	96.76	158.45	594.85	183.45	182.90	572.45	1 692.20
1 irrigation missed at pre-flowering (I_2)	11.50	53.45	62.20	71.40	96.75	160.50	601.30	182.05	185.15	557.90	1 686.95
1 irrigation missed at flowering (I_3)	11.00	53.15	62.90	70.90	96.25	158.85	598.30	183.50	186.55	546.50	1 673.75
1 irrigation missed at grain filling (I_4)	11.00	53.20	63.45	71.30	95.80	158.95	595.45	186.80	176.30	547.05	1 663.65
SEm±	0.35	0.35	0.32	0.29	0.23	5.83	5.84	8.46	6.32	8.59	19.09
CD (P=0.05)	NS	NS	NS	0.64	0.53	NS	NS	NS	NS	19.44	NS

No interaction between D × I

while the minimum when crop was planted on 7 March (Table 1). Effect of soil moisture on germination was similar in all the treatments as an application of pre-sowing irrigation.

The occurrence of 50% button stage took maximum and minimum days after sowing when the crop was planted on 5 February and 7 March respectively. Treatment of 1 missed irrigation at 50% button initiation (I_2) did not affect button stage because it was applied at this stage and effect of this 1 missed irrigation could not be observed immediately (Table 1).

The occurrence of 50% flowering took maximum and minimum days after sowing when crop was planted on 5 February and 7 March respectively. The difference worked out to be 10 days between first date and third date of sowing taken for 50% flowering in both the years. One missed irrigation at flowering took minimum number of days for 50% grain filling. Days taken to 50% flowering under irrigation treatments I_1, I_2, I_3 and I_4 were not significantly different. One missed irrigation at button stage slightly reduced the days to 50% flowering. However, reduction in days was not significant (Table 1).

Grain-filling stage took maximum and minimum days after sowing in 5 February and 7 March planted crops respectively. The crop planted on 5 February took maximum time for harvesting, followed by that on 20 February and 7 March. One missed irrigation at flowering reduced days to grain filling significantly. Irrigation at all growth stages took maximum days to grain filling. The effect of 1 missed irrigation on days to phenology of 50% grain filling was significantly reduced and however difference in days to grainfilling between I_2, I_3 and I_4 was at par.

The crop platned on 7 March physiologically matured 9–10 earlier than that on 5 February. The days taken to mature by 20 February planted crop were between 5 February and 7 March sowing. The effect of irrigation on days to phenological stages from seedling emergence to flowering was not signigficant. However, this effect was sigificant at grain filling and maturity. The crop receiving irrigation at all growth stages (I_1) took significantly more time to harvesting than the I_4 treatment. However, differnce in days taken to harvest of I_1 and I_2 crop was at par. One missed irrigation at grain filling (I_4) significantly reduced days to harvest, followed by I_3 treatment in both the years. The difference between I_3 and I_4 was statistically not significant (Table 1).

Slow emergence and poor growth of sunflower in 5 February-sown crop was due to low temperature which prevailed during that period. Sandhu *et al.* (1998) and Gupta *et al.* (1994) also reported slow emergence and poor growth under low temperature conditions. Slow growth in 5 February-sown crop caused by low temperature resulted in late flowering and consequently the maturity. Crop sown on 5 February took 102 days to mature compared with 90 days in 7 March-sown crop. Slow vegetative growth and

delay in phenological stages of sunflower sown in the first week of February was due to low night temperature which remained below 10°C up to the first fortnight of March. Increase in vegetative phase in 5 February-sown crop accumulated higher dry matter at harvest. Sharp increase in temperature in the 7 March-sown crop hastened the crop maturity.

The irrigation scheduling consisted 4 levels of irrigation, each irrigation had 5–6 cm depth of water. Effect of irrigation levels on days taken to seedling emergence, button initiation and 50% flowering was not significant. However, 50% grain filling was reduced by 1 day when irrigation was missed at pre-flowering stage compared with control. The flower initiation, being critical stage for moisture requirement, it might have altered the normal course of flowering behaviour. Consequent upon alteration in flowering behaviour, days to maturity also fluctuated accordingly. It varied 95 to 97 days in both the years. Stress experienced by sunflower at button initiation reduced the number of days to attain 50% flowering and later optimal moisture regime helped in recovery and behaved normally as that of optimal need-based irrigation treatment. However, skipping irrigation at critical stages of crop growth, especially at flowering and seed-filling stages could not be recovered and registered lower values under 3 treatments compared with optimal moisture regimes which again signifies the need of irrigation at these stages. The results are in accordance with findings of Hegde (1998) and Nandh Gopal *et al.* (1996).

The growing degree-days (heat units) were significantly affected by date of sowing. There was a sharp decrease in growing degree-days required to seedling emergence as date of planting was advanced. In contrast to this, there was a sharp increase in growing degree-days requirement for 50% emergence of seedling to 50% button initiation when the planting was delayed. Maximum and minimum growing degree-days required to reach 50% button to 50% flowering were recorded in 20 Feburary and 7 March-planted crop respectively. The crop sown on 5 Feburary needed maximum and that on 7 March required minimum growing degree-days to attain 50% flowering to 50% grain filling during both the years. The growing degree-days required to 50% grain filling to harvesting were maximum when the crop was sown on 7 March and minimum 20 February-planted crop respectively. The highest total (seedling to harvesting) of growing degree-days was recorded when planting was done on 7 March, while minimum when crop was sown on 5 February (Table 1). The requirement of growing-degree days was 9.0% higher when crop was planted on 7 March than 5 February. The values of growing degree-days of sunflower crop planted on 20 February were in between the two dates of sowing. The lowest growing degree-days required for different phenological stages were recorded in early sowing and subsequently increased in later sowing because of respective increase in minimum and maximum temperatures during April–May. The crop sown in February had longer period with low day–night temperature than crops sown on 7 March. It ensures that each phenological stage requires certain amount of heat units.

Levels of irrigation I_1, I_2, I_3 and I_4 had 4, 3, 3 and 3 number of irrigations, respectively, with equal amount of irrigation water. Growing degree-days from 50% seedling to 50% flowering to grain-filling stages could not be significantly influenced by irrigation levels. However, growing degree-days required for 50% grain filling to harvesting and total growing degree-days from 50% seedling emergence to harvesting were influenced by the levels of irrigation. From 50% grain filling to harvesting, the highest and lowest growing degree-days were recorded under I_1 and I_4 respectively (Table 1). The difference among I_2, I_3 and I_4 was at par. Irrigation scheduling did not change the total growing degree-days required from seedling to harvesting. Crop irrigated at all growth stages (I_1) required the maximum heat units, while I_4 treatment lowest. Difference among I_1, I_2, I_3 and I_4 was statistically non-significant. The requirement of growing degree-days increased under I_1 might be due to increase in crop growing period because plant free from soil-moisture stress took more days to harvest. Irrigation missed at grain filling (I_4) forced to mature the crop early and subsequently decrease in heat units.

It was concluded that temperature and moisture can influence the phenology of the crop. Heat units also vary with the varing of temperature and moisture levels. Date of sowing and irrigation scheduling had no interaction effect on phenology and heat units requirement of the crop.

SUMMARY

An experiment was conducted during the spring season 1998 and 1999 to study the effect of sowing dates, and 4 irrigation schedules on sunflower (*Helianthus annuus* L.) at Pantnagar, Uttranchal. The crop sown on 5 February took maximum time for various phenological stages, viz germination (13.9), flowering (67.6), grain filling (77.5) and harvesting stage (102.3) due to lower temperature (5.5°C) during crop-growing period. However, the crop sown on 7 March took minimum time to attain its phenological stages. The effect of irrigation on button and flowering initiation was not significant, while 1 irrigation missed at 50% flowering reduced days to 50% grain filling (70.9) significantly. Irrigation at all growth stages significantly increased time to maturity (96.7) over the treatment where 1 irrigation was missed at grain filling (95.8). Total growing degree-days were maximum (1 779) as date of sowing was advanced (7 March) and minimum (1619) in 5 February planting. Irrigation did not influence total growing degree-days significantly.

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Indian Journal of Agricultural Sciences 72 (7) : 428–30, July 2002

Assessment of variability for fodder yield and its component traits in forage sorghum (*Sorghum bicolor*)*

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Received: 17 April 2002

Key words: Fodder yield, Forage sorghum, *Sorghum bicolor*, Growth rate, Regeneration, Variability

Sorghum [*Sorghum bicolor* (L.) Moench.] is a good option as a fodder crop especially in semi-arid tropics because of its tolerance to drought, wide adaptability, quick-growing habit and palatability. The importance of genetic resources is tenet among plant breeders and needs no emphasis; however, under-utilization of these resources for crop improvement seems to be of greater concern. Dahlberg (1995) opined that the restricted utilization of extensive germplasm collections has occurred because of several characteristics inherent to the material, eg size of collections and limited or missing passport data. Therefore for effective utilization of the germplasm it is necessary to evaluate and characterize them (Beuselinck and Steiner 1992, Ordas *et al.* 1994). Hence the present study was undertaken to evaluate and characterize the forage sorghum lines from different geographical areas of the world (67 from India, 17 from the USA, 4 from Sudan, 2 from South Africa and Zambia each, 1 from Ethiopia, Yemen, Niger and China each and 10 of unknown origin).

The study was carried out at during the rainy season of 1999 and 2000 at Hisar, with 106 genotypes grown in augmented randomized incomplete block design. Each genotype was grown in 2 rows of 4 m length each with 45 cm × 10 cm spacing. Each block comprised 10 genotypes with 3 checks ('SSG 59-3', 'HC 308' and 'HC 171') randomized between these genotypes. Two cuts of the crop were taken. Observations were recorded on 5 plants in each genotype in both the years on 21 variables, viz plant height, leaf length, leaf breadth, leaves/plant, stem girth, tillers/plant, leaf : stem ratio, days to 50% flowering, regeneration potential (% increase or decrease in total number of tillers in the plot after cutting), growth rates (calculated by dividing the plant height attained by number of days in that specific period) 30, 45 and 60 days after sowing and after first cut, green fodder yield/plant and dry fodder yield/plant in first cut (C_1), second cut (C_2) and total of 2 cuts. Data were pooled over both the years for further analysis after testing the homogeneity of error variances using Bartlett's test. The analysis of augmented design was carried out. Univariate statistics were calculated as per Panse and Sukhatme (1967).

Significant genotypic mean sum of squares for all the characters indicated the presence of enough variation among the genotypes. Blocks mean sum of squares were also significant for plant height, green fodder yield/plant under C_1, C_2 and total of the 2 cuts, dry fodder yield/plant in C_2 and total of the 2 cuts and growth rates at all the 6 stages. Therefore the observed means for these traits were adjusted for the block effects for further analyses.

The coefficient of variation for leaves/plant, tillers/plant, leaf : stem ratio, regeneration potential, growth rate at 45 and 60 days after first cut, green fodder yield/plant (C_1, C_2 and total) and dry fodder yield/plant (C_1, C_2 and total) were in excess of 20%, indicating skewed distribution of variability for these characters. The significant skewness and kurtosis for all the characters except growth rate at 30 days after sowing verified the asymmetrical and abnormal distribution of genotypes. Perusal of the table 1 further revealed wide range of variation for all the traits (Table 1).

Regeneration potential of different genotypes was evaluated and it was found that the green-fodder availability from single-cut sorghum is short lived, whereas the multicut sorghum provides higher yields in shorter period and offers continuous supply of green fodder for longer duration. Satripanon *et al.* (1991) reported improved protein and digestibility with reduced HCN content of multicut sorghum because of the tenderness and succulence of fodder resulted from frequent cuttings implying qualitative superiority of multicut sorghums besides quantitative superiority.

Growth rates might have direct bearing on the fodder production per unit area and time and insect attack escape mechanism. In general, maximum growth rate was observed to be from 30–45 days after sowing, followed by 30–45

* Short note

A part of Ph D thesis of the first author submitted in 2001 to Chaudhary Charan Singh Haryana Agricultural University, Hisar (unpublished)

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Table 1 Univariate statistical parameters for different characters in forage sorghum

Character	Mean	Mode	Median	Minimum	Maximum	CV	Skewness	Kurtosis
Plant height (cm)	264.1	246.8	268.3	158.4 ('IS 6018')	350.2 ('G 133')	14.2	—0.316*	0.484*
Leaf length (cm)	67.8	70.7	68.3	54.9 ('S 522')	80.5 ('G 151')	8.6	—0.324*	—0.253
Leaf breadth (cm)	5.5	5.3	5.5	3.8 ('G 116-1')	7.3 ('IS 20441')	15.9	0.207	—0.700*
Leaves/plant	18.7	18.5	18.5	8.6 ('IS 23234')	39.4 ('IS 722')	37.4	0.879*	0.528*
Stem girth (cm)	4.9	4.6	4.8	3.4 ('G 116-1')	6.6 ('G 138')	13.8	0.303*	-0.303
Tillers/plant	2.4	2.5	2.4	1.0 (7 genotypes)	7.4 ('IS 722')	37.9	1.691*	7.894*
Leaf:stem ratio	0.36	0.30	0.35	0.24 ('G 122', 'G 128')	1.02 ('IS 6018')	29.6	2.719*	12.690*
Days to 50% flowering	64.6	65.5	65.5	49.5 ('IS 4526')	74.5 ('IS 651')	8.7	—0.651*	—0.027
Regeneration potential (%)	—1.9	—27.7	—11.7	—44.4 ('IS 4725')	74.1 ('IS 6018')	—1504.1	0.569*	—0.685*
Growth rate at 30 DAS (cm)	1.8	2.0	1.9	1.0 ('IS 6018')	2.6 ('IS 3075')	15.4	—0.066	0.378
Growth rate at 45 DAS (cm)	4.6	4.4	4.5	2.0 ('IS 6018')	6.1 ('S 520')	16.0	—0.256*	0.509*
Growth rate at 60 DAS (cm)	5.3	5.6	5.4	1.9 ('IS 6018')	7.1 ('G 142')	17.6	—1.152*	2.287*
Growth rate at 30 DAC_1 (cm)	3.4	3.9	3.6	1.8 ('S 521')	4.2 ('IS 4735')	15.9	—1.092*	0.183
Growth rate at 45 DAC_1 (cm)	4.7	3.5	4.7	2.7 ('IS 4725')	7.1 ('IS 3003')	21.5	0.036	—0.859*
Growth rate at 60 DAC_1 (cm)	3.5	3.4	3.4	0.8 ('G 48')	7.5 ('IS 1052')	36.3	0.585*	0.068
GFY/plant–C_1 (g)	359.2	331.5	333.9	183.6 ('IS 4526')	777.8 ('S 199')	30.9	0.895*	0.966*
GFY/plant–C_2 (g)	327.6	247.0	313.3	169.4 ('G 133')	793.6 ('IS 3359')	32.2	1.407*	3.423*
GFY/plant–Total (g)	686.7	610.0	647.1	386.9 ('G 124')	1391.7 ('IS 199')	27.5	1.164*	2.204*
DFY/plant–C_1 (g)	80.2	65.0	75.3	40.4 ('IS 4526')	171.9 ('IS 199')	28.9	0.791*	1.153*
DFY/plant–C_2 (g)	73.7	66.8	70.2	34.6 ('IS 4478')	167.1 ('IS 3359')	32.4	1.321*	2.533*
DFY/plant–Total (g)	153.9	159.5	150.0	84.9 ('IS 4478')	306.9 ('IS 199')	26.3	1.027*	2.066*

C_1, First cut; C_2, second cut; DAS, days after sowing; DAC_1, days after first cut, GFY, green fodder yield; DFY, dry fodder yield;Entries inside parentheses include variety or varieties

days after first cut. Growth rate at 0–30 days after first cut was higher than that of 30 days after sowing, indicating faster growth after cut in the initial stage compared with later stages. The genotypes like 'S 199', 'IS 3359', 'IS 20441', 'G 110', 'G 84' and 'IS 3312' showed faster growth rate in almost all the stages and resulted in higher green and dry fodder yields/plant in 2 cuts and were found to be resistant to shoot-fly infestation. Generally, there was decrease in green fodder yield/plant from first cut to second cut. Some genotypes ('IS 3075', 'IS 3359', 'IS 6018', 'IS 5417', 'G 110' and 'G 84') which exhibited better regeneration potential, followed by more tillers/plant after first cut. A similar trend was in dry fodder yield/plant. Thus for getting higher fodder yield per unit area and time, increased growth rates and higher regeneration potential, green fodder yield, dry fodder yield, plant height, leaves/plant, tillers/plant and length and breadth of leaves must be targeted.

Mean performances of the genotypes revealed that 'S 199' gave the highest green and dry fodder yield/plant in C_1 and total of 2 cuts, respectively, whereas 'IS 3359' gave the highest green and dry fodder yield in C_2. 'G 133' was found to be the tallest genotype and maximum number of leaves and tillers/plant were found in 'IS 722'. Genotype 'G 151' was found to be having longest leaves (80.5 cm), whereas 'IS 20441' had broadest leaves and 'G 116-1' was having minimum stem girth. 'IS 6018' showed maximum regeneration potential and leaf:stem ratio, whereas 'IS 4526' was the earliest flowering genotype.

The 106 forage sorghum genotypes, evaluated in the present study, showed sufficient variability for all the traits studied. Our results confirm those of Mathur *et al.* (1992), Kang and Lee (1996) and Greiner *et al.* (2000), who also indicated presence of enough variability for various characters in forage sorghum.

SUMMARY

An attempt was made during the rainy season of 1999 and 2000 to evaluate 106 genotypes of sorghum [*Sorghum bicolor* (L.) Moench.] of different geographical regions of the world. Sufficient amount of variability was envisaged for green fodder yield/plant (386.9 to 1 391.7 g), dry fodder yield/plant (84.9 to 306.9 g), plant height (158.4 to 350.2 cm), leaf length (54.9 to 80.5 cm), leaves/plant (8.6 to 39.4), tillers/plant (1.0 to 7.4), days to 50% flowering (49.5 to 74.5 days), leaf:stem ratio (0.24 to 1.02), growth rates at 30, 45 and 60 days after sowing and first cut (1.0 to 7.5 cm/day) and regeneration potential (—44.4 to 74.1%), that can be utilized to exploit heterosis or to get transgressive segregants, through hybridization.

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Indian Journal of Agricultural Sciences 72 (7) : 431–2, July 2002

Genetic variability in proso millet (*Panicum miliaceum*)*

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Received: 8 June 2000

Key words: Proso millet, *Panicum miliaceum,* Genetic variability, Harvest index, Seed protein

Proso millet (*Panicum miliaceum* L.) is an important small millet grown in India under dryland, marginal and hilly agroecological situations by tribals and poor farmers for grain as well as fodder. Being a short-duration crop with relatively low water requirement, it escapes drought period and offers better prospects for intensive cultivation in dry areas, therefore, ideally suited for relay and catch cropping. Harvest index is a valuable criterion for an improved plant type (Jain 1975). The major breakthrough in cereal grain yield has been largely owing to the improvement in source–sink relationship without an increase in total dry-matter production (Donald and Hamblin 1976). Contrary among millets, especially in proso millet, existing barriers to high grain yield may be broken by increasing the dry-matter production while maintaining high harvest index. In view of this, an attempt was made to assess the genetic variability present for harvest index, its components and seed protein content so as to identify superior varieties or strains of proso millet which can be utilized for future breeding programmes.

The experimental material for the present study consisted of 34 diverse varieties and strains of proso millet sown in randomized block design with 3 replications in 2 environments or locations during the rainy season 1998 at Udaipur, India. These environments were actually 2 locations (E_1: Instructional Farm with clay loam soil, *p*H 8.02 and 398.8 mm annual rainfall, while E_2: JKB Farm with sandy clay loam soil, *p*H 7.8 and 120.1 mm annual rainfall) at Udaipur and differed in terms of many other physico-chemical soil properties. Each genotype was sown in 3 m long single row keeping spacing of 22.5 cm between rows and 10.0 cm between plants within rows in both the environments. Recommended and uniform agronomical practices as well as plant-protection measurements were followed to raise the crop. Observations were recorded on 10 random plants for each genotype in each environment for harvest index and its contributory traits (Table 1). Seed protein (%) was estimated by analysing seed nitrogen following standard micro-Kjeldahl's method and the values were multiplied by 6.25 in each replication and environment. The mean values obtained were statistically analysed for each environment and pooled over environments. Estimation of phenotypic and genotypic coefficient of variation and heritability in broad sense were made as per method suggested by Burton and De Vane (1953). Genetic gain (genetic advance as percentage of mean) is computed using formula suggested by Johnson *et al.* (1955).

The analysis of variance revealed highly significant differences among the genotypes of proso millet for all the 12 characters studied in both the environments separately and in pooled analysis. Mean, standard error, range, genotypic and phenotypic coefficient of variation, heritability (in broad sense) and genetic gain analysed for each environment and over pool basis are shown in Table 1.

Wide range of variability was conspicuous for almost all the characters including seed yield. Varieties or strains, viz 'DC 3', 'Raum 14', 'GPMS 189' and 'GPMS 108' exhibited high *per se* performance for seed yield, harvest index and their most of the component characters. Therefore, these entries appeared promising. Varieties or strains 'DC 3', 'TNAU 132' and 'GPMS 338' exhibited high *per se* for seed yield as well as for seed protein content.

The results revealed high genetic gain along with high estimates of heritability and genotypic coefficient of variation for tillers/plant, main panicle weight and seed yield/plant, whereas characters like primaries/panicle, 1 000-seed weight, seed protein content and harvest index showed moderately high genotypic coefficient of variation and genetic gain with high heritability. Therefore, it appeared that these characters might be exhibiting predominance of additive gene effects; thereby selection for these traits would be effective for genetic improvement of harvest index in proso millet.Characters like days to flower, days to maturity, main panicle length and dry fodder yield/plant seemed to be greatly affected by environment and hence strong evaluation programme is needed for their exploitation.

* Short note

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Table 1 Mean, standard error (SE±), range, coefficient of variation (CV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (H), genetic gain (GG) in proso millet in 2 environments and pooled analysis (P)

Character	Environment	General mean	SE(±)	Range	CV (%)	GCV (%)	PCV (%)	H (%)	GG (%)
Days to flowering	E_1	36.93	0.84	31.42–47.00	2.78	10.99	11.33	94.00	21.9
	E_2	38.29	1.24	32.89–49.40	3.98	11.41	12.08	89.15	22.18
	P	37.61	0.75	32.16–47.13	3.45	11.21	11.73	91.37	22.07
Days to maturity	E_1	74.63	4.19	64.15–84.50	6.87	6.57	9.52	47.79	9.36
	E_2	71.71	2.49	61.98–80.27	4.22	7.12	8.28	73.99	12.62
	P	73.17	2.43	63.07–82.39	5.76	7.52	8.95	70.65	13.01
Plant height (cm)	E_1	75.86	4.90	66.54–94.19	7.92	9.40	12.29	58.49	14.80
	E_2	75.79	5.37	66.39–91.85	8.69	9.10	12.58	52.30	13.55
	P	75.82	3.64	66.94–93.02	8.31	10.32	12.43	68.89	17.64
Tillers/plant	E_1	5.35	0.45	3.28–8.67	10.32	26.87	28.78	87.13	51.66
	E_2	5.38	0.49	3.43–8.70	11.25	27.24	27.48	85.42	51.87
	P	5.37	0.33	3.36–8.69	10.80	27.59	29.13	89.68	53.82
Main panicle length (cm)	E_1	23.72	2.06	20.00–28.60	10.65	7.36	12.95	32.29	8.61
	E_2	23.80	1.54	20.49–28.10	7.90	7.38	10.81	46.61	10.38
	P	23.76	1.29	20.25–28.35	9.37	8.34	11.92	48.96	12.03
Primaries/panicle	E_1	12.24	0.88	9.25–16.53	8.77	15.54	17.54	75.86	27.89
	E_2	11.80	0.67	9.11–14.99	6.95	13.85	15.50	79.87	25.50
	P	12.02	0.55	9.19–15.76	7.95	14.98	16.76	79.93	27.60
Main panicle weight (g)	E_1	1.74	0.15	1.03–3.12	10.81	34.50	36.16	91.06	67.82
	E_2	1.67	0.09	1.07–3.25	6.24	37.39	37.91	97.29	75.98
	P	1.71	0.09	1.06–3.19	8.92	36.04	37.02	94.81	72.29
1 000-seed weight (g)	E_1	4.02	0.29	2.80–5.26	8.97	18.22	20.30	80.50	33.67
	E_2	4.07	0.23	2.93–5.86	7.05	19.69	20.69	88.62	38.18
	P	4.04	0.19	2.88–5.56	8.05	18.66	20.66	81.88	34.78
Dry fodder yield/plant (g)	E_1	7.42	0.67	5.93–9.54	11.07	9.13	14.35	40.47	11.97
	E_2	7.48	0.83	5.53–9.60	13.55	10.38	17.07	36.98	13.00
	P	7.46	0.53	5.82–9.50	12.38	11.14	15.78	49.85	16.20
Seed yield/plant (g)	E_1	3.69	0.46	2.06–6.95	15.37	31.32	34.89	80.59	57.92
	E_2	3.77	0.46	2.19–6.88	14.81	30.31	33.73	80.73	56.10
	P	3.73	0.32	2.12–6.92	15.09	30.73	34.31	80.26	56.72
Harvest index (%)	E_1	32.57	3.52	22.71–44.40	13.24	16.90	21.47	61.96	27.41
	E_2	32.97	3.22	22.94–43.79	11.97	16.05	20.02	64.25	26.49
	P	32.77	2.39	22.89–44.10	12.61	17.30	20.75	69.59	29.71
Seed protein content (%)	E_1	11.39	0.55	8.69–13.80	5.91	14.05	15.24	84.97	26.67
	E_2	11.42	0.52	8.58–13.83	5.55	13.07	14.20	84.72	24.78
	P	11.41	0.38	8.62–13.77	5.73	13.82	14.71	88.00	26.70

E_1, Instructional Farm; E_2, JKB Farm; P, Pool analysis

While assessing overall position in both the environments separately and over pooled analysis, the present study revealed high genetic advance as percentage of mean (genetic gain) along with high estimates of heritability and genotypic coefficient of variation for tillers/plant, main panicle weight and seed yield/plant. Proso millet entries 'DC 3', 'Raum 14', 'GPMS 189' and 'GPMS 108' appeared promising which could be gainfully utilized.

SUMMARY

An experiment was conducted during the rainy season of 1998 in 2 environments to study genetic variability in proso millet (*Panicum miliaceum* L.).

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Indian Journal of Agricultural Sciences 72 (7) : 433–5, July 2002

Stability of seed yield and yield contributing characters in french bean (*Phaseolus vulgaris*)*

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Received: 16 February 2002

Key words: French bean, *Phaseolus vulgaris*, Stability, Interaction, Response, Regression

The ultimate aim of any plant-breeding programme is to develop cultivars with high-yield potential with consistent performance over diverse environments. Productivity of population is the function of its adaptability, while later is the compromise of fitness (stability) and flexibility. Stability of genotypes depends on the ability to retain certain morphological characters steadily and allowing others to vary resulting in predictable genotype × environment (G × E) interaction for yield. A population that can adjust its genotypic and phenotypic state in response to environmental fluctuations to give high and stable yield is termed as well buffered. Study of individual yield components can lead to simplification in genetic explanation and determination of environmental effects, models for estimating G × E interaction have been proposed by several workers. Sharma *et al.* (1993), Panwar *et al.* (1995) and Harer *et al.* (2000) used Eberhart and Russell (1966) model to identify suitable promising french bean genotypes and identify the stable yield components.

French bean (*Phaseolus vulgaris* L.) is being grown in rainy season in western Maharashtra. The cultivators of this region are using local types, viz 'Vaghya', 'Manus', etc, which are poor yielder and late maturing. Hence it was felt necessary to test the newly developed early- and high-yielding genotype for their consistency in performance across over the years.

Sixteen french bean genotypes were grown in 6-row plot of 4 m length with 30 and 10 cm spacing between and within rows, respectively, in completely randomized block design with 3 replications during the rainy season of 1998, 1999 and 2000 at National Agricultural research Project (Plain Zone), Ganeshkhind, Pune. All the treatments received dose of fertilizers @ 60 kg N + 35 kg P/ha, timely interculturing and plant protection measures. Five plants/plot were randomly selected and data were obtained on 7 characters, viz days to maturity, plant height, primary branches, pods/plant, pod length, 100-seed weight and seed yield/ha.

Data from 3 environments as well as pooled data were subjected to analysis of variance (Panse and Sukhatme 1967). The characters, which showed significant G × E interaction, were subjected to stability analysis as per Eberhart and Russell (1966). Based on the stability model, 3 parameters, (*i*) overall mean performance of each genotype across the environments, (*ii*) the regression of each genotype on the environmental index (bi) and (*iii*) squared deviation from the regression (S^2di), were estimated. The significance of stability parameters and deviation from unity were tested by Student's 't' test.

The analysis of variance for individual as well as pooled environments revealed that the mean differences between genotypes and environments were highly significant for yield and yield attributes, indicating presence of genetic variability among the genotypes and environments for majority of the characters studied. The G × E interaction was also significant for days to maturity, plant height and seed yield, however, the mean squares due to E + (G × E) interaction was highly significant for all the characters studied. Highly significant mean square due to environment (linear) except the trait pod length indicated the differences between environments and their influence on the characters studied. The mean squares due to G × E (linear) were also significant except the character plant height, branches/plant and seed yield indicating that linear component of G × E interaction in the performance of different genotypes when grown over environments could be predicted. Thus, present results are in conformity with those of Panwar *et al.* (1995) and Harer *et al.* (2000).

As proposed by Eberhart and Russell (1966), an ideal and stable genotype may be characterized as having high performance, unit regression and zero or minimum mean squared deviation from regression. They further pointed out that the varieties exhibiting high regression coefficients ($b > 1$) could be considered as below-average stable varieties, which will perform better, only in favourable environments. The varieties with low regression coefficient

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Table 1 Estimates of stability parameters for different characters in french bean varieties

Strain	Days to maturity			Plant height (cm)			Primary branches/plant		
	X	bi	S^2di	X	bi	S^2di	X	bi	S^2di
'ACPR 5'	71.333	0.000	—0.571	24.430	0.558**	—2.602	3.444	0.894**	0.190
'ACPR 9'	71.444	3.532	—0.568	30.259	0.813*	—4.985	3.704	0.981**	—0.121
'ACPR 11'	71.444	—2.702**	—0.575	31.741	0.862**	117.369**	4.000	1.080**	—0.036
'ACPR 94034'	78.111	2.909**	—0.565	42.074	1.509**	44.557	3.815	0.964**	0.553
'ACPR 94035'	78.222	3.948**	—0.568	39.296	1.102**	13.274	3.852	1.196**	—0.091
'ACPR 94036'	76.444	0.415**	—0.569	39.370	1.285**	—4.101	3.556	1.251**	0.388
'ACPR 94037'	74.889	.831**	—0.574	42.111	1.362**	-6.543	3.259	1.028**	—0.024
'ACPR 94038'	76.000	1.870**	—0.570	42.444	1.401**	42.806	3.667	0.955**	—0.119
'ACPR 94039'	74.556	3.948**	—0.568	31.778	0.986**	19.452	3.222	0.737**	0.127
'ACPR 94040'	71.778	0.415**	—0.572	29.074	0.623**	—3.246	3.630	0.694**	0.086
'Red Cloud'	70.667	—1.247**	—0.573	40.333	1.231**	—6.484	3.407	1.088**	1.108
'PDR 5'	72.556	1.454**	—0.572	33.778	1.048**	—0.286	3.148	0.906**	0.962
'EC 49844'	71.778	—0.208**	—0.569	33.926	1.001**	24.008	3.519	0.836**	—0.037
'Vaghya' ©	79.556	—2.286**	—0.579	28.222	0.639**	11.120	3.741	1.007**	—0.123
'HPR 35' ©	70.000	0.000	—0.572	28.889	0.772**	—6.276	3.037	1.106**	—0.042
'HUR 137' ©	77.333	3.117**	—0.569	33.259	0.808	63.949**	3.593	1.277**	0.374
Mean	74.132	1.000		34.437	1.000		3.537	1.000	
SE±	0.767	0.025		2.296	0.254		0.288	0.164	

* P= 0.05; ** P= 0.01

(b < 1) are above-average stable and are adapted especially to poor environments.

The G × E interaction was significant for seed yield. On partitioning it into linear and non-linear components, both the components were equally responsible for expression of this trait. However, linear component was higher in magnitude than non-linear component, indicating that the seed yield could be predicted across the environments, confirming the findings of Panwar *et al.* (1995). The genotypes, 'ACPR 94040' and 'ACPR 94036' had below-average stability for seed yield; however, 'ACPR 94035', 'ACPR 94039' and 'PDR 5' exhibited above-average stability.

Similarly, all the genotypes were significant for the traits, days to maturity except, 'ACPR 5' and 'HPR 35'; for plant height except 'HUR 137'; for branches/plant; for pods/plant except 'ACPR 94040' and 'Red Cloud' and 100-seed weight. 'ACPR 94036', 'ACPR 94038' and 'HPR 35' for pod length and 'ACPR 5', 'ACPR 94040', 'PDR 5' and 'HUR 137' for seed yield had significant regression coefficient, indicating an independent genetic mechanism controlling their response to environmental changes (Table 1).

The mean square deviation from regression was significant for the genotypes, 'ACPR 11' and 'HUR 137' for plant height; 'ACPR 94039' for pod length and 'ACPR 94037', 'ACPR 94038' and 'ACPR 94040' for seed yield, indicating preponderance of linear component of G × E interaction for component traits which was also confirmed from analysis of variance, where variance due to G × E (linear) was more than due to non-linear G × E interaction indicating that the possibility of predicting the performance for component characters studied.

On the basis of individual parameter of stability, it became evident that the genotypes, 'Red Cloud' and 'PDR 5' for days to maturity; 'PDR 5' for plant height, 'ACPR 11', 'ACPR 94037' and 'HPR 35' for primary branches; 'ACPR 94035' for pods/plant; 'ACPR 94038' for 100 seed-weight; and 'ACPR 94040' for seed yield were most responsive and stable. Present results confirm the findings of Singh *et al.* (1994) and Harer *et al.* (2000) for seed yield and pods/plant.

The genotype, 'ACPR 94040', recording highest seed yield (2 250 kg/ha) had unit regression (1.19) and least mean squared deviation from regression (0.004), indicating its plasticity to withstand against buffering environmental conditions to produce stable yield performance. This indicated that the genotype, 'ACPR 94040', could be identified and released as stable genotype for general cultivation and to develop stable varieties in french bean.

SUMMARY

An experiment was conducted during rainy season of 1998, 1999 and 2000 to study stability in seed yield and yield-contributing characters of 16 genotypes of french bean (*Phaseolus vulgaris* L.). The genotype × environment interaction was significant for days to maturity, plant height and seed yield/plant. However, linear component was of larger magnitude than of non-linear components for all the traits except branches/plant and pod length, indicating that the variation in the performance of genotypes when grown over environments could be predicted. Environment

Table 1 Continued...

Pods/plant			Pod length (cm)			100-seed-weight (g)			Seed yield (kg/ha)		
X	bi	S^2di	X	bi	S^2di	X	bi	S^2di	X	bi	S^2di
13.630	0.687**	—1.535	11.722	4.491	0.379	29.750	6.381**	—0.465	1 361.111	4.922**	—0.004
10.704	1.658**	—0.088	12.389	0.323	—0.252	43.650	3.606**	—0.467	1 468.056	—1.084	0.016
16.407	2.188**	4.924	11.611	3.616	0.445	37.700	2.219**	—0.468	1 444.444	—1.456	0.037
12.667	0.996**	—1.126	10.722	2.322	—0.133	38.850	—1.203**	—0.473	1 797.222	—1.947	0.015
13.259	1.941**	0.443	11.407	—5.507	0.834	44.250	2.496**	—0.467	1 962.500	—0.349	0.009
12.148	1.799**	—1.579	11.796	2.810**	—0.263	39.950	3.051**	—0.467	2 030.556	1.889	0.003
9.926	0.747**	—0.719	10.778	2.656	—0.031	39.950	0.831**	—0.470	1 919.444	0.673	0.022
11.889	0.646**	—1.492	11.389	4.434*	—0.156	41.850	1.016**	—0.470	1 844.444	1.394	0.047*
14.889	0.311**	16.730*	9.667	0.114	0.622	39.200	—3.515**	—0.475	2 108.333	0.635	0.040*
16.667	—0.698	5.561	9.815	—1.022	0.490	40.300	0.739**	—0.470	2 250.000	1.195**	—0.004
9.704	0.312	8.869	10.778	2.531	1.771	44.000	4.438**	—0.465	1 468.056	—0.001	0.047*
10.185	0.706**	—0.861	10.056	2.436	0.068	37.250	—0.093**	—0.471	1 519.444	1.220*	—0.001
12.778	1.883*	—0.971	10.981	2.004	0.277	37.100	—1.481**	—0.472	1 404.167	2.889	0.026
10.148	0.776**	—0.870	9.963	—0.330	0.479	33.300	1.479**	—0.470	1 112.500	2.392	0.007
9.852	0.442*	—1.083	10.722	—1.675*	—0.250	40.550	0.463**	—0.471	1 254.167	1.323	0.001
11.037	1.606**	—0.946	10.500	—3.198	1.375	36.700	—3.515**	—0.475	1 008.333	2.305*	0.002
12.243	1.000		10.894	1.000		39.022	1.000		1 622.222	1.000	
0.955	0.446		0.446	3.909		0.741	0.045		68.056	1.590	

+ (genotype × environment) sum of squares were significant for all the environments and their considerable influence. On examination of individual parameter of stability for different genotypes, 'ACPR 94040' possessed stability, indicating its suitability for general cultivation and also to use as one of parents in breeding programme aimed at development of stable french bean varieties.

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Indian Journal of Agricultural Sciences 72 (7) : 436–8, July 2002

Intergeneric hybridization of indian mustard (*Brassica juncea*) with taramira (*Eruca sativa*)*

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Received: 1 October 2001

Key words: Hybridization, Indian mustard, Taramira

A wide genetic base is the prime requirement of any crop-improvement programme. Genetic enriching of crop species from their wild relatives constitutes an important approach to broadening the base of genetic variability. An impressive spectrum of wild and weedy species closely related to crop *Brassicas* exists with extensive genetic diversity. The present study was conducted to develop an intergeneric hybrid between indian mustard [*Brassica juncea.* (L.) Czernj. & Cosson] with taramira (*Eruca sativa* Mill.) to transfer some desirable characters from taramira to indian mustard.

Flower buds of *B. juncea* to be used as female were emasculated the previous day before anthesis. Pollination was carried the next morning with pollen from freshly dehisced anthers of *E.sativa.* Hundred pollinated pistils were studied for pollen germination, pollen-tube growth and micropylar penetration 5 days after pollination using aniline blue flourescence method of Linskens and Esser (1957). Another set of 100 pollinated pistils were collected 10 days after pollination to study the embryo development. These pistils were fixed in 3:1 alcohol : acetic acid and preserved in 70% alcohol. The ovules were dissected out from the fixed pistils, squashed in 2% acetocarmine and observed under light microscope for the presence of embryos. Crossed siliquas were harvested 15–35 days after pollination and cultured in culture tubes containing MS media with various combinations of indole-acetic acid , kinetin and casein hydrolysate (E_1, MS + 1mg/litre indole acetic acid + 0.5 mg/litre kinetin + 500 mg/litre casein hydrolysate; E_2, MS + 2 mg/litre indole acetic acid + 0.5 mg/litre kinetin + 400 mg/litre casein hydrolysate; E_3, MS + 2mg/litre indole acetic acid + 0.5 mg/litre kinetin + 500 mg/litre casein hydrolysate). Cultures were incubated at temperature of 25 ± 2°C and 16 hr photoperiod. Observations were made daily and the germination of ovules were recorded at 10, 15, 25, 30 days after culture. In order to determine whether germination in different culture media and the different ages at which the hybrid ovules were cultured differed significantly, the data were analysed in completely randomized block design and the CD at 5% level was calculated. Nodal segments of the hybrid seedlings with 1 or 2 axillary buds were cultured in MS media modified with indole acetic acid and benzyl amino purine (C_1, MS + 0.5 mg/litre indole acetic acid; C_2, MS + 0.1 mg/litre indole acetic acid + 0.5 mg/litre benzyl amino purine; C_3, MS + 0.5 mg/litre benzyl amino purine). Another set of 100 pollinated pistils were left on the plant up to maturity to observe seed set. Morphological characters such as stem colour and texture; leaf shape, size and flower colour and size were studied in the hybrid and the parents. Leaves of the second and third internode of the parents and hybrid plants were used for isozyme analysis according to the standard procedures. Peroxidase, malate dehydrogenase, alcohol dehydrogenase, glutamate dehydrogenase and isocitrate dehydrogenase isozyme patterns were studied.

Percentage of ovule development at 10 days after pollination (28.00) was lower than that of ovules fertilized at 5 days after pollination (31.30). Hybridization barriers were encountered in *Brassica* crossability studies. Lelivelt (1993) observed good pollen germination and pollen tube growth in the stylar region for the cross between swede rape (*Brassica napus* L.) and *Brassicoraphanus*, but low frequency of ovules with micropylar penetration per siliqua or embryo abortion was observed. Penchan (1988) reported that failure of fertilization is the major factor that hinders seed formation in swede rape in wide hybridization. Lakshmikumaran *et al.* (1998), also reported that occurrence of matromorphy (development of unfertilized ovule) is a common phenomenon during the intergeneric/interspecific crosses among *Brassica* coenospecies.

The ovules cultured 15 days after pollination failed to germinate. A gradual increase in the germination (%) of ovules was observed after this followed by decline in germination after 30 days (Table 1). Highest number of ovules germinated when cultured 30 days after pollination. Culture of ovules from 20–35 days after pollination failed

* Short note

Based on complete information of M Sc thesis of first author, who submitted it to Assam Agricultural University, Jorhat, in 1999

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Table 1 Effect of different modifications of MS media and different age of embryos on the germination of ovules of the cross *B. juncea* × *E. sativa*

Days after pollination	Germination (%)		
	E_1	E_2	E_3
15	0	0	0
20	10	18.18	15.16
25	18.18	40.0	50.0
30	16.16	58.33	80.0
CD (P=0.05) for days after pollination		14.83	
for media		11.48	

E_1, MS + 1 mg/litre IAA + 0.05 mg/litre kinetin (KN) + 500 mg/litre casein hydrolysate (CH); E_2, MS + 2 mg/litre IAA + 0.05 mg/litre KN + 400 mg/litre CH; E_3, MS + 2 mg/litre. IAA + 0.5 mg/litre KN + 500 mg/litre CH

to produce any significant differences. This indicates that embryo at different ages remain at different stages of maturation and a minimum time (20 days) should be allowed for a certain amount of maturation of the ovules, so that they are capable of absorbing the nutrients from the medium. Similarly, on direct comparison of the mean germination (%) it was observed that media E_3 was the best. But pair-wise comparison of the treatment means showed that media E_3 and E_2 did not differ significantly.

Nodal segments did not show any response in C_1 and C_2 media. In C_3 media the nodal segments showed callusing and shoot proliferation to some extent. Subculturing of the nodal segments did not show increase in the length of shoots and the nodal segments became yellow and ultimately dried up. This may be due to the fact that media used for nodal segment culture was suitable for callusing and shoot-bud proliferation but not for further growth and development of the shoots.

Only few seeds were obtained through field pollination. Germination test of these seeds revealed lower germination (%) both under *in-vivo* and *in-vitro* conditions in comparison to the open-pollinated seeds.

Table 2 Morphological characters of hybrids and the parents of cross *B. juncea* × *E. sativa*

Character	*B. juncea*	F_1	*E. sativa*
Stem			
Colour	Dark green	Intermediate	Light green
Thickness of stem	Normal	Thick	Normal
Leaves			
Colour	Dark green	Dark green	Dark green
Leaf margin	Serrated	Serrated	Even
Shape	Lyrate	Lyrate	Lyrate
Apex of leaf	Acute	Obtuse	Obtuse
Flower			
Colour	Bright yellow	Yellow	Pale yellow
Size	Small	Small	Larger

The F_1 plants had thicker stems than either of the parents and the stem colour of the F_1 plants was intermediate to both the parents (Table 2). The leaves were dark green in both the hybrid and the parents. The leaf margin was serrated in *B.juncea* and the F_1, while it was even in *E. sativa*, and the leaf apex was acute in *B.juncea* but it was obtuse in the hybrid and *E.sativa*. The shape of the leaf was lyrate for both hybrid and parents. There was a slight difference in the flower colour between the parents and the hybrid. The apex of the flower petals of *B. juncea* was oval in shape and the joint between the claw and the limb of the petal was sharp. The petal of the F_1 hybrid and *E. sativa* had a flat apex but the joint between the claw and the limb was distinct but gradual. In the present study, differences in leaf , stem and flower characters observed between the parents and the F_1 hybrid is an indication of hybridity. However, isozyme analysis has to be performed to confirm hybridity.

In the present investigation, in 2 of the enzyme systems, peroxidase and malate dehydrogenase, stained regions with allozymes were observed. In *B. juncea* 2 bands (R_m = 0.82 and 0.89) were recorded and in *E. sativa* also 2 bands (R_m = 0.23 and 0.43) were recorded. In the hybrid out of the 2 bands recorded, one was adjacent to the R_m = 0.43 band of *E. sativa* and the other was intermediate (R_m = 0.84) between the two bands of *B. juncea*. The malate dehydrogenase isozymes of leaves showed 2 bands in *B. juncea* (R_m = 0.38 and 0.51) respectively and in *E. sativa* also 2 bands (R_m = 0.42 and 0.51) were recorded. The hybrid had 2 bands (R_m = 0.41 and 0.52). Crosses between individuals bearing different electromorphs will result in F_1 progeny that display both parental bands. In addition to the parental bands the F_1 may posses hybrid bands not observed in either parent, the presence and the number of which depend on the number of polypeptide subunits contained in the active enzyme. No enzyme activity of alcohol dehydrogenase, isocitrate dehydrogenase and glutamate dehydrogenase could be reported on the gel after staining with enzyme specific stains. Jones (1984) reported that absence of enzyme activity may be due to the absence or inhibition of enzyme activity by other enzymes. By observing the banding pattern of the parents and the hybrid in the peroxidase and malate dehydrogenase enzyme systems the possibility of an intergeneric hybrid between *B.juncea* and *E.sativa* cannot be ruled out.

SUMMARY

An experiment was carried out during 1999 to develop intergeneric hybrid between indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] and taramira [*Eruca sativa* Mill.).

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Indian Journal of Agricultural Sciences 72 (7) : 439–41, July 2002

Effect of calotropis (*Calotropis procera*) extract on infestation of termite (*Odontotermes obesus*) in sugarcane hybrid*

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Received: 16 February 2002

Key words: Termite infestation, Sugarcane, Cane yield

On the basis of severity of damages caused to sugarcane crop, the termite (*Odontotermes obesus* Rambur) is now being regarded as most notorious pest of sugarcane and deserves much greater attention towards development of an effective control measure with plant extract without disrupting environment. There are many reports of the efficacy of natural plant products against some specific insects and some report on the effectiveness of *Calotropis procera* L. against the termites infesting (setts, sett ends and sett buds) sugarcane, but the specific doses used against termites in subtropical climates have not been reported. Hence the present investigation was carried out to find out the effective dose and method of extract application of *Calotropis procera* for the control of termites in sugarcane.

This investigation was carried out on a hybrid sugarcane 'CoS 802' during 1998–99 to 2000–2001. The extract of *Calotropis* was obtained from its leaves by crushing and filtering. The treatments were: T_1, dipping of cane setts in 20.0 %; T_2, 15.0%, T_3, 10.0%, T_4, 5.0% solution; T_5, soil treatment with 2.0% solution of *Calotropis* extract; T_6, soil treatment with phorate 10 G @ 2.5 kg ai/ha; and T_7, control (untreated).

Canes were cut into pieces (with 3 buds) and dipped in these concentrations of extract solution just before the planting. Phorate 10 G was applied in furrows by hand, while 2.0 % solution of *Calotropis* extract was sprinkled with a hand-sprinkler just before the setts were covered with soil. The experiment was laid out in randomized block design with 3 replications in February 1998–99 to 2000–2001. Trial plot size was 4.5 m × 5 m. To record termite infestation on setts, the planted setts of second and fourth rows (5 m length) of each plot were dug up 45 days after planting (Singh 1999). Damage caused was recorded as:

$$\text{Infestation (\%)} = \frac{\text{Number of material affected}}{\text{Total number of material examined}} \times 100$$

The germination was recorded 45 days after planting as per method of Singh and Singh (1998). Total number of millable canes were registered in each plot and millable canes were harvested 12 months after planting to record yield (tonnes/ha).

On the basis of pooled analysis there were no significant differences for sett damage among treatments. However, damage was significantly greater in the untreated control (T_7) (Fig 1, *top*). Minimal infestation of termites on sett end basis was recorded under treatment T_6, followed by T_5 and T_1, while it was maximum in T_7. Treatments T_1, T_2, T_5, and T_6 were found equally effective and significantly superior to the untreated control (Fig 1, *middle*). Minimum infestation of termite on bud basis was recorded under T_6 followed by T_5 and T_1 compared with the maximum in T_7 treatment. On bud basis also treatments T_1, T_2, T_5 and T_6 were significantly superior ($P = > 0.05$) to the untreated control (Fig 1, *bottom*). Maximum germination was recorded under treatment T_6 followed by T_1 and T_5 compared with minimum in T_7. Regarding germination treatments T_1, T_2, T_5 and T_6 were statistically at par with each other and significantly superior ($P = > 0.05$) to the untreated control (Fig 2, *top*). The number of millable canes was maximum under treatment T_6 followed by T_1 and T_5, while it was minimum under T_7 (Fig 2, *middle*). The maximum cane yield was recorded under treatment T_6, followed by T_1 and T_5 compared with minimum in T_7 (Fig 2, *bottom*). Treatments T_1, T_2, T_5 and T_6 were significantly superior to the untreated control.

The maximum destruction of buds was recorded due to termite in under treatment T_7 22.9%, confirming the findings of Avasthy (1967) and Singh *et al.* (1997). Minimum cane yield was recorded under treatment T_7 due to termite infestation. The result confirm the findings of Mill (1992) and Mora *et al.* (1996).

The damage to setts, sett ends and sett buds was significantly reduced under treatments T_1, T_2, T_5 and T_6. These treatments T_1, T_2, T_5 and T_6 had the effect of protecting planted sett buds from termite attack owing to feeding deterrent and enhancing germination, millable canes

*Short note

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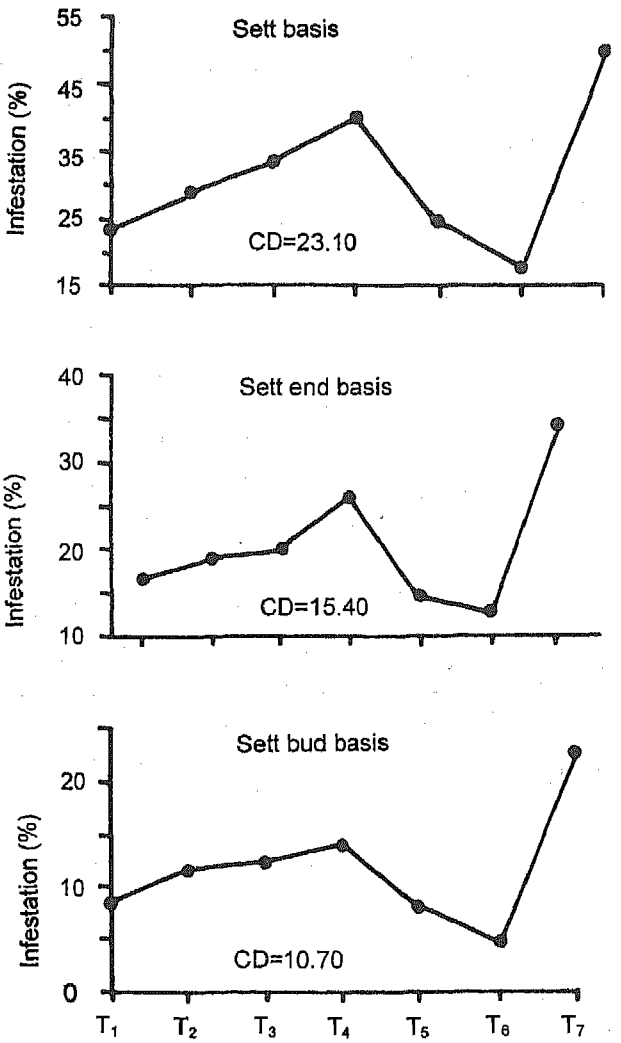

Fig 1 Effect of *Calotropis procera* extract on infestation of termites in sugarcane (T_1, Dipping of cane sett in 20%; T_2, 15 %; T_3, 10%; T_4, 5% solution; T_5, soil treatment 2% solution of calotropis extract; T_6, phorate 10G @ 2.5 kg ai/ha; T_7, control)

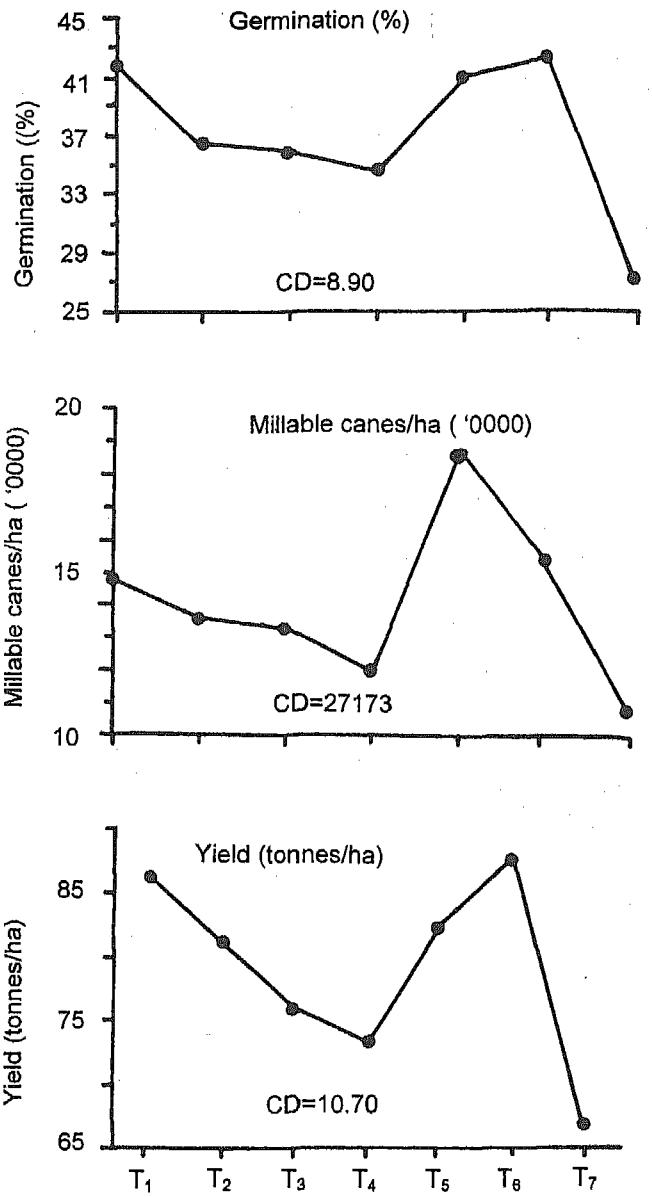

Fig 2 Effect of *Calotropis procera* extract on yield and yield-contributing characters (T_1, Dipping of cane sett in 20%; T_2, 15 %; T_3, 10%; T_4, 5% solution; T_5, soil treatment 2% solution of calotropis extract; T_6, phorate 10G @ 2.5 kg ai/ha; T_7, control)

and yield of sugarcane. Our findings on effectiveness of *Calotropis* extract for termite control confirm those of Parihar (1994). The increase in germination under treatments T_1, T_2,T_5 and T_6 ($P = > 0.05$) was owing to protection of planted sett buds from termite attack, resulting in more millable canes of good health and higher yield. Hence the dipping of cane setts in 20.0 or 15.0% solution of *Calotropis* extract or soil treatment with 2.0% solution of *Calotropis* extract may be used for termite control in termite-prone area of sugarcane-growing belts.

SUMMARY

A field experiment was conducted during 1998–2001 at Shahjahanpur, Uttar Pradesh, to investigate the effect of calotropis (*Calotropis procera* L.) extract on termite (*Odontotermes obesus* Rambur) damage to the planted sugarcane setts. Dipping setts in 20.0 or 15.0% solution of *Calotropis* extract and soil treatment with 2.0 % solution of *Calotropis* extract were equally effective and as effective as the soil application of phorate 10G @ 2.5 kg ai/ha. These treatments were more effective ($P= > 0.05$) than untreated control in reducing termite infestation from 28.8, 19.4 and 11.6 to 17.7, 12.7 and 4.8% compared with 49.9, 34.4 and 22.9% in control on sett, sett end and sett bud

basis, respectively, and increasing the cane yield from 14.15 to 21.10 tonnes/ha over the control.

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