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Production potential and economics of different rice (*Oryza sativa*)-based cropping systems in Andhra Pradesh

A KRISHNA¹ and K ANAND REDDY²

Regional Sugarcane and Rice Research Station, Acharya N G Ranga Agricultural University, Rudrur,
Andhra Pradesh 503 188

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ABSTRACT

A 3-year (1989–92) experiment conducted at Rudrur with 6 rice (*Oryza sativa* L.)-based crop sequences, viz rice with safflower (*Carthamus tinctorius* L.), indian mustard [*Brassica juncea* (L.) Czernj. & Cosson], bengal gram (*Cicer arietinum* L.), maize (*Zea mays* L.), wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and sunflower (*Helianthus annuus* L.) showed that rice–sunflower gives significantly higher rice equivalent yield (8.48 tonnes/ha), higher production efficiency (36.4 kg/ha/day), higher net return Rs 26 160/ha and benefit : cost ratio (3.18). This was followed by rice–bengal gram with rice-equivalent yield 7.97 tonnes/ha, net return Rs 23 865/ha and benefit : cost ratio 2.98. The land-use efficiency of rice with bengal gram, indian mustard, wheat or sunflower was 61–64% in the year, whereas that of rice with safflower or maize was 65–71%. The value of sustainable yield index revealed that rice–sunflower system was more stable (89%), followed by rice–bengal gram (82.8%).

Key words : rice-equivalent yield, production efficiency, land-use efficiency, sustainable yield index, *Oryza sativa*

In command areas of Andhra Pradesh, cropping intensity is low. Rice (*Oryza sativa* L.) is dominant crop in this area, grown in monsoon season (June–October). Rice–rice is the popular cropping sequence in irrigated areas, but with water depletion in the projects only irrigated dry crops could be raised profitably. It is therefore necessary to find out the most suitable pulse and oilseed crop in a sequence after rice, so that the profitability and soil fertility may be improved and the irrigated water may be utilized more economically in the region.

MATERIALS AND METHODS

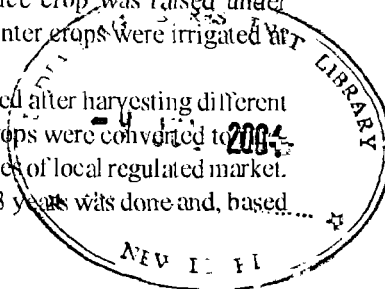
The field experiment was conducted at Rudrur (Andhra Pradesh) during 3 rainy seasons (June–October) and winter seasons (November–March) of 1989–90, 1990–91 and 1991–92 on medium black soils. The soil had pH 8.1, was medium in organic carbon and had 15.5 kg/ha available phosphorus and 285 kg/ha available potassium.

The treatments included 6 cropping systems in randomized block design on a fixed site for 3 years. These were replicated 4 times. During rainy season (*kharif*) rice

'Varsha' was grown in all the cropping sequences, whereas during winter season different crops like safflower (*Carthamus tinctorius* L.), bengal gram (*Cicer arietinum* L.), maize (*Zea mays* L.), wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and sunflower (*Helianthus annuus* L.) with recommended packages of practices were cultivated. 'Varsha' rice was sown at 15 cm x 15 cm spacing with fertilizer N, P and K @ 120, 60 and 40 kg/ha respectively ($N_{120} P_{60} K_{40}$). 'Manjira' safflower at 30 cm x 15 cm with $N_{50} P_{25} K_{30}$, 'Varuna' indian mustard at 45 cm x 10 cm with $N_{60} P_{40} K_{30}$, 'Annegiri-1' bengal gram at 30 cm x 10 cm with $N_{25} P_{50} K_{30}$, 'DHM 103' maize at 60 cm x 30 cm with $N_{120} P_{60} K_{40}$, 'Sonalika' wheat at 22.5 cm x 10 cm with $N_{100} P_{50} K_{40}$ and 'APSH 11' sunflower at 45 cm x 30 cm with $N_{90} P_{50} K_{30}$. The rainy-season rice was sown in the second week of June and harvested in the third week of October. The winter crops were sown in the second week of November and were harvested at physiological maturity. The rice crop was raised under continuous submergence and winter crops were irrigated at their critical stages.

The crop yields were recorded after harvesting different crops. The yields of sequence crops were converted to rice equivalent yield based on the prices of local regulated market. Pooled analysis of yield data of 3 years was done and, based

¹ Assistant Agronomist, Regional Agricultural Research Station, ANGRAU, Jagtial 505 327; ² Senior Scientist (Water Management), Agricultural Research Station, ANGRAU, Garikapadu



on this, sustainable yield index (SYI) was worked out by the formula :

$$SYI = \frac{\bar{A} - \bar{Y}}{Y_{max}} \times 100$$

where $\bar{A}$, mean of particular treatment; $\bar{Y}$, standard deviation of a particular treatment; Y_{max} , potential yield in different years and treatments.

The production efficiency, ie economic produce (kg) of both the crops/day/ha (Tomar and Tiwari 1990), and land-use efficiency [growing period (%) occupied by both the crops in a year] were worked out for the cropping system. The economic indices like gross and net returns (Rs/ha) and benefit : cost ratio were also calculated in different cropping systems.

RESULTS AND DISCUSSION

The pooled analysis of rice yield showed that there was significant difference with various winter crops. The yield of rice was significantly higher when it was grown after bengal gram (5.16 tonnes/ha), indian mustard (5.10 tonnes/ha), wheat (5.0 tonnes/ha) and safflower (4.88 tonnes/ha) and lower when grown after sunflower (4.80 tonnes/ha) and maize (4.83 tonnes/ha). This shows that sunflower and maize, which are exhaustive crops, might have depleted the soil nutrients, affecting rice yield in the sequence. The rice yield was stable when grown after pulse crop, as the latter improves the soil fertility of a cropping system (Ahlawat *et al.* 1981, Ghosh and Singh 1994). Rice grown after indian mustard was not adversely affected due to poor yield of the latter, which normally would have depleted more nutrients with higher yield. The low yield of indian mustard and safflower was due to delayed sowing in November and incidence of aphids (*Aphis gossypii* Glover).

The mean rice-equivalent yield (Table 1) revealed that rice-sunflower (8.48 tonnes/ha) and rice-bengal gram (7.97 tonnes/ha) cropping systems produced significantly higher rice-equivalent yield when compared with other systems.

Inclusion of high-value crops like sunflower in the system increased the rice-equivalent yield. Similarly, the addition of a pulse crop like bengal gram increased the rice yield and in turn increased the rice-equivalent yield. Lower rice-equivalent yield was obtained in rice-wheat (6.93 tonnes/ha), rice-indian mustard (7.14 tonnes/ha), rice-maize (7.17 tonnes/ha) and rice-safflower (7.24 tonnes/ha) systems. The yield and value of these sequence crops were lower than of rice-sunflower and rice-bengal gram, which gave lower rice-equivalent yields.

The production efficiency (Table 1) was higher with rice-sunflower (36.4 kg/ha/day) and rice-bengal gram (35.7 kg/ha/day), where the crop occupied only 61–64% of the growing season. The lowest production efficiency was observed in rice-maize (27.8 kg/ha/day). The result indicates that though the crops remained in the field for longer time, the yields were lower in rice-maize system, leading to lower production per day.

The land-use efficiency indicated that rice-bengal gram, rice-indian mustard, rice-wheat and rice-sunflower cropping systems used the land for 61–64% period of the year, whereas rice-safflower and rice-maize used land for 65–71% period.

Net returns showed that rice-sunflower (Rs 26 160/ha) and rice-bengal gram (Rs 23 865/ha) systems gave significantly higher net returns when compared with rice-indian mustard, safflower, wheat, maize systems. The high net return in rice-sunflower is mainly due to the addition of a high-value crop like sunflower in the system, which increased the net return of the system.

The benefit : cost ratio was also higher in rice-sunflower (3.18), followed by rice-bengal gram (2.98). This indicates the suitability of these 2 crops after rice. The lowest benefit : cost ratio was observed in rice-maize system (2.48).

The values of sustainable yield index were high in the rice-sunflower cropping system (89%), irrespective of weather conditions in 3 years. This was followed by rice-bengal gram (with SYI 82.8%). These 2 cropping systems are therefore more stable than others.

Table 1 Rice-equivalent yield, gross and net returns, benefit : cost ratio, production efficiency, land-use efficiency and sustainable yield index in different rice-based cropping systems (mean data of 3 years)

Cropping system	Rice-equivalent yield (tonnes/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit : cost ratio	Production efficiency (kg/ha/day)	Land-use efficiency	SYI (%)
Rice-safflower	7.24	32 580	20 580	2.72	30.4	65	77.8
Rice-indian mustard	7.14	32 130	20 630	2.79	31.6	62	75.4
Rice-bengal gram	7.97	35 865	23 865	2.98	35.7	61	82.8
Rice-maize	7.17	32 265	19 265	2.48	27.8	71	74.0
Rice-wheat	6.93	31 185	19 685	2.71	30.1	63	74.0
Rice-sunflower	8.48	38 160	26 160	3.18	36.4	64	89.0
S Em $\pm$	0.22		782				
CD ($P = 0.05$)	0.60		2 300				

SYS, Sustainable yield index

The result indicates that in the medium black soils of command areas of Andhra Pradesh, rice-sunflower system gives higher rice-equivalent yield, net return and production efficiency. This was followed by rice-bengal gram.

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Response of rice (*Oryza sativa*) to urea form and nitrogen level under transplanted condition

S M MUTANAL¹, PRASAD KUMAR², V R JOSHI³ and A S PRABHAKAR⁴

Agricultural Research Station, University of Agricultural Sciences, Sirsi 581 401

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ABSTRACT

A field experiment was conducted during rainy season (*khari*) 1992, 1993 and 1994 at Sirsi in Karnataka to study the response of urea forms and nitrogen levels on grain yield of rice (*Oryza sativa* L.) under transplanted condition. The experiment consisted of 3 levels of nitrogen and 4 sources of nitrogen and was replicated thrice in factorial randomized block design. Application of nitrogen through nimin-coated urea proved superior than through prilled urea, tar-coated urea and large urea granules. The optimum dose was 75 kg/ha, which recorded higher return compared with 50 and 100 kg/ha.

Key words : transplanted, rice, urea form, nitrogen, *Oryza sativa*

Crop productivity depends mainly on plant population and fertilizer requirement of rice (*Oryza sativa* L.). In Karnataka rice is grown in lateritic soils under high-rainfall conditions in hilly zone (Malnad tract). Nitrogen is a major input for higher productivity of rice but its efficiency never exceeds 40% under wetland rice cultivation (Pandey and Tripathi 1994). The lower yield is due to heavy loss of nitrogen through deep percolation caused by heavy rains

along with porous soil types (Santra *et al.* 1988). An integrated nutrient management like slow-release nitrogenous fertilizers is necessary to increase the nitrogen efficiency in rice when applied in reduced zone (Prasad and De Datta 1979, Savant *et al.* 1983). Balanced application of major nutrients like nitrogen, phosphorus and potassium gives higher yield and greater economic return (Kanwar 1972, Chandra and Misra 1991, Panda *et al.* 1994). The present study was carried out to know the effect of coated urea forms and nitrogen levels on rice yield in Malnad tract of Karnataka.

¹ Scientist S-1, ² Assistant Professor, ³ Farm Superintendent, ⁴ Director of Instructions

Table 1 Yield components of rice as influenced by urea forms and nitrogen levels (pooled data)

Urea form or N (kg/ha)	Panicle length (cm)				Panicles/m ²				Grain yield (g/hill)				1 000-grain weight (g)			
	N ₅₀	N ₇₅	N ₁₀₀	Mean	N ₅₀	N ₇₅	N ₁₀₀	Mean	N ₅₀	N ₇₅	N ₁₀₀	Mean	N ₅₀	N ₇₅	N ₁₀₀	Mean
Prilled urea	19.3	19.6	19.6	19.5	383	433	450	422	7.6	9.7	10.8	9.36	18.2	18.2	18.7	18.4
Nimin-coated urea	20.8	20.3	20.5	20.5	456	490	500	482	10.6	10.6	12.9	11.4	20.2	16.9	19.8	19.0
Large urea granules	19.2	19.8	20.9	19.9	440	476	476	464	9.2	10.0	11.7	10.3	19.3	18.6	18.4	18.7
Tar-coated urea	19.7	19.5	18.4	19.2	453	473	488	471	10.0	10.5	11.3	10.6	18.7	20.1	16.9	18.5
Mean	19.7	19.8	19.8		433	468	47.8		9.35	10.2	11.9		19.1	18.4	18.4	
	<i>SEm</i> ±		<i>LSD</i> (0.05)		<i>SEm</i> ±		<i>LSD</i> (0.05)		<i>SEm</i> ±		<i>LSD</i> (0.05)		<i>SEm</i> ±		<i>LSD</i> (0.05)	
Forms of urea (F)	0.32		0.93		12.16		35.67		0.37		1.08		0.63		NS	
N levels (N)	0.27		NS		10.53		30.89		0.32		0.94		0.54		NS	
Interaction (F x N)	0.55		1.61		21.09		NS		0.64		1.88		1.08		NS	

Table 2 Grain yield of rice and net returns as influenced by form of urea and nitrogen level

Fertilizer	Grain yield (tonnes/ha)										Net return (Rs/ha) (pooled)									
	N																			
	1992-93					1993-94					1994-95					Mean of 3 years				
	N ₅₀	N ₇₅	N ₁₀₀	Mean	N ₅₀	N ₇₅	N ₁₀₀	Mean	N ₅₀	N ₇₅	N ₁₀₀	Mean	N ₅₀	N ₇₅	N ₁₀₀	Mean				
F ₁	3.84	4.74	4.65	4.41	4.45	4.72	4.80	4.68	4.54	5.55	5.60	5.33	4.28	5.00	5.04	4.77	5.100	6.952	6.896	6.316
F ₂	4.34	4.46	4.53	4.45	4.51	4.92	4.63	4.69	5.51	5.89	5.78	5.73	4.79	5.09	4.98	4.95	6.419	7.024	6.508	6.650
F ₃	4.43	4.42	4.43	4.45	4.46	4.65	4.60	4.57	5.13	5.61	5.80	5.51	4.57	4.89	4.94	4.84	6.192	6.649	6.621	6.487
F ₄	4.29	4.81	4.53	4.42	4.59	4.86	4.55	4.67	5.01	5.28	5.58	5.30	4.63	4.98	4.89	4.83	6.045	6.837	6.383	6.421
Mean	4.25	4.61	4.53		4.50	4.79	4.72		5.12	5.58	5.69		4.59	4.99	4.96		5.935	6.865	6.602	
Forms of urea (F)																				
N levels (N)																				
Interaction (F x N)																				
					</															

tar-coated urea) were found more effective than prilled urea. Thus the nitrogen release was regulated in accordance with the crop need and thus improved the yield parameters, viz grain yield/hill, 1 000-grain weight and panicles/m². Our result confirms the finding of Singh and Singh (1986), who also obtain the highest grain yield of 0.3 tonnes/ha (6.3%) with large urea granules than prilled urea. The response was in the order: nimin-coated urea > tar coated urea > large urea granules > prilled urea. Raju *et al.* (1994) also observed a similar response. The superiority of nimin-coated urea in wetland rice cultivation could be due to its slow release of nitrogen and minimum loss by leaching. Net return was significantly higher (Rs 6 650/ha) with application of nimin-coated urea, followed by large urea granules (Rs 6 487/ha) compared with prilled urea (Rs 6 316/ha). Nitrogen application @ 75 kg/ha recorded significantly higher net return (Rs 6 865/ha) compared with 50 or 100 kg N/ha.

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Uptake of nitrogen, phosphorus, potassium and sulphur by rice (*Oryza sativa*) and sunflower (*Helianthus annuus*)

SHARANAPPA¹ and B SHIVARAJ²

Main Research Station, University of Agricultural Sciences, Bangalore, Karnataka 560 065

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ABSTRACT

A field experiment was conducted during 1989–91 at Bangalore. There were 7 early rainy-season crop treatments and a fallow. Among the treatments *Sesbania rostrata* green-manure-rice (*Oryza sativa* L.)–sunflower (*Helianthus annuus*) sequence had the highest uptake of N, P, K and S, followed by sunnhemp (*Crotalaria juncea* L.) rice–sunflower. The organic carbon content and available N, P and K status of the soil increased significantly with *Sesbania rostrata* followed by sunnhemp green-manure. Rice–sunflower sequence following fodder maize (*Zea mays* L.) had the lowest N, P, K and S uptake as well as the lowest organic carbon and available N, P, K and S status of soil at the end of second cycle of sequence crops, followed by fallow–rice–sunflower. Grain yield of rice and sunflower (4.47 and 0.78 tonnes/ha) was significantly highest with *S. rostrata* green-manure, followed by sunnhemp, and the least with early rainy-season maize. Biomass yield also followed a similar trend.

Key words : nutrient uptake, rice–sunflower sequence, green-mannure

Rice (*Oryza sativa* L.) and sunflower (*Helianthus annuus* L.) are exhaustive crops, requiring high amount of external supply of N, P and K. In an intensive cropping system like rice–sunflower the supply of nutrients through inorganic sources alone cannot sustain the productivity and maintain the fertility of the soil. Inclusion of green-manure in the early rainy season and incorporation of green biomass known to supplement nutrients increase the availability of native nutrients, which in turn increase the crop productivity. The present study was therefore conducted to evaluate the efficiency of green-manure crops in comparison with fodder maize (*Zea mays* L.) and fallow on uptake of N, P, K and S and soil-fertility sustainance.

MATERIALS AND METHODS

The field experiment was conducted at the Main Research Station of the university at Hebbal in Bangalore during 1989–91 and 1990–91. The soil was sandy clay-loam with pH 8.2. The organic carbon content of the soil was 0.44 %, the available N, P and K contents were 256, 56 and 218 kg/ha, and the available sulphur was 20.8 ppm. Maize, soybean [*Glycine max* (L.) Merr.], *Sesbania rostrata* and sunnhemp (*Crotalaria juncea* L.) were grown sole and as intercrops, viz. maize + sunnhemp, maize + *S. rostrata* and

maize + soybean, along with a fallow (no early rainy-season crop). Thus there were 8 treatments replicated thrice. The net plot size was 3.6 m x 6.0 m. The early rainy-season crops were sown during the last week of May. At 50% flowering green-manure crops were cut and incorporated into the soil, whereas fodder maize was harvested for fodder. Seedlings of 'Mangala' rice at 21 days were transplanted during the first week of August. After harvesting rice, without disturbing the lay-out, land was prepared. 'Morden' sunflower was raised following 60 cm x 20 cm spacing under residual soil fertility.

The organic carbon (%) and the available N, P and K content of the soil were analysed before beginning the experiment and at the end of second cycle of crops following the procedure given by Jackson (1973). The N, P, K and S content of the plant was analysed (Jackson 1973) and uptake of N, P, K and S was calculated using the dry-matter yield. The grain and straw yields (kg/ha) were recorded.

RESULTS AND DISCUSSION

Uptake of N, P, K and S by rice and sunflower

Green-manuring with *S. rostrata* significantly increased the uptake of N, P, K and S by rice and sunflower, followed by sunnhemp. The uptake of these nutrients was lowest when fodder maize was grown preceding rice–sunflower sequence (Table 1). The increase in uptake of nutrients may be attributed to significantly higher grain and biomass yields of rice and sunflower (Table 2). Sole crops of *S. rostrata* and

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¹ Associate Professor, ² Professor, Department of Agronomy

Table 1 Influence of green-manure crops on uptake (kg/ha) of nitrogen, phosphorus, potassium and sulphur by crops in rice-sunflower sequence (pooled data of 1989-90 and 1990-91)

Pre-season crop	Nitrogen		Phosphorus		Potassium		Sulphur	
	Rice	Sunflower	Rice	Sunflower	Rice	Sunflower	Rice	Sunflower
Maize	112.3	26.9	35.9	7.2	73.9	35.2	7.1	2.7
Soybean	156.9	38.9	43.6	10.3	99.8	57.6	10.1	3.7
<i>Sesbania rostrata</i>	172.7	51.3	57.5	12.5	113.5	67.5	13.9	4.4
Sunn hemp	161.8	44.1	43.5	10.1	102.4	60.3	11.9	4.3
Maize + sunn hemp	137.5	37.4	39.4	9.7	77.9	46.7	9.2	3.5
Maize + <i>S. rostrata</i>	138.0	38.5	39.3	10.5	83.3	47.0	10.5	3.8
Maize + Soybean	133.3	33.9	40.1	9.6	82.9	46.6	8.9	3.3
Fallow	132.4	29.6	40.8	8.6	83.1	40.7	7.4	3.0
SEm $\pm$	1.9	1.0	0.5	0.3	1.7	0.79	0.17	0.05
CD ($P=0.05$)	5.6	2.9	1.4	0.8	4.8	2.3	0.51	0.16

Table 2 Grain and biomass yields (tonnes/ha) of rice and sunflower as influenced by green-manure crops (pooled data of 1989-90 and 1990-91)

Pre-season crop	Grain yield		Biomass yield	
	Rice	Sunflower	Rice	Sunflower
Maize	3.55	0.43	7.57	1.43
Soybean	4.13	0.61	9.32	2.01
<i>Sesbania rostrata</i>	4.47	0.78	10.76	2.37
Sunn hemp	4.36	0.71	10.34	2.21
Maize + sunn hemp	3.96	0.65	8.85	1.92
Maize + <i>S. rostrata</i>	4.04	0.64	9.14	1.96
Maize + Soybean	3.78	0.58	8.36	1.79
Fallow	3.62	0.47	7.96	1.59
SEm $\pm$	0.05	0.02	0.12	0.03
CD ($P=0.05$)	0.15	0.05	0.36	0.08

sunn hemp added more green matter compared with intercropped green-manures. Incorporation of green-manure increased the availability of N, P, K and S. During decomposition of green-manures several organic acids were released, which increased the availability of phosphorus and potassium. During mineralization process of green-manure

crops, nitrogen and sulphur were released. Maximum uptake of nutrients by rice and sunflower with *S. rostrata* green-manure may be attributed to increased availability of N, P, and K in soil (Table 3). The result confirms those of Bharadwaj *et al.* (1981) and Rinaudo *et al.* (1988).

Soil-fertility status at end of second cycle of crop

The initial organic carbon and available phosphorus content of the soil did not differ significantly. But significantly highest initial available N and P were recorded with *S. rostrata* and soybean green-manure. After harvesting sunflower during the second cycle of the sequence, the organic carbon, available phosphorus and available potassium contents of the soil significantly increased compared with the initial level with *S. rostrata* green-manure, followed by sunn hemp. Available nitrogen content of the soil was significantly highest at the end of second cycle in the sequence with *S. rostrata* green-manure, but there was no increase from the initial level. There was decline in available N content of the soil with premonsoon maize. There was increase in available nitrogen in the rest of the treatments (Table 3). Swarup (1987), Sahu *et al.* (1988) and Sharma and Mittra

Table 3 Organic carbon, nitrogen, phosphorus and potassium status of soil as influenced by green-manure crops in rice-sunflower sequence

Preseason crop	Initial status				After harvesting sunflower in second year			
	Organic C (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Organic C (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Maize	0.64	236	18	115	0.70	209	50	434
Soybean	0.70	223	20	148	1.11	263	80	551
<i>Sesbania rostrata</i>	0.88	285	21	109	1.24	285	99	591
Sunn hemp	0.96	216	22	138	1.16	274	86	561
Maize + sunn hemp	0.93	183	17	125	1.07	242	77	527
Maize + <i>S. rostrata</i>	0.93	220	23	115	1.04	274	65	531
Maize + soybean	0.99	189	21	125	0.98	242	62	522
Fallow	0.91	236	26	141	0.86	245	51	448
SEm $\pm$	0.08	13.2	3.7	7.4	0.05	15.3	4.0	14.4
CD ($P=0.05$)	NS	38.5	NS	22.6	0.14	45.8	12.1	43.6

(1988) also reported improvement in the organic carbon and available N, P, and K status of the soil.

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Integrated nutrient management in maize (*Zea mays*)–wheat (*Triticum aestivum*) sequence under rainfed condition in Himachal Pradesh

K K MAHAJAN¹, RANJODH SINGH², V K SHARMA³, C L ACHARYA⁴, B S DEOR⁵, N K GOYAL⁶
and S S MASAND⁷

Regional Research Station, Himachal Pradesh Krishi Vishvavidyalaya, Palampur 176 062

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ABSTRACT

A field experiment was conducted during 1991–92 to 1994–95 on fixed sites in different agro-climatic zones of Himachal Pradesh to study the effect of different combinations of N, P and K in the presence and absence of farmyard manure on maize (*Zea mays* L.) – wheat (*Triticum aestivum* L. emend. Fiori & Paol.) system. In sandy loam soil (Udifuvent) the response of P was not observed in the presence as well as absence of farmyard manure but was observed on wheat in the absence of farmyard manure only. In coarse soil (Ustipsamment) the response of P was found in both maize and wheat in the presence and absence of farmyard manure. In sandy loam soil (Hapludalt) the addition of P was useful in the absence of farmyard manure only, but in clay loam soil (Ustochrept) there was no effect of P application. Application of 45 kg N/ha + farm yard manure for maize crop followed by 25–30 kg N/ha in the absence or presence of farmyard manure for wheat crop was in general as good as 90 kg N/ha and 50–60 kg N/ha respectively. The addition of K was beneficial in only coarse soils. In general NP (140 to 150 + 30.5 to 37 + 10 tonnes farmyard manure has given the maximum return.

In Himachal Pradesh fertilizer is used @ N = 9.0, P = 1.96 and K = 25 kg/ha for maize (*Zea mays* L.) under low rainfall and N = 50, P = 1.09, K = 2.08 for wheat (*Triticum aestivum* L. emend. Fiori & Paol.) under rainfed conditions. Since a limited part of manure is utilized by a crop, fertilizer requirement of the succeeding crop may be modified in view of residual nutrients. Addition of farmyard manure to maize or wheat is a regular practice in the state. The information on the use of N, P and K on 2 important crops (maize–wheat) sequence in combination with farmyard manure is lacking. Since the rainfall varies from medium to high in the state, the information on fertilizer use under different situations is also needed. An experiment was therefore conducted at different research stations to work out the integrated nutrient-supply approach for maize–wheat system.

MATERIALS AND METHODS

The Himachal Pradesh is divided into 4 agro-climatic zones. In Zone I (submontane and low-hills subtropical) the experiment was conducted at Regional Research station

Dhaulakuan in district Sirmour and at Research Station, Akrot in district Una. In Zone II (mid-hills subhumid) the locations were Regional Research Station, Bajaura in district Kullu and Research Station, Sundernagar in district Mandi. There were 3–4 replications at the fixed site of each location. The dose of N, P and K was respectively 90, 19.6 and 25 kg/ha for maize and 50, 10.9 and 20.8 kg/ha for wheat, except for Sundernagar where dose was 60, 17.4 and 16.7 kg/ha for wheat crop. The 25, 50 and 100% of N and NP levels in the presence of 10 tonnes farmyard manure/ha and 100% of N, NP and NPK levels were the 9 treatments as shown in the data tables. Farmyard manure was applied to rainy-season crop only, except at Sundernagar where it was applied to both in rainy and winter-season. The date of sowing maize ('Naveen') was last week of June and that of wheat ('HD 2380') was second week of November in Zone I (Dhaulakuan and Akrot). Maize ('Parvati') was sown in the last week of June in 1992 and first week of July in 1991 and 1993 at Bajaura, whereas 'Early Composite' maize was sown at Sundernagar in second week of June. Wheat ('HD 2380') was sown in the second week of January in 1991–92 and third week of November in 1992–93 and 1993–94 at Bajaura. At Sundernagar the sowing date wheat was last week of December in 1991–92, second week of December in 1992–93 and second week of October in 1993–94.

At Sundernagar the farmyard manure was also applied in T₁ to T₆ and there was a slight variation in NIP and K doses as given in methods and materials.

¹ Senior Soil Scientist, ³ Assistant Professor (Soils), ⁴ Chief Scientist and Head (Soils), ⁷ Soil Scientist, Department of Soil Science; ² Director of Research,

⁵ Senior Agronomist, Research Station, HPKV, Sundernagar 174 402; ⁶ Training Associate and Junior Scientist (Soils), Krishi Vigyan Kendra, Chaudhary Charan Singh Haryana Agricultural University, Yamunanagar 135 001

Table 1 Effect of different N, P and K combinations with and without farmyard manure on grain yield (tonnes/ha) of maize and wheat.

Treatment	Maize				Wheat			
	1992	1993	1994	Mean	1992-93	1993-94	1994-95	Mean
<i>Dhaulakuan</i>								
T ₁	1.96	2.03	1.01	1.66	2.13	2.51	2.08	2.24
T ₂	2.15	2.20	1.23	1.86	2.27	2.66	2.15	2.36
T ₃	2.57	2.58	1.52	2.22	2.73	2.71	2.27	2.57
T ₄	2.08	2.16	1.14	1.79	2.10	2.85	2.24	2.39
T ₅	2.24	2.37	1.30	1.97	2.73	2.93	2.31	2.66
T ₆	2.69	2.79	1.57	2.35	2.82	2.97	2.36	2.72
T ₇	2.62	2.75	1.46	2.28	2.29	2.42	2.06	2.36
T ₈	2.66	2.87	1.54	2.36	2.96	2.65	2.13	2.58
T ₉	2.76	3.19	1.64	2.53	3.03	2.75	2.17	2.65
CD (<i>P</i> = 0.05)	3.9	5.7	2.9		6.0	NS	NS	
<i>Arkot</i>								
T ₁	2.24	1.46	2.12	1.94	1.19	1.69	1.95	1.61
T ₂	2.59	1.75	2.60	2.31	1.59	1.82	2.15	1.85
T ₃	3.04	2.22	3.24	2.83	1.82	2.01	3.46	2.43
T ₄	2.42	1.58	2.39	2.13	1.42	1.80	2.01	1.74
T ₅	2.85	1.94	2.86	2.55	1.78	2.00	2.47	2.08
T ₆	3.26	2.54	3.69	3.16	2.10	2.41	3.66	2.72
T ₇	2.62	1.90	2.85	2.46	1.69	1.75	2.62	2.02
T ₈	2.78	2.13	3.14	2.68	1.79	2.06	2.95	2.27
T ₉	3.15	2.36	3.53	3.01	2.10	2.18	3.46	2.58
CD (<i>P</i> = 0.05)	0.8	0.9	1.2		1.7	1.0	1.2	-
<i>Bajaura</i>								
	1991	1992	1993		1991-92	1992-93	1993-94	
T ₁	3.90	3.16	2.41	3.16	1.94	1.99	1.35	1.76
T ₂	4.60	3.99	2.97	3.85	2.29	2.32	1.67	2.09
T ₃	4.89	6.26	3.25	4.80	2.85	2.79	1.76	2.47
T ₄	5.08	3.36	2.82	3.75	1.96	2.18	1.39	1.85
T ₅	4.49	4.52	2.71	3.91	2.29	2.53	1.99	2.27
T ₆	4.66	5.80	3.34	4.60	3.16	3.21	2.14	2.84
T ₇	5.09	5.96	2.61	4.55	3.07	2.21	1.14	2.14
T ₈	4.87	6.31	3.19	4.79	3.14	2.86	1.96	2.65
T ₉	5.57	5.30	3.02	4.63	2.91	2.95	2.18	2.68
CD (<i>P</i> = 0.05)	NS	14.5	5.4		6.2	4.4	4.3	3.8
<i>Sundernagar</i>								
T ₁	4.08	4.83	2.81	3.91	3.00	2.27	3.48	2.92
T ₂	4.60	4.50	3.04	4.05	3.90	2.83	3.89	3.54
T ₃	3.90	5.29	4.55	4.58	4.66	3.63	5.38	4.56
T ₄	4.75	3.80	2.88	3.81	3.43	2.32	4.37	3.38
T ₅	5.66	4.00	3.79	4.48	3.74	2.32	3.87	3.31
T ₆	5.30	4.98	4.78	5.02	4.91	3.28	5.47	4.55
T ₇	5.66	4.51	3.08	4.42	4.94	3.03	4.02	3.99
T ₈	4.75	4.80	3.86	4.47	4.96	3.08	4.88	4.31
T ₉	4.48	5.20	3.85	4.51	5.34	3.13	4.97	4.48
CD (<i>P</i> = 0.05)	NS	NS	12.1		NS	NS	9.8	

T₁, 22.5 kg N/ha + farmyard manure 12.5 kg N/ha; T₂, 45 kg N/ha + farmyard manure 25 kg N/ha; T₃, 90 kg N/ha + farmyard manure 50 kg N/ha; T₄, 22.5 kg N/ha + 4.9 kg P/ha + farmyard manure 12.5 kg N/ha + 2.72 kg P/ha; T₅, 45 kg N/ha + 9.8 kg P/ha + farmyard manure 25 kg N/ha + 5.45 kg P/ha; T₆, 90 kg N/ha + 19.6 kg P/ha + farmyard manure 50 kg N/ha + 10.9 kg P/ha; T₇, 90 kg N/ha 50 kg N/ha; T₈, 90 kg N/ha + 19.6 kg P/ha 50 kg N/ha + 10.9 kg P/ha; and T₉, 90 kg N/ha + 19.6 kg P + 25 kg K/ha 50 kg N/ha + 10.9 kg P/ha + 20.8 kg K/ha

The soils of Dhaulakuan, Akrot, Bajaura and Sundernagar were sandy loam, loamy sand, sandy loam and clay loam, having pH 6.8, 8.2 and 6.2 and 6.4; organic carbon 0.54, 0.40, 0.93 and 0.60; and belong to Udifluent, Ustipsamment, Hapludalf and Ustochrept soil groups respec-

tively. The respective figures for available N were 291, 155, 421 and 305; available P(Olsen-P) were 29, 6, 19 and 34 and available K (neutral NH acetate K) were 153, 170, 104 and 309 kg/ha. The mean rainfall at Dhaulakuan, Akrot, Bajaura and Sundernagar was 1 271, 1 296, 432 and

1 089 mm during rainy season (May–September) and 1 478, 1 584, 756 and 1 365 mm during winter season (October–April) respectively. Bajaura is medium (750–1 250 mm/year) rainfall area whereas Dhaulakuan, Akrot and Sundernagar are high rainfall (more than 1 250 mm/year) areas (Tandon 1992). The average maximum and minimum temperature were 29.3 and 15.0 C° at Dhaulakuan, 27.5 and 17.5 C° at Akrot, 5.9 and 9.8 C° at Bajaura, and 27.1 and 14.1 C° at Sundernagar.

RESULTS AND DISCUSSION

The grain yield of maize and wheat (Table 1) showed that in Zone I at Dhaulakuan there was no response of P in the absence as well as presence of farmyard manure on maize. In wheat also there was no response of P in the presence of farmyard manure. However, a significant response of P (39%) was found in the absence of farmyard manure in 1992–93. N @ 90 kg/ha was better than 45 kg/ha + farmyard manure in 1992, but later on both the treatments were at par with each other for maize. In wheat even 12.5 N/ha + farmyard manure was as good as 50 kg N/ha. At Akrot the response of P was found in the presence and absence of farmyard manure on both the crops. The increase in maize yield due to P addition was 11 and 9% and that of wheat was 11 and 12% in the presence and absence of farmyard manure respectively. The low response due to P addition may be due to overall low yield of crops. The addition of nitrogen was found useful up to 90 kg N/ha even in the presence of farmyard manure. N @ 90 kg/ha + farmyard manure was better by 14% in maize and 40% in wheat than 90 kg N/ha. In Zone II at Bajaura there was no response of P in the presence of farmyard manure in both the crops. In the absence of farmyard manure the response due to P started appearing in 1992–93, bringing on increase in wheat yield by 30 and 72% in 1992–93 and 1993–94 respectively and that in maize by 23% in 1993. N @ 90 kg/ha was better than 45 kg/ha + farmyard manure in 1992, but later on the latter was at par with the former in maize. In wheat 50 kg N/ha was better by 34% than 25 kg N/ha + farmyard manure in 1991–92, at par in 1992–93, but in 1993–94 25 kg N/ha + farmyard manure was better by 47% than 50 kg N/ha. At Sundernagar there was no response of P in the absence as well as presence of farmyard manure in both the crops. 45 kg N/ha + farmyard manure for maize and 25 kg N/ha + farmyard manure for wheat were at par with 90 kg N/ha and 50 kg N/ha respectively in all the years. The addition K was not useful for both maize and wheat under all locations except soils of Akrot. K application increased the yield of maize and wheat by 12–14% over NP at this station.

The result indicates that coarse soils of Akrot having low available N and P and medium available K need the application of farmyard manure in addition to recommended doses of NPK, as also reported by Badiyala and Verma (1991). Regarding other locations there is no response of P

in the presence of farmyard manure for both maize and wheat on soils rating medium to high in available P status. Thus farmyard manure helps in making native P available. Sharma and Gupta (1994) reported that farmyard manure improved phosphorus utilization by 93–99% in wheat. Singh and Jones (1976) attributed to reasons such as release organic acids that can complex Al and Fe, thereby reducing P retention and in inducing greater P availability. Datta and Goswami (1962) reported formation of phosphate complexes, which are usually assimilated by plants, on ion replacement of phosphate by humate and coating of sesquioxides surfaces by humus to form protective cover that reduces P fixation. There was also no response of P on maize in the absence of farmyard manure, except at Bajaura where response due to P appeared in 1993 only. This may be due to higher rainfall during *kharif* at Dhaulakuan and Sundernagar compared with Bajaura. This keeps the soil wet and thus solubility factor helps in making native soil P available to maize crop. In wheat the response due to P in the absence of farmyard manure started from 1991–92 at Dhaulakuan and from 1992–93 at Bajaura, but did not appear at Sundernagar during all the years of experimentation. According to Brady (1984) phosphorus fixation is at a minimum and availability to higher plants is maximum between pH 6 and 7. Phosphorus fixation tends to be more pronounced in clay soils than in coarse ones. The soils sandy loam under the experiment belong to moderately coarse category except clay loam soils of Sundernagar and pH varies from 6.2 to 6.8. Thus the maize and wheat crops were able to utilize the native phosphorus in the soils of Dhaulakuan, Bajaura and Sundernagar.

Though the performance of 90 kg N/ha was better than of 45 kg N/ha + farmyard manure in the beginning at Dhaulakuan and Bajaura, later on 45 kg N/ha + farmyard manure was as good as 90 kg N/ha for maize. In wheat even 22.5 kg N/ha + farmyard manure remained at par with 90 kg N/ha at Dhaulakuan, but at Bajaura 45 kg N/ha + farmyard manure was inferior to 90 kg N/ha in 1991–92, at par with 90 kg N/ha in 1992–93 and superior to 90 kg N/ha in 1993–94. This shows faster decomposition of farmyard manure at Dhaulakuan than at Bajaura due to higher rainfall and temperature in the former compared with the latter. At Sundernagar 45 kg N/ha + farmyard manure for maize and 30 kg N/ha + farmyard manure for wheat remained as good as 90 and 60 kg N/ha respectively.

Our finding supports the work of Suri *et al.* (1995), who reported that farmyard manure contributed 14% in meeting nutrient needs of maize crop. The highest significant residual effect due to farmyard manure was recorded in following wheat. Singh (1983) also reported that at 60 kg N/ha, 6 kg P/ha and 21 kg K/ha farmyard manure significantly increased the grain yield of maize and wheat.

The economic data (Table 2) showed that if farmyard manure is taken free of cost with the farmer, the net profit is maximum in NPK (140 + 30.5 + 45.8 kg/ha), followed by

Table 2 Economics of maize + wheat under different treatments

Treatment	Net profit (Rs/ha) (cost of produce – cost of fertilizer)				Net profit (Rs/ha) Cost of produce – (Cost of fertilizer + cost of farmyard manure)			
	Dhaulakuan	Akrot	Bajaura	Sundernagar	Dhaulakuan	Akrot	Bajaura	Sundernagar
T ₁	18 806	17 663	25 060	33 149	17 306	16 163	23 560	30 149
T ₂	20 345	19 815	30 073	36 759	18 845	18 315	28 573	33 759
T ₃	22 562	24 868	36 900	43 809	21 062	23 368	35 400	40 809
T ₄	20 026	18 177	28 272	34 624	18 526	16 677	26 773	31 624
T ₅	21 723	21 507	30 851	38 064	20 223	20 007	29 351	35 064
T ₆	23 016	27 065	36 652	44 805	21 516	25 565	35 152	41 805
T ₇	21 789	21 072	33 514	40 217	21 789	21 072	33 514	40 217
T ₈	22 567	22 371	36 311	40 958	22 567	22 371	36 341	40 958
T ₉	23 619	25 403	36 255	41 748	23 619	25 403	36 255	41 748

Price (Rs/100 kg) : maize grain 412, wheat 360, maize straw 48, wheat 90; Cost of fertilizer (Rs/100 kg) : urea 285, superphosphate 205, muriate of potash 288, farmyard manure 15

NP (140 + 30.5 kg/ha) + 10 tonnes farmyard manure at Dhaulakuan and the reverse was true at Akrot. At Bajaura N (140 kg/ha) + 10 tonnes farmyard manure followed by NP (140 + 30.5 kg/ha) + 10 tonnes farmyard manure and at Sundernagar NP (150 + 37 kg/ha) + 10 tonnes farmyard manure showed the maximum returns. When cost of farmyard manure is taken into consideration, net returns are again higher in NP + farmyard manure, compared with N + farmyard manure, except at Bajaura where the latter is only slightly better than the former. At Sundernagar and Akrot NP(140 to 150 + 30.5 to 37 kg/ha) + farmyard manure was as good as NPK (140 to 150 + 30.5 to 37 + 45.8 to 50 kg/ha) + farmyard manure was as good as NPK (140 to 150 + 30.5 to 37 + 45.8 to 50 kg/ha).

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Economy in fertilizer use in maize (*Zea mays*)–wheat (*Triticum aestivum*) sequence under rainfed condition in Himchal Pradesh

RAMESHWAR¹ and C M SINGH²

College of Agriculture, Himachal Pradesh Krishi Vishvavidyalaya, Palampur 176 062

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ABSTRACT

A field study was conducted for 3 years during rainy season (*kharif*) 1993–94 to winter season (*rabi*) 1995–96 under mid-hill conditions of Himachal Pradesh to determine the appropriate combination of fertilizer scheduling along with appropriate time of farmyard manure application. The cumulative application of farmyard manure to both maize (*Zea mays* L.) and wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crops @ 10 tonnes/ha in each season gave significantly higher grain yield, followed by farmyard manure applied directly, and the lowest yield with its residual effect in both maize and wheat crops. Although during the first year both the crops responded to $N_{120}P_{60}K_{40}$ in maize and $N_{80}P_{40}K_{40}$ in wheat, during the second and third years the crops responded to $N_{90}P_{45}K_{30}$ in maize and $N_{60}P_{30}K_{30}$ in wheat. There is possibility of economizing fertilizer by 25% of NPK in both maize and wheat under rainfed condition without compromising with grain-yield production.

Key words : maize–wheat sequence, farmyard manure, fertilizer schedule, rainfed maize, *Zea mays*, wheat, *Triticum aestivum*

For realization of higher yield from a system, judicious use of organic and inorganic sources of plant nutrients is essential (Lal and Mathur 1988). Farmyard manure is an important organic source of essential elements. Though this source contains essential nutrient elements for plant growth, their quantity is not enough to meet the full requirement. However, the inherent property of farmyard manure—slow and steady release of nutrients—is highly useful for exploitation in a cropping system, where its application in 1 season may have carry-over effect, necessitating reduction in fertilizer application in the next crop. Hence an investigation was undertaken to study the extent of reduction in fertilizer requirement of maize (*Zea mays* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) sequence in combination with farmyard manure under agro-climatic conditions of Palampur.

MATERIALS AND METHODS

A field experiment in randomized block design was conducted for 3 years (1993–94 to 1995–96) on the same piece of land at the research farm of the College of Agriculture, Palampur (32°6'N and 76°3'E at 1 290 m above mean sea-level. The soil was silty clay-loam, having pH 5.6, organic carbon 0.64%, available N 284.0 kg/ha, available P

16.8 kg/ha, available K 275.3 kg/ha, and with total N 2 565 kg/ha at the time of beginning the experiment.

The treatments consisted all possible combinations of 3 doses and NPK schedules of fertilizer, viz application of $N_{120}P_{60}K_{40}$ to maize and $N_{40}P_{20}K_{20}$ to wheat, $N_{90}P_{45}K_{30}$ to maize and $N_{60}P_{30}K_{30}$ to wheat, and $N_{60}P_{30}K_{20}$ to maize and $N_{80}P_{40}K_{40}$ to wheat; representing N, P and K (kg/ha) respectively; along with 3 farmyard manure treatments, viz farmyard manure to maize, farmyard manure to wheat and farmyard manure to both maize and wheat crops. During the first maize-crop season of 1993, there were only 2 farmyard manure treatments, with and without its application to maize. In the subsequent seasons all the 3 levels of farmyard manure were applied. Farmyard manure was incorporated @ 10 tonnes/ha on dry-weight basis in the soil in each season as per treatment.

The whole quantity of farmyard manure, and P and K were applied basal. In maize, one-third nitrogen was applied at sowing, one-third at knee-high stage and the remaining at tasselling stage, whereas in wheat half the N was applied at sowing and the remaining half at tillering stage. The N, P and K were applied through urea, single superphosphate and muriate of potash respectively. 'Parvati' maize was sown under rainfed condition at a spacing of 60 cm X 20 cm on 19 May 1993, 28 May 1994 and 19 June 1995, and the soil moisture at the time of sowing was 22.3, 21.8 and 22.7% respectively. The total rainfall received in maize-

¹ Research Associate, Department of Agronomy; ² Director of Extension Education

crop season during different years was 1 261, 1 689 and 1 561 mm. 'VL 616' wheat was sown at 22 cm spacing on 6 October 1993, 28 October 1994 and 9 October 1995, and soil moisture at the time of sowing was 21.2, 18.1 and 18.8% respectively. The total rainfall received in wheat-crop season during different years was 290, 296 and 218 mm.

RESULTS AND DISCUSSION

Response of maize

Farmyard manure : Farmyard manure @ 10 tonnes/ha improved the different yield attributes of maize and ultimately increased the grain and stover yields compared with the control in 1993. Rao and Bhardwaj (1981) also observed a similar influence of farmyard manure application on maize-grain yield. The plots receiving farmyard manure in both maize and wheat improved the yield attributes in maize significantly, followed by those receiving it in maize, and the lowest those receiving it in the preceding wheat (Table 1). The better crop growth was the result of adequate nutrition,

viz improved cobs/plant, cob diameter, grain yield/cob and 1 000-grain weight, with the addition of farmyard manure. Significant variation in the yield-contributing characters of maize led to significantly higher grain and stover yields of maize, with the cumulative application of farmyard manure followed by direct effect of farmyard manure, and the lowest yield with the residual effect of farmyard manure (Table 2). Nambiar (1994) reported similar result in a long-term experiment of maize and wheat under model agronomic project at Ludhiana in 1968-78.

Fertilizer schedule : The application of $N_{90}P_{45}K_{30}$ remained at par with both $N_{60}P_{30}K_{20}$ and $N_{120}P_{60}K_{40}$, whereas $N_{60}P_{30}K_{20}$ recorded the lowest yield. Due to minor increase in fertility level, $N_{60}P_{30}K_{20}$ and $N_{90}P_{45}K_{30}$ remained at par with each other, whereas application of $N_{120}P_{60}K_{40}$ resulted in significantly higher growth, development and yield attributes, leading to production of 9.4% significantly higher grain yield than $N_{60}P_{30}K_{20}$ fertilizer application. Maskina *et*

Table 1 Effect of farmyard manure and fertilizers on yield-contributing characters of maize (pooled values of 1994-95)

Treatment	Cobs/ plant	Cob length (cm)	Cob diameter (cm)	Grains/ cob	Grain weight/ cob (g)	1 000- grain weight (g)
<i>Effect of farmyard manure</i>						
Maize	1.00	17.49	3.91	331	81.3	246.1
Wheat	0.97	16.22	3.55	301	67.4	224.5
Maize, wheat	1.02	18.78	4.07	356	89.4	250.1
SEm ±	0.008	0.309	0.002	2.9	1.15	3.09
CD (P = 0.05)	0.02	0.89	0.006	8.5	3.3	9.27
<i>Effect of fertilizer</i>						
$N_{120}P_{60}K_{40}$	1.04	18.12	3.88	345	80.3	244.2
$N_{90}P_{45}K_{30}$	0.99	17.52	3.86	331	78.3	235.5
$N_{60}P_{30}K_{20}$	0.97	16.86	3.76	324	74.5	236.7
SEm ±	0.008	0.31	0.002	2.9	1.15	3.09
CD (P = 0.05)	0.02	0.89	0.006	8.5	3.32	NS

Table 2 Effect of farmyard manure and fertilizers on yield of maize

Treatment	Grain yield (kg/ha)				Stover yield (kg/ha)			
	1993	1994	1995	Pooled 1994-95	1993	1994	1995	Pooled 1994-95
<i>Effect of farmyard manure</i>								
Maize	5 472	4 497	4 155	4 325	14 892	11 530	9 882	10 706
Wheat		3 871	3 549	3 709		8 818	8 332	8 570
Maize, wheat		4 858	4 591	4 774		12 040	10 650	11 341
Control	4 465				13 014			
SEm ±	96.1	123.0	131.2	89.0	162.1	257.1	292.1	188.0
CD (P = 0.05)	310.4	369.3	393.0	256.2	496.8	722.1	872.0	545.7
<i>Effect of fertilizer</i>								
$N_{120}P_{60}K_{40}$	5 614	4 491	4 316	4 453	1 560	1 110	1 035	1 072
$N_{90}P_{45}K_{30}$	5 139	4 457	4 110	4 263	1 401	1 105	962	1 033
$N_{60}P_{30}K_{20}$	4 825	4 278	3 868	4 072	1 359	1 022	889	956
SEm ±	123.1	123.0	131.2	89.0	197.0	257.1	292.1	188.0
CD (P = 0.05)	370.2	NS	393.0	256.2	592.0	722.1	872.0	545.7

Table 3. Effect of farmyard manure and fertilizer on yield-contributing characters of wheat (pooled values of 1993–96)

Treatment	Spikes/ m ²	Spike length (cm)	Spikelets/ spike	Grains/ spike	Grain weight/ spike (g)	1 000- grain weight (g)
<i>Effect of farmyard manure</i>						
Maize	193	9.2	16	47	1.92	40.82
Wheat	208	9.3	16	48	1.95	40.92
Maize, wheat	240	10.5	17	49	2.08	42.37
SEm ±	5.1	0.12	0.1	1.1	0.018	0.231
CD (<i>P</i> = 0.05)	15	0.4	0.4	NS	0.05	0.68
<i>Effect of fertilizer</i>						
N ₄₀ P ₂₀ K ₂₀	208	9.6	16	47	1.93	41.04
N ₆₀ P ₃₀ K ₃₀	212	9.7	16	48	1.96	41.40
N ₈₀ P ₄₀ K ₄₀	223	9.8	16	49	2.04	41.67
SEm ±	5.1	0.12	0.13	1.1	0.018	0.231
CD (<i>P</i> = 0.05)	NS	NS	NS	NS	0.05	NS

Table 4. Effect of farmyard manure and fertilizers on yield of wheat

Treatment	Grain yield (kg/ha)				Straw yield (kg/ha)			
	1993–94	1994–95	1995–96	Pooled	1993–94	1994–95	1995–96	Pooled
<i>Effect of farmyard manure</i>								
Maize	2 754	2 956	3 053	2 921	3 218	3 516	3 798	3 511
Wheat	3 161	3 247	3 343	3 247	3 733	3 870	4 103	3 901
Maize, wheat	3 450	3 636	3 734	3 673	4 043	4 567	4 647	4 419
SEm ±	91.2	99.2	97.0	67.1	101.1	118.0	119.0	77.1
CD (<i>P</i> = 0.05)	274.1	297.3	295.8	201.0	304.2	353.7	362.5	224.3
<i>Effect of fertilizer</i>								
N ₄₀ P ₂₀ K ₂₀	2 889	3 139	3 208	3 078	3 467	3 735	4 009	3 737
N ₆₀ P ₃₀ K ₃₀	3 052	3 330	3 339	3 240	3 605	3 951	4 167	3 907
N ₈₀ P ₄₀ K ₄₀	3 422	3 569	3 583	3 524	3 923	4 268	4 371	4 187
SEm ±	91.2	99.2	97.0	67.1	101.1	118.0	119.0	77.1
CD (<i>P</i> = 0.05)	274.1	297.3	295.8	201.0	304.2	353.7	NS	224.3

al. (1988) also found substitution of 50 and 75% of NPK with the application of 6 and 12 tonnes/ha farmyard manure respectively to maize crop while working on maize-wheat sequence. The effect of fertilizer application on the stover yield of maize was also similar (Table 2).

Response of wheat

Farmyard manure : The different yield attributes of wheat were significantly higher with cumulative effect of farmyard manure. The direct effect of farmyard manure remained at par with its residual effect on different yield attributes (Table 3).

The significant variation in the yield-contributing characters of wheat led to significant variation in grain and straw yields (Table 4). The cumulative application of farmyard manure to maize improved the grain and straw yields of wheat, followed by direct effect of farmyard manure. The lowest yield was obtained with residual effect of farmyard manure, whereas during 1994 and 1995 there was no difference between direct and residual effects of farmyard manure, due to improvement in soil conditions, build up of soil

nutrients etc. The result confirms the finding of Chaudhary *et al.* (1981). Continuous application of farmyard manure season after season might have resulted in slow release of nutrients from farmyard manure, which might have reduced their losses and resulted in build up of these nutrients. The finding confirms that of Singh *et al.* (1980).

Fertilizer schedule : In different yield attributes, only grain weight/spike was significantly higher with N₈₀P₄₀K₄₀ fertilizer application, whereas N₆₀P₃₀K₃₀ and N₄₀P₂₀K₂₀ remained at par, owing to the difference in yield of the crop with increase in fertility dose (Table 3). The weight of individual grain and grain weight/spike is governed by the grain growth, which depends on the CO₂ assimilation during the grain-filling phase than by the stored reserves of carbohydrates during the vegetative phase. Due to significantly increase in grain weight per spike, the yield increased with increase in fertilizer application. During the subsequent years N₆₀P₃₀K₃₀ was at par with both N₄₀P₂₀K₂₀ and N₈₀P₄₀K₄₀, whereas N₄₀P₂₀K₂₀ recorded the lowest yield. N₈₀P₄₀K₄₀ gave significantly higher grain as well as straw yield compared with N₄₀P₂₀K₂₀ (Table 4).

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Influence of nitrogen, phosphorus and potassium on composition of leaf and its relationship with fruit yield in 'Allahabad Safeda' guava (*Psidium guajava*) on an Alfisol

S C KOTUR¹, RAMKUMAR² and H P SINGH³

Central Horticultural Experiment Station, Indian Institute of Horticultural Research, Ranchi, Bihar 834 010

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ABSTRACT

In a field experiment on 8-year-old 'Allahabad Safeda' guava (*Psidium guajava* L.), an increase in N level (0–800 g/tree/year) significantly increased the N and K but decreased the P and Cu contents of leaf. Calcium content of leaf increased up to 500 g N but decreased at higher levels of N. The increase in P level (0–349 g) significantly increased the N, P and K in leaf. Calcium and Mg in leaf increased up to 131 g P, whereas higher P application decreased it. Iron content continuously decreased with increase in P application up to 262 g P/tree. Maximum Mn content was observed at 175 kg P/plant. Similarly, increase in K application (0–482 g) increased the N, P and K contents of leaf. A quadratic relationship was observed between fruit yield and nutrient applied as well as its content in leaf. Accordingly, the maximum fruit yield was obtained at 583 g N/plant 271 g P/plant and 399 g K/plant and at 1.89% N, 0.16% P and 2.34% K in the leaf. The range of nutrients associated with maximum fruit yield was 1.8–2.0% N, 0.12–0.16% P, 1.46–2.08% K, 1.13–1.69 Ca, 0.25–0.31% Mg, 266–345 µg/g Fe, 176–267 µg/g Zn and 10–13 µg/g Cu in the leaf.

Key words : guava, *Psidium guajava*, NPK effect, leaf composition, yield

Monitoring of leaf composition in fertilizer experiments and relating it to fruit yield gives valuable information for optimizing the fertilizer use. Guava (*Psidium guajava* L.) is scarcely fertilized (Pathak and Pathak 1993), and the information regarding satisfactory range of nutrients in guava leaf is very limited (Khanduja and Garg 1980). In an Alfisol under subtropical conditions 'Allahabad Safeda' guava of 5–8 years responded to N, P and K application (Ramkumar *et al.* 1995, 1996) in terms of growth, vigour, fruit yield and quality. The optimum doses of these nutrients for maximum fruit yield as well as for maximum net return were also worked out. However, leaf-nutrient status in response to applied nutrients was not evaluated, which can be used for monitoring the nutrients. Therefore an attempt was made to find out the optimum level of N, P and K fertilizers based on leaf-nutrient status *vis-a-vis* fruit yield as well as to study the effect of applied N, P and K on the contents of secondary and micro-nutrients in the leaf.

MATERIALS AND METHODS

In an experiment 3 field trials were carried out using graded levels of N 0–800 g, P 0–349 g and K 0–482 g/tree/

year on a sandy loam (Ultic Haplustalf), having pH 6.2, organic carbon 0.6%, available N 40 kg/ha, available (Bray-I) P 3 kg/ha, available K 107 kg/ha, exchangeable Ca and Mg 4.5 and 0.45 meq/100 g respectively, and the available (Morgan) S 5 µg/g, available DTPA (diethyl triamine penta acetic acid)- Fe, Mn, Zn and Cu 4.5, 2.0, 0.9 and 0.5 µg/g respectively. The experiment was laid out on 5-year-old 'Allahabad Safeda' guava trees, raised on air-layers and planted at 5 m x 5 m spacing. There were 9 treatments in each trial laid out in a stratified design, having 3 replications with 4 plants in each treatment unit. Excluding the nutrient in question, a common dose of 400 g N, 175 g P and 370 g K/tree/year. The fertilizers were applied in 2 split doses, the first in the fourth week of June and the second in the fourth week of August. The experiment commenced in 1989 and continued till 1992. The plant beds were kept free of weeds using paraquat weedicide. The leaf samples were collected during November 1991 and 1992, adopting the procedure outlined by Rao *et al.* (1988) ; and cleaned, dried, powdered and analysed adopting the methods described by Chapman and Pratt (1961). The mean values of fruit yield of 1990–91 and 1991–92 were used for regression analysis.

RESULTS AND DISCUSSION

N effect

An increase in N level (0–800 g N/plant/year) significantly affected the composition of leaf in respect of N, P, K,

¹ Senior Scientist, and ² Scientist, Central Institute of Subtropical Horticulture, Lucknow, Uttar Pradesh 226 002 and ³ Director, National Research Centre on Banana, Tiruchirapalli, Tamil Nadu 639 103

Table 1 Effect of N, P and K application (g/tree/year) on composition of leaf of 'Allahabad Safeda' guava

Treatment	Nutrient (%)					Nutrient (µg/g)			
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
<i>N (kg/plant)</i>									
0	1.61	0.15	1.38	1.34	0.33	280	198	32	14
100	1.64	0.14	1.44	1.42	0.32	264	196	33	14
200	1.66	0.14	1.46	1.58	0.31	273	212	36	13
300	1.72	0.13	1.45	1.63	0.33	314	200	35	13
400	1.79	0.13	1.47	1.70	0.31	270	162	36	13
500	1.84	0.12	1.51	1.69	0.31	266	176	36	12
600	1.88	0.12	1.52	1.55	0.31	270	207	35	13
700	1.94	0.12	1.56	1.53	0.29	281	209	33	12
800	2.02	0.11	1.57	1.39	0.29	280	219	31	11
CD ($P = 0.05$)	0.066	0.010	0.022	0.081	NS	NS	27.3	NS	1.5
<i>P (kg/plant)</i>									
0	1.63	0.12	1.35	1.37	0.29	354	249	29	13
44	1.76	0.13	1.36	1.37	0.29	341	245	26	14
87	1.84	0.13	1.39	1.47	0.32	318	255	28	12
131	1.89	0.14	1.39	1.51	0.32	309	293	31	13
175	1.94	0.14	1.41	1.44	0.29	295	315	25	13
218	1.98	0.15	1.42	1.44	0.28	273	235	22	13
262	1.97	0.15	1.43	1.33	0.28	281	231	22	11
306	2.02	0.15	1.43	1.14	0.27	366	239	24	12
349	2.09	0.16	1.46	1.13	0.25	345	267	21	13
CD ($P = 0.05$)	0.063	0.009	0.025	0.117	0.031	59.6	36.5	4.3	NS
<i>K (kg/plant)</i>									
0	1.76	0.13	1.25	1.31	0.33	282	209	34	12
60	1.83	0.14	1.43	1.17	0.31	254	193	32	12
120	1.84	0.15	1.61	1.17	0.30	267	213	30	12
181	1.90	0.16	1.66	1.14	0.31	280	197	28	12
241	1.90	0.16	1.84	1.16	0.29	267	193	31	12
301	1.91	0.15	1.91	1.27	0.29	278	180	25	12
361	1.97	0.14	1.92	1.19	0.29	284	183	28	11
422	2.01	0.14	2.06	1.28	0.28	279	203	26	11
482	2.01	0.14	2.08	1.26	0.27	269	209	27	10
CD ($P = 0.05$)	0.094	0.009	0.194	NS	NS	NS	NS	NS	1.2

Table 2 Relationship between nutrient levels (X) and fruit yield (Y) in 'Allahabad Safeda' guava

Regression equation	Coefficient of determination (R^2)	$X_{Y_{max}}$	Y_{max} (kg/tree)
<i>Nutrient application (x, g nutrient/plant/year)</i>			
$Y = 30.6816 + 0.0586 N - 0.0001 N^2$	0.96	583	47.77
$Y = 58.7300 + 0.2093 P - 0.0002 P^2$	0.97	271	54.00
$Y = 33.2098 + 0.1285 K - 0.0002 K^2$	0.97	399	45.56
<i>Nutrient content in leaf (x, % nutrient)</i>			
$Y = -654.0366 + 744.2595 N - 197.2002 N^2$	0.87	1.89	48.20
$Y = -482.0311 + 6868.502 P - 22022.39P^2$	0.89	0.16	53.52
$Y = -76.5033 + 104.0247 K - 21.6810 K^2$	0.93	2.34	48.28

Ca, Mn and Cu contents (Table 1). The contents of N (1.61–2.02%) and K (1.38–1.57%) in leaf increased continuously with increase in N level, whereas those of P (0.15–0.11%) and Cu (14–11 µg/g) showed an opposite trend. Calcium content significantly increased up to 500 g N (1.34–1.70%)

but decreased at higher levels (1.55–1.39%). Wagh and Mahajan (1988) made similar observations. Significantly lower values of Mn were observed at 400–500 g N (162–176 µg/g), whereas at other levels its content did not change much (196–219 µg/g).

P effect

The composition of leaf showed a significant effect on all the nutrients analysed except on Cu (Table 1). Nitrogen, P and K contents of leaf increased with increase in P level (1.63–2.09%, 0.12–0.16% and 1.35–1.46% respectively). Both Ca and Mg contents increased on P application up to 131 g, and further increase reduced it (1.44–1.13% and 0.32–0.25% respectively). Wagh and Mahajan (1988) observed a similar effect. The Fe content showed continuous decline (354–273 µg/g) up to 262 g P and a significant increase at higher levels. Manganese content was higher at 131–175 g P application, whereas it was lower at both lower and higher applications. Zinc content declined progressively with increase in P application above 131 g N.

K effect

An increase in K application showed significant effect only in respect of N, P, K and Cu contents of leaf (Table 1). Wagh and Mahajan (1988) also found that increase in K application significantly increased the P and K contents of leaf, but the improvement in N, Ca and Mg contents was slight. The improvement in N contents was continuous (1.76–2.10%) with increase in K level (0–482 g), but the increase was significant only above 300 g K application; the maximum increase being at 422 g (2.01%) and at 482 g (2.10%) both were at par. Phosphorus content in leaf increased at 0–241 g K application (0.13–0.16%), whereas further increase caused a reduction (0.16–0.14%); the maximum being at 482 g K. The trend of increase in K content was similar to that observed in N content in leaf. Copper content did not vary at 0–301 g K application (12 µg/g) but higher levels depressed it in leaf (11–10 µg/g); the reduction being maximum at 482 g K.

Relationship between N, P and K contents of leaf with fruit yield

A quadratic relationship was observed between N, P and K levels as well as their contents in leaf and fruit yield (Table 2). Rao *et al.* (1988) also found high correlation between N and P status of leaf sampled in November and fruit yield during winter. Similarly, Singh and Rajput (1981) found positive correlation between K status of leaf and fruit yield. According to the fit, maximum fruit yield of 48 kg/plant was obtained at 583 g N application or when the leaf contained 1.89% N, the latter being close to the values reported by Khanduja and Garg (1980) and Singh and Rajput (1981). Similarly, the corresponding maximum fruit yield of 54 kg/plant was obtained at 271 g P application or 0.16% in the leaf. In respect of P content of leaf, Rao *et al.* (1988) found that the critical value of Cate and Nelson was 0.125%,

whereas the confidence limits reported by Khanduja and Garg (1980) were 0.18–0.24%. Maximum fruit yield of 46–48 kg/plant was obtained at 399 g K/plant application or at 2.34% K in the leaf (not attained within the range of K - application treatment). Singh and Rajput (1981) reported relatively lower value of 1.25–1.47 % as the most productive range. In general, the leaf composition associated with maximum fruit yield in these trials was 1.8–2.0% of N, 0.12–0.16% of P, 1.46–2.08% of K, 1.13–1.69% of Ca, 0.25–0.31% of Mg, 266–345 µg/g of Fe, 176–267 µg/g of Mn, 21–36 µg/g of Zn and 10–13 µg/g of Cu.

The depression in the composition of leaf for some nutrients at higher levels of the fertilizers applied indicated that at 583 g N/plant associated with Y_{max} , the level of P application will have to be higher than 175 g P/plant (common dose applied in the experiment) to offset the reduction of P content in the leaf. Similarly, at 271 g P/plant a higher input of Ca, Mg and Zn is needed. At 399 g K/plant, Cu may be supplemented. On the basis of the N, P and K doses obtained in this study as related to Y_{max} , further experimentation may be taken up to arrive at the best combination of N, P and K dosage as well as the leaf-nutrient norms for high fruit yield.

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Effect of irrigation and inoculation on growth and yield of wheat (*Triticum aestivum*) and lentil (*Lens culinaris*) grown pure and in intercropping systems

AMAL GHOSH¹ and A M PUSTE²

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal 741 252

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ABSTRACT

A field experiment was conducted during 1990-91 and 1991-92 to study the performance of wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and lentil (*Lens culinaris* Medik.) after pre-sowing seed inoculation with N-fixing bacteria (*Azotobacter lipoferum* Beijerinck, comb. nov. and *Rhizobium leguminosarum* Rank respectively) grown pure and in intercropping systems under different levels of irrigation scheduled at critical growth stages of wheat. Result showed higher grain yield (3.40 tonnes/ha) due to 4 irrigations for wheat and 2 irrigations for lentil (1.16 tonnes/ha). The seed inoculation before sowing recorded 7.04-9.37% more yield of wheat and 64.28-65.35% of lentil compared with the uninoculated control. The inoculated pure crop outyielded the mixed one. However, grain yield due to wheat intercropped with lentil in 5 : 3 ratio was superior to that in 4 : 2 ratio.

Key words : bacteria, crop stand, inoculation, intercropping, irrigation

Sustainable crop production deserves more attention to improve the Indian agriculture. Degenerated soil productivity due to indiscriminate use of chemical fertilizers alone gravitates the intensity of the problem. Immense potential of biofertilizer application is considered worthwhile for sustaining the productivity of crop and soil. Since long seed inoculation for atmospheric N-fixation ensured better productivity of leguminous crops (Subba Rao 1988). Ashgar Ali *et al.* (1988) reported higher yield of lentil (*Lens culinaris* Medik) due to seed inoculation with *Rhizobium* spp. However, seed inoculation with *Azospirillum* spp was also found to increase the grain yield of wheat (*Triticum aestivum* L. emend. Fiori & Paol.) (Mertens and Hess 1984). But ground water-table depleted due to indiscriminate use is another important production factor. Khan *et al.* (1989) reported significant response of wheat to different schedules of irrigation, ensuring higher yield. But considering the limited scope of horizontal expansion, intercropping is an important crop-management system for increasing vertical crop productivity. Chander *et al.* (1989) reported increase in yield due to intercropping of wheat and lentil. However, sufficient information is not available on the impact of seed inoculation on irrigated crops of wheat and lentil in intercropping system. Keeping these points in view, the

present experiment was taken up to determine the appropriate time and frequency of irrigation for sustaining optimal moisture during crop growth and the performance of wheat and lentil after pre-sowing seed inoculation in pure and intercropping systems.

MATERIALS AND METHODS

The study was made at the university research farm at Kalyani in West Bengal during 1990-91 and 1991-92. The experimental soil was Gangetic alluvium (Entisol), containing 54.05, 25.00 and 20.50% sand, silt and clay, 0.91 and 0.03% organic carbon and total nitrogen, and 18.62 and 162.31 kg/ha available phosphorus and potassium respectively. It was alkaline in reaction (pH 7.45). 'Sonalika' wheat and 'Asha' lentil were sown @ 125 and 25 kg/ha respectively during the last week of November. Wheat was treated with liquid inoculum of *Azospirillum lipoferum* @ 8 ml/kg dry seed (100-300 million viable bacterial cells/ml carrier solution) and lentil with power inoculum of *Rhizobium leguminosarum* @ 15 g/kg dry seed (100-300 million viable bacterial cells/g carrier mass; Burton 1967) before sowing. Fertilizer nitrogen was applied in 2 equal splits each @ 25 kg N/ha as urea at sowing and 21 days after sowing, whereas phosphorus and potassium were applied basal only each @ 17.60 kg P/ha and 33.20 kg K/ha as single superphosphate and muriate of potash respectively. Depth of irrigation water applied through Parshall flume was 5 cm during each time of application. A polythene sheath placed ver-

¹ Scientist, Division of Agronomy, Central Rice Research Institute, Cuttack Orissa 753 006,

² Senior Lecturer, Department of Agronomy

tically from surface to 1 m soil depth restricted the horizontal movement of water (seepage) to the control plots. Total effective rainfall received during the period of experimentation was 87.6 and 73.3 mm respectively. The experiment was arranged in split-plot design comprising 3 levels of irrigation (main factor); 4 levels of irrigation at crown-root initiation (21 days after sowing), completion of tillering (40 days after showing), boot initiation (65 days after sowing) and milk formation (21 days after sowing) stages of wheat; 2 levels of irrigation at 21 and 65 days after sowing, and an unirrigated control. Eight different crop stands (subfactor) were pure crop of inoculated and uninoculated wheat and lentil, intercrop of inoculated wheat with inoculated and uninoculated lentil each at 4 : 2 and 5 : 3 crop-stand ratios.

RESULTS AND DISCUSSION

Effect of irrigation on wheat

Higher level of irrigation ensured better vegetative growth, improving the yield-contributing factors. Crop-growth rate due to 4 irrigations (0.12–8.78 g/m²/day) helped develop the yield attributes like more ears/m length and grains/ear, giving higher yield than 2 irrigations (crop-growth rate 0.08–7.80 g/m²/day) (Table 1). However, crops with 2 irrigations outyielded the unirrigated control (crop-growth rate — 0.06–7.06 g/m²/day).

The increased growth and subsequent development of the yield attributes was associated with an increase in accumulation and distribution of assimilates in the plant parts from tillering to the late-heading stage (Kapulnik *et al.* 1985). This was attributed to adequate soil moisture due to irrigation scheduling on the critical growth periods (Yoshida 1972). Most of the yield attributes suffered much on with-

holding irrigation from some critical growth periods before anthesis (Hassan *et al.* 1987).

Effect of seed inoculation on wheat

Pre-sowing inoculation of crop seed facilitated better N fixation into soil; thus the efficacy to provide greater amount of N to the plant ensured better crop growth. Consequently, progressive improvement in yield attributes towards ultimate grain yield was recorded due to inoculated crop in both the pure and intercrops compared with uninoculated crop. It confirms the result of Singh *et al.* (1984). The grain yield of pure stand of inoculated wheat was significantly higher than of other crop stands. While pure stand of uninoculated wheat gave yield comparable to that of intercrop of both the inoculated wheat and lentil at 5 : 3 ratio, it outyielded that of the inoculated wheat intercropped either with inoculated lentil at 4 : 2 ratio or with uninoculated lentil at 4 : 2 and 5 : 3 ratios. Pooling of the grain yield due to interaction of irrigation and inoculation was found significant. Result showed higher grain yield of inoculated wheat treated with 4 irrigations.

Higher grain yield due to inoculation was consistent with greater density of fertile ears/ m length (Kapulnik *et al.* 1983). Greater number of fertile tillers perhaps led to accumulation of mineral nutrients in the plant body, ensuring better vegetative growth (crop-growth rate 0.12–7.98 g/m²/day) (Kapulnik *et al.* 1987).

Effect of irrigation on lentil

Under rainfed situation adequate soil moisture available due to irrigation, especially during its critical growth periods, might augment the stand establishment and subse-

Table 1 Yield and yield attributes of wheat as influenced by irrigation and seed inoculation

Treatment	Plant height (cm)		Ears/m length		Ear length/(cm)		Grains/ear		1 000-grain weight (g)		Grain yield (tonnes/ha)		Pooled grain yield (tonnes/ha)
	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92	
<i>Irrigation</i>													
I ₀	64.59	65.98	40.19	42.85	5.45	6.10	14.60	15.41	36.10	40.88	2.02	2.15	2.08
I ₂	81.17	83.54	55.54	57.77	8.99	10.53	23.52	25.98	40.05	43.62	2.89	3.08	2.99
I ₄	87.92	90.32	62.27	67.73	11.10	12.88	27.64	32.11	42.11	45.40	3.34	3.45	3.40
CD (<i>P</i> = 0.05)	6.02	6.29	6.45	9.66	1.50	2.30	4.05	5.14	2.80	2.11	0.41	0.45	0.40
<i>Seed inoculation</i>													
W	63.17	64.99	62.95	65.26	8.18	9.89	23.75	27.12	40.99	45.76	2.98	3.20	3.09
W _i	70.96	72.78	68.36	71.81	8.56	9.53	25.96	30.55	42.12	46.88	3.19	3.50	3.30
W _i + L (4 : 2)	80.91	81.73	29.43	34.63	9.20	10.51	18.06	20.32	37.88	41.23	2.33	2.55	2.44
W _i + L _i (4 : 2)	90.82	92.64	45.61	54.20	10.78	11.02	20.85	25.00	38.47	43.11	2.48	2.70	2.59
W _i + L (5 : 3)	75.83	77.65	52.66	49.15	8.67	10.00	19.51	22.00	38.35	42.14	2.41	2.63	2.47
W _i + L _i (5 : 3)	87.07	88.89	56.99	61.64	9.69	12.11	23.32	24.00	39.39	43.94	2.90	3.12	3.02
CD (<i>P</i> = 0.05)	3.04	5.67	2.90	3.98	2.05	1.00	1.05	1.58	4.21	1.18	0.20	0.14	0.20

I₀, No irrigation; I₂, 2 irrigations; I₄, 4 irrigations; W, uninoculated wheat; W_i, inoculated wheat

W_i + L (4 : 2), W_i + L_i (4 : 2), Inoculated wheat with uninoculated and inoculated lentil in 4 : 2 ratio; W_i + L (5 : 3), W_i + L_i (5 : 3), inoculated wheat with uninoculated and inoculated lentil in 5 : 3 ratio

Table 2 Yield and yield attributes of lentil as influenced by irrigation and seed inoculation

Treatment	Plant height (cm)		Branches/plant		Pods/plant		Seeds/pod		1 000-seed weight (g)		Seed yield (tonnes/ha)		Pooled seed yield (tonnes/ha)
	1990-91	1991-92	1990-91	1991-92	1990-91	1991-92	1990-91	1991-92	1990-91	1991-92	1990-91	1991-92	
<i>Irrigation</i>													
I ₀	23.05	20.12	8.50	7.31	72.53	70.15	2.10	1.98	16.10	14.01	0.73	0.64	0.68
I ₂	29.50	26.62	11.90	10.99	92.88	89.98	3.10	2.71	18.43	16.56	1.21	1.10	1.16
I ₄	28.10	25.82	10.20	9.67	81.79	78.92	2.74	2.45	17.18	15.15	0.98	0.90	0.94
CD (P = 0.05)	4.46	3.84	1.54	1.29	6.98	6.52	0.59	0.38	0.82	1.11	0.23	0.19	0.20
<i>Seed inoculation</i>													
L	23.60	20.80	9.60	8.56	84.76	82.12	2.62	2.39	17.90	14.85	0.78	0.70	0.74
Li	26.80	24.62	13.50	12.46	94.11	91.47	3.02	2.60	18.60	15.89	1.28	1.15	1.28
W _i + L (4 : 2)	25.10	23.10	7.50	7.36	67.97	65.33	2.13	2.19	16.03	13.32	0.67	0.58	0.63
W _i + L _i (4 : 2)	30.10	27.60	10.80	9.76	86.62	83.96	2.65	2.40	17.55	14.84	1.05	0.96	1.01
W _i + L (5 : 3)	24.90	21.90	8.40	7.46	72.31	69.67	2.52	2.20	16.48	14.60	0.74	0.68	0.71
W _i + L _i (5 : 3)	28.60	27.10	11.40	10.36	88.19	85.55	2.93	2.50	18.16	15.53	1.16	1.04	1.10
CD (P = 0.05)	3.11	2.41	2.73	2.47	6.41	5.08	0.62	NS	0.80	1.07	0.26	0.25	0.23

I₀, No irrigation; I₂, 2 irrigations; I₄, 4 irrigations; L, uninoculated lentil; and L_i, inoculated lentil;

W_i + L (4 : 2), W_i + L_i (4 : 2), inoculated wheat with uninoculated and inoculated lentil in 4 : 2 ratio; W_i + L (5 : 3), W_i + L_i (5 : 3), inoculated wheat with uninoculated and inoculated lentil in 5 : 3 ratio

quent crop vigour of lentil considerably (Lal *et al.* 1988). However, such improvement may not be proportionate with linear increase in frequency of irrigation number. Rather judicious utilization of water through irrigation scheduling may fetch economically higher return in lieu of its indiscriminate usage. Two irrigations scheduled at branching and flowering stage, the most critical growth periods of lentil due to greater sensitivity to moisture stress, ensured better growth (crop-growth rate 0.48–8.50 g/m²/day), resulting in higher yield compared with 4 irrigations (Verma and Kalra 1983) (Table 2). Nonetheless, second and fourth irrigations were found superfluous due to their scheduling during such periods as pre- and post-flowering stages, when soil moisture might not be considered a limiting factor for final seed yield (Lal *et al.* 1988).

Effect of seed inoculation on lentil

Pre-sowing seed inoculation was more effective in influencing the crop growth rate (0.49–9.90 g/m²/day) leading to better development of yield attributes than uninoculated lentil (crop-growth rate 0.44–6.90 g/m²/day). Consequently, seed yield was significantly more due to seed inoculation at its both pure and mixed stands. While inoculated lentil gave comparable yield of pure and mixed stands, uninoculated pure stand of lentil outyielded that of its mixed stand. Interaction between irrigation and inoculation was absent in the present investigation.

Phenomenal increase in yield due to supplemental N availability can be attributed to *in-vitro* inoculation, which could have ensured greater occurrence of the specific bacterial strain (*Rhizobium leguminosarum*) with sufficient popu-

lation, as native bacterial population did not help fix the atmospheric N efficiently (efficiency observed 60–70% of the most effective strain) at the proximity of the developing roots. Several scientists explained such a potential differently like higher nitrogenase activity of nodule (Rai 1985) or higher leghaemoglobin content (Bhattacharya and Sen 1989). However, the impact of *in-vitro* bacterial inoculation was found essential where native rhizobial population was discernible either scanty, inefficient or non-functional. In contrast, uninoculated lentil devoid of this factor led to less N fixation, resulting in decreased yield.

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Effect of alley cropping of white popinac (*Leucaena latisiliqua*) on crop productivity and soil fertility under rainfed condition

ARJUN PRASAD¹ and RATAN SINGH²

Research Centre, Central Soil and Water Conservation Research and Training Institute, Kota, Rajasthan 324 002

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ABSTRACT

A field experiment was conducted during 1981–82 to 1990–91 on a clay soil to study the effect of alley cropping of white popinac [*Leucaena latisiliqua* L.] Gillis; syn *L. leucocephala* (L.) de Wit] with field crop of sorghum [*Sorghum bicolor* (L.) Moench], sorghum + pigeonpea [*Cajanus cajan* (L.) Millsp.] and pigeonpea + blackgram (*Phaseolus mungo* L.) on crop productivity and soil fertility under rainfed condition. Hedge rows of white popinac at 3.75 m spacing grown with field crops reduced the grain yield of sorghum, sorghum + pigeonpea and pigeonpea + blackgram by 12.4, 13.6 and 16.9% respectively compared with the expected reduction of 20%. But the reduction in green-fodder yield of white popinac was 65.4, 73.6 and 63.0% compared with the expected reduction of 80% sole cropping at 0.75 m spacing. The values of land-equivalent ratio of 1.20–1.22 under white popinac grown with field crops were higher than of sole cropping. White popinac with sorghum + pigeonpea intercropping gave overall higher yield advantage by producing higher biomass as grain and fodder. Field crops with white popinac also improved the soil-fertility status by increasing the organic carbon, and the available N and P content of soils.

Key words : white popinac, sorghum, pigeonpea, blackgram, advantage, organic carbon, fertility

In semi-arid climatic conditions of south-east Rajasthan more than 90% of the annual rainfall (750 mm) is received during July–September. Late onset, early recession of monsoon and long dry spell in rainy season adversely affects the crop productivity under rainfed cropping in the region. Under such a situation alley cropping may optimize biomass production in the region. White popinac [*Leucaena latisiliqua* (L.) Gillis; *L. leucocephala* (L.) de Wit] provides protein-rich fodder, increases soil fertility supplements the need of fuel and reduces soil erosion. It may be raised in various edaphic and climatic conditions along with field crops (Singh 1983). White popinac 2 m apart produced 9.1 tonnes/ha/year green fodder without adverse effect on agricultural crops (Patil and Gill 1980). Hazra (1990), Rawat and Hazra (1991) and Hazra (1994) reported the inclusion of multi-purpose tree species with field crops for their beneficial role in forage production and soil-fertility build-up. Since such an information is not available for south-east Rajasthan, an experiment was conducted to study the effect of white popinac on crop productivity and soil fertility under rainfed condition.

MATERIALS AND METHODS

The field experiment was conducted at the Research Farm of the institute at Kota during 1981–82 to 1990–91.

¹ Senior Scientist (Agronomy), ² Senior Scientist (Soils)

The soil was Typic Chromusterts (Vertisol), clay, having pH 7.6, organic carbon 0.37%, available N 163 kg/ha, P 8.5 kg/ha and K 460 kg/ha in 0–15 cm soil layer. The climate is subtropical subhumid. The experiment was laid out in randomized block design with 8 treatments replicated 3 times, having plot size 67.5 m². The treatments were : T₁, hedge of 'Hawaii Giant K8' white popinac grown at narrow row spacing at 0.75 m; T₂, white popinac hedge grown in wider row spacing at 3.75 m; T₃, T₂ + 'CSH 5' sorghum hybrid [*Sorghum bicolor* (L.) Moench]; T₄, T₂ + intercrop of sorghum + 'Local' pigeonpea [*Cajanus cajan* (L.) Millsp.] in 1 : 1 rows; T₅, T₂ + intercrop of pigeonpea + 'Type 9' blackgram (*Phaseolus mungo* L.) in 1 : 1 rows; T₆, sole sorghum; T₇, sorghum + pigeonpea (1 : 1); and T₈, pigeonpea + blackgram (1 : 1) under rainfed condition.

Seedlings of white popinac at 4 months were planted with intra-row spacing of 0.25 m in the first week of July 1981 with fertilizer dose of 20 kg N/ha and 22 kg P/ha and thereafter no fertilizer was given during the years of experiment. The crops were sown with the onset of monsoon in July each year with fertilizer dose of 75 kg N/ha and 22 kg P/ha to sorghum, 50 kg N/ha and 22 kg P/ha to sorghum + pigeonpea, and 20 kg N/ha and 22 kg P/ha to pigeonpea + blackgram. Inter-row spacing was 30 cm in each crop. Recommended plant population was maintained for each crop. White popinac was allowed to grow up to 1.25 m height and

was pruned to 0.70 m for green fodder. Blackgram was harvested during 80–85 days, sorghum 105–110 days and pigeonpea 235–245 days after sowing. Grain and fodder yields of crops were recorded. White popinac woody hedge was harvested at the end of experiment to determine air-dry weight of fuel wood. Land-equivalent ratio (LER) was calculated as suggested by Meed and Willey (1980) :

$$\text{LER} = \text{La} + \text{Lb} = (\text{Ya} / \text{Sa}) + (\text{Yb} / \text{Sb})$$

where La and Lb, the LERs for the individual crops; Ya and Lb, the individual crop yields in intercropping; and Sa and Sb, their yields as sole crops. The competitive ratio (CR) was worked out as suggested by Willey and Rao (1980) :

$$\text{CRa} = (\text{LERa} / \text{LERb}) \times (\text{Zba} / \text{Zab}) \text{ and}$$

$$\text{CRb} = (\text{LERb} / \text{LERa}) \times (\text{Zab} / \text{Zba})$$

where CRa and CRb, the CR of a and b crops; LERa and

Table 1 Year-wise yield of field crops and their sorghum grain-equivalent yield (kg/ha)

Parameter		Yield (kg/ha) in									
		1981–82	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91
T ₃	S	111	464	1 702	2 586	2 301	614	318	2 267	762	4 917
T ₄	S	137	378	1 562	1 520	2 041	526	235	2 113	567	3 972
	P	732	1 278	196	137	742	301	116	227	218	101
	E	2 170	3 928	2 106	1 901	4 102	1 362	557	2 744	1 173	4 253
T ₅	P	987	1 368	379	184	1 034	390	168	262	235	141
	B	87	284	144	85	293	335	85	217	213	556
	E	2 969	4 641	1 479	763	3 740	2 076	719	1 371	1 284	2 039
T ₆	S	228	656	1 929	2 603	2 780	807	387	3 206	896	5 278
T ₇	S	173	639	1 831	2 020	2 144	559	296	2 440	681	4 222
	P	423	1 649	315	224	1 096	428	187	291	240	147
	E	1 348	5 220	2 706	2 642	4 958	1 748	815	3 248	1 348	4 630
T ₈	P	834	1 692	390	300	1 231	496	256	312	296	160
	B	78	345	232	130	321	409	112	355	326	685
	E	2 548	5 720	1 771	1 219	4 317	2 990	1 043	1 919	1 788	2 474
SEm ±		36	36	31	114	59	45	19	114	79	401
CD (P = 0.05)		114	115	99	360	186	142	60	360	249	1 264

Details of treatments are given under Materials and Methods

S, Sorghum; P, pigeonpea; B, blackgram; E, sorghum grain-equivalent yield; SEm ± and CD (P = 0.05) for sorghum grain-equivalent yield

Market rate (Rs/kg); Sorghum 2.70; pigeonpea 7.5; blackgram 8.00

Table 2 Grain yield of field crops and fodder and fuel-wood yields of white popinac as influenced by different treatments (pooled data of 10 years)

Treatment	Grain yield (kg/ha)			Sorghum-grain-equivalent yield (kg/ha)	White popinac yield (tonnes/ha)	
	Sorghum	Pigeonpea	Black-gram		Green fodder	Fuel wood
T ₁					44.9	4.1
T ₂					19.8	1.4
T ₃	1 644 (4 112)			1 644	15.3	1.1
T ₄	1 305 (3 028)	405 (1 256)		2 430	11.9	1.2
T ₅		515 (1 364)	230 (615)	2 112	16.6	1.3
T ₆	1 877 (4 667)			1 877		
T ₇	1 478 (3 479)	500 (1 454)		2 866		
T ₈		597 (1 788)	299 (720)	2 544		
CD (P = 0.05)				276	2.5	0.4

Figures in parentheses indicate stover, stick or husk yield (kg/ha)

Details of treatments are given under Materials and Methods

LERb, the individual LER of a and b crops; and Zab and Zba, sown proportion of species 'a' (in mixture with b) and sown proportion of species 'B' (in mixture with a) respectively. Representative soil samples from 0–15 cm soil depth were collected for analysis after the end of the experiment and were analysed for organic carbon and available N, P and K as per conventional methods.

RESULTS AND DISCUSSION

Crop yield

Alley cropping of white popinac reduced the grain yield of all field crops (Table 1). On an average, the reduction in grain yield of sorghum, sorghum + pigeonpea and pigeonpea + blackgram was 12.4, 13.6 and 16.9% respectively compared with yield of their respective sole cropping (Table 2). However, the reduction in grain yield of crops was less than the expected reduction of 20% based on space occupied by each component crop with white popinac. This indicated that white popinac hedge line 3.75 m apart had no adverse effect on the productivity of associated field crops. The result confirms the findings of Korewar (1992) and Hazra (1994). Sorghum-grain-equivalent yield of sorghum + pigeonpea and pigeonpea + blackgram intercropping system decreased significantly in association with white popinac

compared with sole intercropping, whereas it was comparable in sorghum. Considering the yield advantage of white popinac green fodder in addition to grain yield under the system tried, alley cropping of white popinac with sorghum + pigeonpea proved most effective to optimize the grain and fodder production under rainfed farming. Prasad *et al.* (1989) and Singh *et al.* (1990) also observed overall advantage in yield from the system.

Green fodder of white popinac

The yields of green fodder and air-dry fodder of white popinac under different treatments increased up to 9 years of plantation (Fig 1), except in 1986 when the rainfall was inadequate. This may be ascribed to good growth and development of white popinac plants. This reduction in fodder yield was observed during tenth year due to degeneration and termite (*Odontotermes obesus* Rambur) attack. As expected, white popinac grown under narrow spacing (T_1) gave significantly higher green-fodder yield (44.9 tonnes/ha/year), followed by wider spacing (19.8 tonnes/ha/year) in their sole croppings (Table 2). The result confirms the finding of Hazra (1994). The green-fodder yield decreased by 65.4, 73.6 and 63.0% when grown with field crops of sorghum, sorghum + pigeonpea and pigeonpea + blackgram respectively compared with sole cropping of white popinac in narrow spacing (T_1). However, such a reduction in green-fodder yield was less than the expected maximum reduction of 80% based on space occupied by white popinac under the corresponding treatments (T_3 , T_4 and T_5). This further confirms that alley cropping of white popinac with field crops gave higher yield advantage. The finding corroborates those of Venkateswarlu *et al.* (1981) and Prasad *et al.* (1989).

Land-equivalent ratio and competitive ratio

The land-equivalent ratio of alley cropping with field crops of sorghum, sorghum + pigeonpea and pigeonpea + blackgram was higher compared with that of their sole cropping (Table 3). The maximum yield advantage of 18.2 and 16.7% was observed with sorghum + pigeonpea (T_4) and pigeonpea + blackgram (T_5) respectively. This shows that growing of white popinac with sorghum + pigeonpea is more beneficial, followed by that of pigeonpea + blackgram. Wani and Umrani (1993) and Hazra (1994) also reported increased crop yield and higher land-equivalent ratio under white popinac-based forage intercropping systems. White popinac had higher competitiveness than field crops, and therefore the field crops under the study are compatible without adverse effect.

Soil fertility

The soil-fertility status (Table 4) revealed an appreciable increase in organic carbon, and available N and P over the initial value under all the treatments. Alley cropping of white popinac with sorghum, sorghum + pigeonpea and pigeonpea + blackgram increased the organic carbon from its initial value of 0.37% to 0.46, 0.48 and 0.51% respec-

Table 3 Land-equivalent ratio and competition ratio as influenced by treatments (pooled data of 10 years)

Treatment	Land-equivalent ratio			Competition ratio	
	White popinac	Field crops	Total	White popinac	Field crops
T_1	1.0		1.0		
T_2	0.44		0.44		
T_3	0.35	0.88	1.23	1.98	0.51
T_4	0.26	0.87	1.13	1.53	0.66
T_5	0.37	0.83	1.20	1.23	0.45
T_6		1.00	1.00		
T_7		1.00	1.00		
T_8		1.00	1.00		

Details of treatments are given under Materials and Methods

Table 4 Soil-fertility status as influenced by different treatments

Treatment	Organic C	Available nutrient (kg/ha)		
	(%)	N	P	K
T_1	0.46	210	12.6	500
T_2	0.44	192	12.0	470
T_3	0.46	181	11.8	465
T_4	0.48	187	12.0	468
T_5	0.51	190	12.5	470
T_6	0.40	171	9.8	465
T_7	0.41	172	10.2	468
T_8	0.43	168	10.5	470
Initial status	0.37	163	8.5	460

Details of treatments are given under Materials and Methods

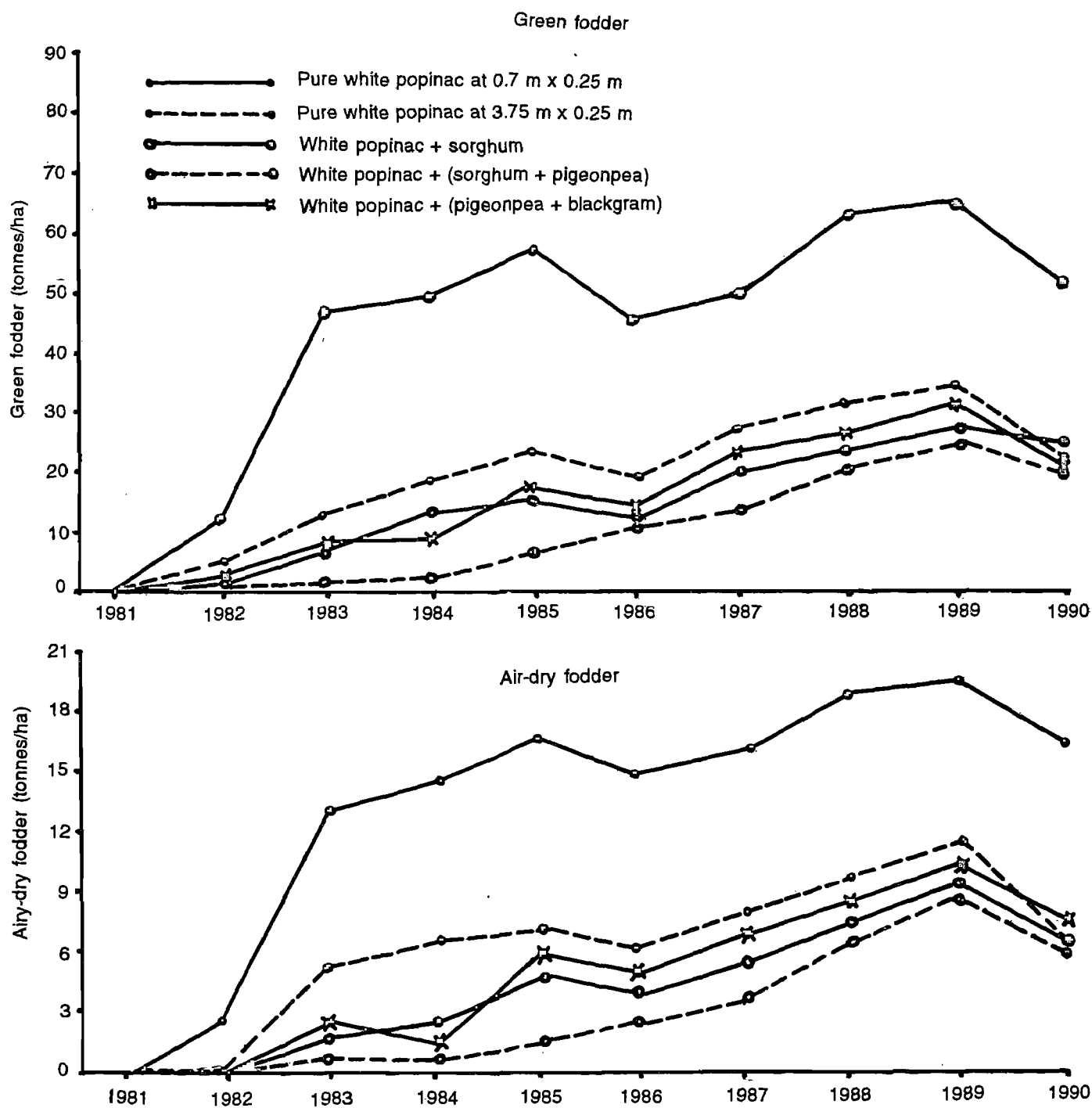


Fig 1 Fodder yield of white popinac during 1981-90

tively in 10-year period. Sole cropping of white popinac at narrow spacing (T_1) had highest beneficial effect to increase the available N by 47 kg/ha and available P by 4.1 kg/ha compared with initial status. Similarly, white popinac with sorghum (T_3), sorghum + pigeonpea (T_4) and pigeonpea + blackgram (T_5) improved the available N by 18, 24 and 27 kg/ha and available P by 3.3, 3.5 and 4.0 kg/ha respectively. Available K did not show marked variation with the treatment. Sole cropping of field crops also improved the fertil-

ity status but less than alley cropping. Improvement in organic carbon, and the available N and P status of soil under sole white popinac might be due to its higher nutrient-rich root residues in the surface, whereas in other treatments it may be ascribed to annual addition of N and P fertilizer to crops as well as crop residues. Hazra (1990) and Wani and Umrani (1993) also reported an increase in soil fertility except for K under forage intercropping system based on hedge rows of white popinac.

It was concluded that alley cropping of white popinac interspaced 3.75 m with sorghum + pigeonpea intercropping in 1 : 1 rows proved most productive to optimize food, fodder and fuel production with increased soil fertility under rainfed condition in south-east Rajasthan.

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Yield attributes of rice (*Oryza sativa*) under acidic, low-phosphorus and high-iron soils of north-eastern region of India

B D SHARMA¹ and D K HORE²

Regional Station, National Bureau of Plant Genetic Resources, Shillong, Meghalaya 793 013

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ABSTRACT

In a path analysis and correlations study of 50 diverse varieties of rice (*Oryza sativa* L.) in randomized block design experiment conducted on acidic, P-deficient and high-iron soils under lowland conditions of mid-hills of Meghalaya, panicle weight was found the most reliable single yield component. Besides, panicle length, panicles/plant and days to flower were the factors that deserve priority for selection of well-adapted superior types.

Key words : yield attributes, acid soils, rice, *Oryza sativa*

The phenotypic value of characters is dependent equally on the growing environment. The environment for field-crop plants comprises mainly the soil quality and weather factors. The performance of wetland rice (*Oryza sativa* L.) is constrained by limitation in the supply of nutrients. Plant development and yield are also severely affected by soil conditions such as acidic, alkaline or saline. The acidic soils reduce the availability of phosphorus (P_2O_5), Ca etc and toxic effects of high amounts of iron and aluminium impose further limitations (Salim and Saxena 1991). The response to all these is generally genetically controlled (Devine 1982). But the application of soil amendment is very costly. The feasible option is breeding for tolerance to low phosphorus. To achieve this objective it is imperative to identify stable yield-contributing characters before undertaking such a programme. To identify the genotypes possessing yield components least influenced by the abnormal soil conditions, the present study was undertaken involving high diverse germplasm.

MATERIALS AND METHODS

A set of 50 varieties from the western, eastern and north-eastern Himalayan hills was grown in completely randomized block design with 2 replications at Barapani farm (950 m above mean sea-level) during the rainy season (*kharif*) of 1990 and 1991. These were : 'BD 1', 'BD 2', 'BD 10', 'BD 18', 'BD 19', 'BD 38', 'BD 57', 'BD 71', 'BD 77', 'BD 93', 'BD 99', 'BD 101', 'BD 118', 'BD 133', 'BDS 7/

40', 'BDS 7/36', 'BDS 7/376', 'BDS 7/378', 'BDS 7/383', 'BDJ 1253', 'C 1003', 'C 1630', 'C 1645', 'C 1800', 'C 1875', 'C 1926', 'C 1946', 'C 1947', 'C 1964', 'C 1981', 'C 1999', 'DKH 60', 'DKH 74', 'DKH 89', 'MMH 6/6', 'MMH 6/26', 'NH 6/27', 'NH 6/42', 'NKG 160', 'NKG 1046', 'NKG 1047', 'NKG 1120', 'NKG 1154', 'NKG 1161', 'NKG 1192', 'NKG 1209', 'NKG 1211', 'P 532', 'Manipuri' and 'Gnoba'. The testing field was submerged and had suitable conditions with 15–20 kg/ha available phosphorus (P_2O_5), pH 5.05–6.50 and 150–300 ppm iron and 0.05–2.85 meq exchangeable Al(%) (personal communication), and soil was clay to grey shale. The seedlings after a month were transplanted in this field at a distance of 115 cm x 30 cm. Three rows of plants in each case were transplanted. The recommended cultural practices except fertilizer dosages were followed. Nitrogenous fertilizers were top-dressed 1 month after transplanting. Data were recorded on 5 selected and well-guarded plants for 10 quantitative characters, viz plant height (cm), tillers/plant, days to flower, panicles/plant, panicle length (cm), days to maturity, panicle weight (g), grains/panicle, 100-seed weight and grain yield/plant (g). The phenotypic and genotypic coefficients of variation, broad-sense heritability, genetic advance (Johnson *et al.* 1955), phenotypic and genotypic correlations (Robinson *et al.* 1951) and path coefficients (Dewey and Lu 1959) were calculated from the mean data.

RESULTS AND DISCUSSION

Grain yield had the maximum variation, followed by panicle weight, plant height, grains/panicle and 100-seed weight (Table 1). Heritability (broad sense) was high for days to flower, grain yield, 100-seed weight, panicle weight

¹ Senior Scientist, Regional Station, NBPGR, Phagli, Shmla, Himachal Pradesh 171 004

² Senior Scientist

Table 1 Genetic parameters of variation for various yield attributes in diverse rice varieties

Character	Plant height (cm)	Tillers/plant	Days to flower	Panicles/plant	Panicle length (cm)	Days to maturity	Panicle weight (g)	Grains/panicle	100-seed (g)	Grain yield/plant (g)
Mean	102.5	8.3	135.3	7.9	22.8	168.4	2.3	103.2	2.30	14.50
Minimum	48.5	6.6	111.0	6.4	18.6	145.0	1.5	80.1	1.50	4.25
Range										
Maximum	159.4	11.5	155.0	11.4	28.2	194.5	3.4	145.1	2.95	21.35
pcv	22.83	18.37	8.61	17.95	9.66	8.29	23.33	15.60	13.95	28.12
gcv	15.94	10.46	8.48	10.40	8.57	6.73	22.25	14.62	13.37	27.06
h ²	0.687	0.324	0.970	0.336	0.789	0.659	0.910	0.878	0.919	0.926
G A (% of mean)	22.78	1.01	23.27	0.98	3.57	18.87	0.98	29.13	0.62	7.80

Table 2 Estimates of phenotypic (P) and genotypic (G) correlation coefficients in 50 lines of rice

Character		Plant height (cm)	Tillers/plant	Days to flower	Panicles/plant	Panicle length (cm)	Days to maturity	Panicle weight (g)	Grains/panicle	100-seed weight (g)	Yield/plant (g)
Plant height	P	1.000	-0.211	0.139	-0.094	0.379**	0.116	-0.067	0.373**	-0.229	-0.040
	G	1.000	-0.248	0.145	-0.050	0.519**	0.160	-0.080	0.554**	-0.323**	-0.082
Tillers plant	P			0.155	0.896**	-0.185	0.088	-0.144	-0.074	-0.182	-0.111
	G			0.318*	0.926**	-0.368**	0.390**	-0.264	-0.222	-0.366**	-0.254
Days to flower	P				0.176	-0.130	0.886**	-0.073	0.168	-0.297*	0.049
	G				0.331*	-0.176	1.087	-0.094	0.171	-0.318**	0.040
Panicles/plant	P					-0.142	0.084	-0.132	-0.024	-0.159	-0.052
	G					-0.226	0.411**	-0.220	-0.115	-0.314*	-0.179
Panicle length (cm)	P						-0.143	0.133	0.445**	0.011	0.186
	G						-0.214	0.145	0.508**	-0.006	0.223
Days to maturity	P							-0.053	0.154	-0.309*	0.046
	G							-0.093	0.241	-0.382*	0.096
Panicle weight	P								0.460**	0.442**	0.646**
	G								0.496**	0.473**	0.695**
Grains/panicle	P									-0.127	0.283*
	G									-0.153	0.294*
100-seed weight	P										0.287*
	G										0.286*

*P = 0.05, **P = 0.01

and grains/panicle; moderate for panicle length, days to maturity and plant height and low for the remaining characters. The high genetic advance (as % of mean) was associated with high heritability for days to flower, indicating substantial contribution of additive genetic variance present for grains/panicle and days to maturity, indicating equal contribution of additive and non-additive genetic variance. The high heritability estimates for grain yield, 100-seed weight and panicle weight were not associated with high genetic advance, thus the expression of these characters can be modified through hybridization, followed by selection.

Simple correlations

Phenotypic and genotypic correlations of grain yield with panicle weight, grains/panicle, and 100-seed weight were significantly positive (Table 2). Panicle weight showed positive and highly significant correlations with grains/panicle, 100-seed weight as well as with grain yield, indicating

its importance in rice improvement. Chaubey and Richharia (1993) also reported similar result. Highly significant positive correlations at both levels were observed for panicle length with grains/panicle and plant height. The 100-grain weight showed significant negative correlation with days to flower and days to maturity but positive and highly significant with panicle weight at both the levels. At both these levels panicle number showed highly significant positive correlation with tillers/plant. Negative significant genetic correlations of 100-seed weight were observed with plant height, tillers/plant and panicles/plant. Panicle weight had also negative significant genetic correlation with tillers/plant. Genetic correlations of tillers/plant were positive and significant with days to flower and maturity but negative and significant with panicle length, panicle weight and 100-seed weight. Genotypic correlation of panicles/plant with days to maturity was positive and highly significant and negative but significant with 100-seed weight.

Table 3 Direct and indirect effects at phenotypic (P) and genotypic (G) levels in 50 lines of rice

Character		Effects via								Correlation with yield/plant (g)
		Plant height (cm)	Tillers/plant	Days to flower	Panicles/plant	Panicle length (cm)	Days to maturity	Panicle weight (g)	Grains/panicle	100-seed weight (g)
Plant height	P	-0.069	0.056	0.017	-0.025	0.071	0.003	-0.047	-0.049	0.003
	G	-0.277	0.186	0.082	-0.029	0.137	-0.052	-0.069	-0.153	0.094
Tillers/plant	P	0.015	-0.264	0.019	0.238	-0.035	0.002	-0.099	0.010	0.003
	G	0.069	-0.751	0.181	0.532	-0.097	-0.128	-0.227	0.062	0.106
Days to flower	P	-0.010	-0.041	0.126	0.047	-0.025	0.020	-0.050	-0.022	0.004
	G	-0.040	-0.239	0.568	0.191	-0.047	-0.357	-0.081	-0.047	0.092
Panicles/plant	P	0.007	-0.237	0.022	0.266	-0.027	0.002	-0.091	0.003	0.002
	G	0.014	-0.695	0.188	0.575	-0.060	-0.135	-0.189	0.032	0.091
Panicle length (cm)	P	-0.026	0.049	-0.016	-0.038	0.188	-0.003	0.092	-0.059	0.000
	G	-0.144	0.276	-0.100	-0.130	0.264	0.070	0.125	-0.141	0.002
Days to maturity	P	-0.008	-0.023	0.111	0.022	-0.027	0.023	-0.036	-0.020	0.004
	G	-0.044	-0.293	0.617	0.236	-0.057	-0.328	-0.080	-0.067	0.111
Panicle weight	P	0.005	0.038	-0.009	-0.035	0.025	-0.001	0.691	-0.061	-0.006
	G	0.022	0.199	-0.053	-0.127	0.038	0.031	0.860	-0.137	-0.137
Grains/panicle	P	-0.026	0.020	0.021	-0.006	0.084	0.004	0.318	-0.133	0.002
	G	-0.154	0.167	0.097	-0.066	0.134	-0.079	0.462	-0.277	0.044
100-seed weight	P	0.016	0.048	-0.037	-0.042	0.002	-0.007	0.305	0.017	-0.014
	G	0.090	0.275	-0.181	-0.180	-0.002	0.125	0.407	0.042	-0.290

Residual effects = 0.53 (P), 0.41 (G); * $P = 0.05$, ** $P = 0.01$

Path analysis

Among all the traits, panicle weight showed the highest direct effects on grain yield/plant, both at genotypic and phenotypic levels, and also had highly significant and positive association with grain yield (Table 3). From path analysis, Jagale *et al.* (1987) and Chaubey and Richharia (1993) concluded that panicle weight was the most important trait contributing to grain yield in rice. The present finding supports this conclusion. Panicle length, days to flower and panicle number/plant were other traits showing high positive direct effects on grain yield. But plant height, days to maturity, grains/panicle and tiller number showed negative direct effects on grain yield. Thus greater significance must be given to panicle weight, panicle length, panicles/plant and days to flower while selecting adaptable and better-yielding genotypes for acidic, low-phosphorus and high-iron soil conditions. Reddy and Nerkar (1990) reported similar observation in upland rice under irrigated condition for screening parental lines sensitive to iron chlorosis. However, caution is needed while selecting for yield components such as grains/panicle and 100-seed weight, which had positive and significant association with grain yield but showed negative direct effect on yield. Thus it can be concluded that panicle weight is the most reliable yield component that also had highly significant, positive association with grains/panicle and 100-seed weight and could be relied upon for the selec-

tion of better-yielding types suited to the adverse soil conditions indicated above.

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Diallel analysis for seed-cotton yield and its contributing traits in upland cotton (*Gossypium hirsutum*)

RANA TAUQEER AHMAD¹, IFTIKHAR AHMAD KHAN² and MOHAMMAD ZUBAIR³

University of Agriculture, Faisalabad, Pakistan

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ABSTRACT

Four upland cotton (*Gossypium hirsutum* L.) varieties were genetically analysed for gene action controlling the phenotypic expression of seed-cotton yield and its related traits. Additive type of gene action with partial dominance was observed for boll number/plant, boll weight, seed-cotton yield and seed index. Epistatic effects were also involved in the expression of all the characters except boll weight.

Key words : plant breeding, gene action, diallel analysis, interaction, upland cotton, *Gossypium hirsutum*

Upland cotton (*Gossypium hirsutum* L.) is one of the most important cash crops of Pakistan. Realizing the importance of cotton plant, the breeders in Pakistan have been making efforts to improve its yield and quality. Consequently, a large number of cotton varieties with improved characteristics were evolved and recommended for cultivation in the cotton belt of Pakistan. Since the plant improvement is a continuous process, the present study pertaining to the evaluation of gene action involved in the inheritance of various plant traits was taken up.

MATERIALS AND METHODS

The experiment consisted of a complete diallel set of crosses among 4 varieties, 'S 12', 'BP 52-63', 'Okra' and 'Bar 8'. All the varieties except 'S 12' (local) were exotic. The varieties were grown in earthen pots, in green-house during October 1990. They were ready for crossing during March-April 1991. The 16 genotypes (4 parents, 6 crosses and 6 reciprocals) were sown in the field at Faisalabad (Pakistan) during June 1991. The experiment was laid out in randomized complete block design with 3 replications. The experimental plot was 3 m single row with a distance of 75 cm between and 30 cm and within the plants respectively. Each plot comprised 10 plants. One plant was left on either side of the row as the control to avoid the border effect. At crop maturity the data on individual plant basis were recorded for boll number/plant, boll weight, seed-cotton yield and seed index. The data thus collected were statistically analysed for their variance following Steel and Torrie (1990), and for genetic analysis the diallel-cross technique developed by Hayman (1954) and Jinks (1954) was used.

¹ Research Officer, ² Professor, Department of Plant Breeding and Genetics

RESULTS AND DISCUSSION

Analysis of variance indicated significant differences among parents and their F_1 progenies for all the 4 characters (Table 1).

Bolls/plant

Additive type of gene action with partial dominance was involved in the inheritance of boll number/plant. Since the regression line deviated significantly from a unit slope, some non-allelic interactions appeared to complicate the situation. Variety 'Bar 8' seemed to have maximum dominant whereas 'BP 52-63' the recessive genes because of their closest and the farthest position from the origin respectively (Fig 1). Chaudhry (1988), Rehman *et al.* (1991) and Shah *et al.* (1993) also observed additive type of gene action in the phenotypic manifestation of this trait.

Boll weight

The variance (V_r)-(W_r) covariance graph for boll weight showed additive type of gene action with partial dominance (Fig 1). From the varietal position on the regression line, 'BP 52-63' seemed to have maximum dominant whereas 'Okra' the recessive genes for boll weight. The result

Table 1 Mean squares from analysis of variance of 4 characters of upland cotton

Source of variation	df	Bolls/plant	Boll weight	Seed-cotton	Seed index
Replications	2	9.495	0.90075	5.060	0.362
Genotypes	15	48.67**	0.9856*	744.01**	2.0529*
Error	30	6.89	0.278	16.03	0.7957

* $P = 0.05$, ** $P = 0.01$

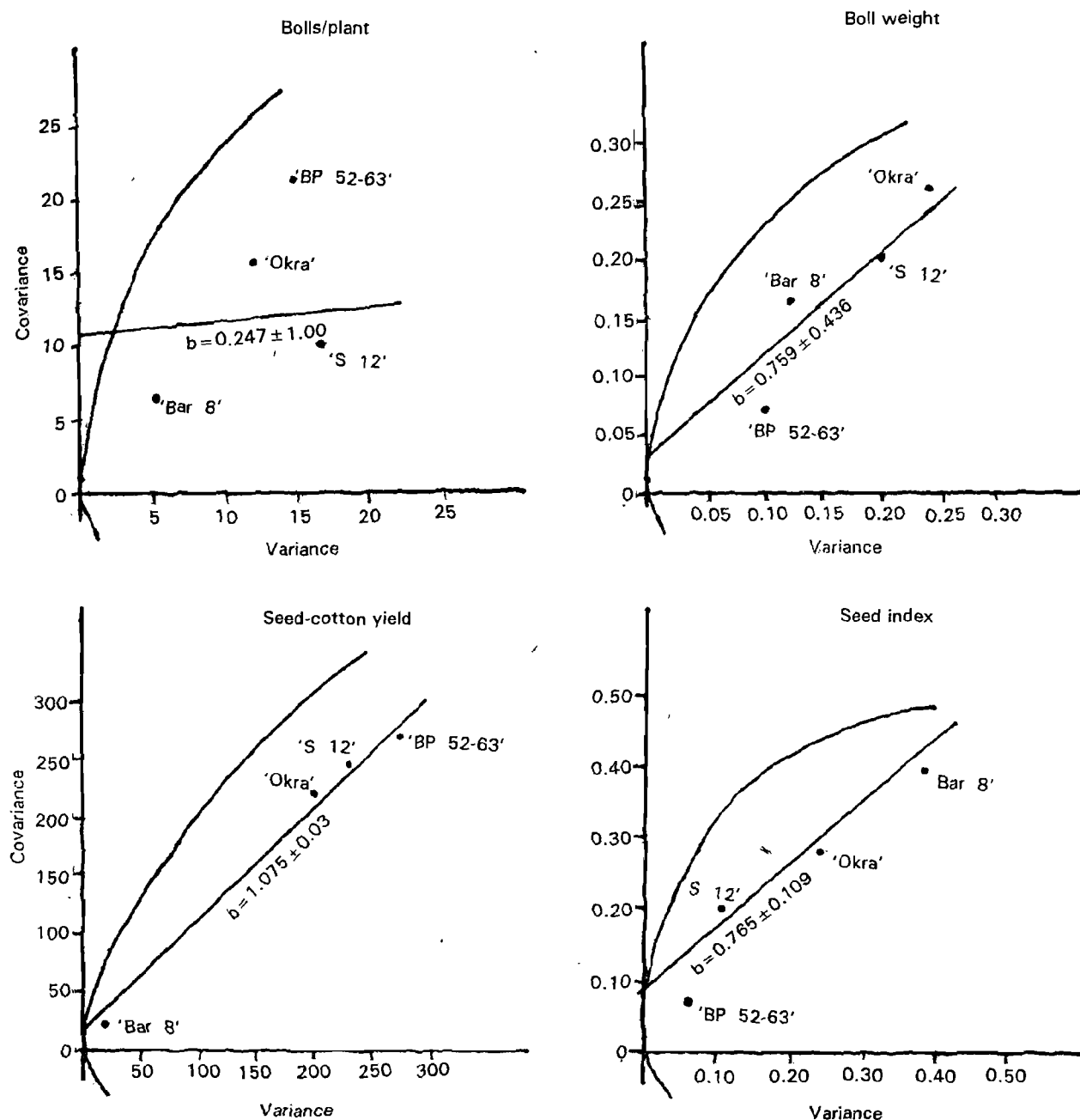


Fig 1 Mode of gene action for yield parameters in upland cotton

corroborates the findings of Zhou *et al.* (1983), Mirza and Khan (1984) and Thombre *et al.* (1987) in upland cotton.

Seed-cotton yield

The V_r - W_r graph (Fig 1) for seed-cotton yield showed the involvement of additive type of gene action in its inheritance. Some epistatic effect was also indicated, as the regression line deviated significantly from unit slope.

Variety 'Bar 8' was dominant and 'BP 52-63' recessive, being close and far from the origin in the graph respectively.

Various workers (Murtaza *et al.* 1992, Gururajan and Henry 1995, Saeed *et al.* 1996) reported additive type of gene action controlling the inheritance of seed-cotton yield.

Seed index

Additive type of gene some non-allelic interactions was observed for seed index, as the regression line deviating from a unit slope intercepted the W_r axis above the origin (Fig 1). From the position of array points on the regression line, 'BP 52-63' seemed to possess maximum dominant whereas 'Bar

8' the recessive genes for seed index. Khan (1988) and Rehman *et al.* (1988) also reported similar observations for this character in their studies.

The predominance of additive type of gene action involved in the inheritance of the characters discussed above may facilitate the possibility of their improvement through selection, but the involvement of epistatic effects in boll weight, seed-cotton yield and seed index complicates the situation.

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Water-use efficiency of soybean (*Glycine max*) using line-source oprinkler technique

PAVNEET KAUR¹ and S S HUNDAL²

Punjab Agricultural University, Ludhiana 141 004

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ABSTRACT

A field study was conducted with a line-source sprinkler technique during rainy season (*kharif*) 1995 at Ludhiana to characterize evapo-transpiration and water-use efficiency of soybean [*Glycine max* (L.) Merr.]. Four water-application treatments (I₁, I₂, I₃ and I₄) with progressively decreasing amounts of irrigation were marked in the direction perpendicular to the line source. The I₁, I₂, I₃ and I₄ treatments received differential irrigation of 187.8, 136.6, 109.1, and 57.9 mm respectively, in addition to season's monsoon rainfall. The cumulative seasonal soil-water use by the crop amounted to 661, 654, 644 and 571 mm for the I₁, I₂, I₃ and I₄ treatments respectively. The water-use efficiency of 2.48, 2.46, 2.34 and 2.46 kg/ha/mm for straw yield and 0.826, 0.716, 0.688 and 0.711 kg/ha/mm for seed yield was obtained under the I₁, I₂, I₃ and I₄ treatments respectively. A linear relationship between water use and dry-matter production existed for various treatments. Dry-matter production and seed yield were maximum in I₁, followed by I₂, I₃ and I₄ treatments (in the decreasing order).

Key words: water-use, evapo-transpiration, soybean, line source irrigation

The prevailing rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system in punjab is causing a severe strain on underground water resources due to high irrigation demand of the rainy season (*kharif*) crop. Due to continuous lowering of water-table, the water for irrigation is becoming both scarce and expensive. Under such conditions there is a need to increase the water-use efficiency of the crops. Soybean [*Glycine max* (L.) Merr.], a high-protein legume crop with less irrigation requirement, needs to be studied to evaluate crop-diversification alternatives. Soil-moisture availability exerts a great influence on water-use rate and plant growth of soybean (Doss and Thurlow 1974). Zur and Jones (1984) observed decreased water-use efficiency of soybean with progressive water stress, which was considerably lower than in well-watered plants. Daniels and Scott (1991) reported that irrigated soybean had a higher water-use efficiency than non-irrigated one. Garside *et al.* (1993) observed that leaf-water potential and stomatal conductance of water vapour was consistently greater in the frequently irrigated treatments during the period of strong evaporative demand. However, total water use was directly proportional to crop growth, indicating that the water-use efficiency did not increase by restricting the water supply. Hence the evapo-transpiration requirements and water-use

Table 1 Water depletion (mm) in 0-150 cm soil profile under different water-regime treatments for soybean

Period	Water depletion (mm)			
	I ₁	I ₂	I ₃	I ₄
9 Jun - 15 Jun	42.0	42.0	42.0	42.0
16 Jun - 17 Jun	10.4	10.4	10.4	10.4
18 Jun - 21 Jun	19.1	19.1	19.1	19.1
22 Jun - 30 Jun	16.0	16.0	17.0	16.0
1 Jul - 6 Jul	26.0	4.0	17.0	6.0
7 Jul - 13 Jul	38.3	51.7	40.0	35.0
14 Jul - 20 Jul	46.2	26.2	30.2	31.2
21 Aug - 7 Aug	61.4	61.4	61.4	61.4
8 Aug - 11 Aug	15.0	15.0	15.0	15.0
11 Aug - 17 Aug	23.0	23.0	23.0	23.0
18 Aug - 27 Aug	69.2	66.2	77.2	60.2
28 Aug - 31 Aug	15.0	15.0	15.0	15.0
1 Sep - 7 Sep	34.4	34.4	34.4	34.4
8 Sep - 14 Sep	85.3	85.3	97.3	83.3
15 Sep - 19 Sep	9.0	25.0	21.0	18.0
20 Sep - 22 Sep	43.0	35.0	39.0	20.0
23 Sep - 30 Sep	25.0	13.0	26.0	29.0
1 Oct - 3 Oct	32.0	38.4	21.0	16.0
4 Oct - 5 Oct	4.0	2.0	4.0	5.0
6 Oct - 12 Oct	17.0	15.0	14.0	5.0
13 Oct - 14 Oct	30.0	16.6	20.0	16.0
15 Oct - 19 Oct	0	0	0	0
Total water depletion	661.3	654.1	644.0	571.0

¹ Research Fellow, Department of Agronomy; and ² Senior Agrometeorologist-cum-Head, Department of Agricultural Meteorology

efficiency of soybean was evaluated under different water regimes using a line-source sprinkler technique (Hanks *et al.* 1976), which facilitates the application of variable water at different perpendicular distances from the sprinkler line.

MATERIALS AND METHODS

The field experiment was conducted on a loamy-sand soil at research farm at Ludhiana during *kharif* 1995. 'PK 416' soybean was sown on 9 June in rows 45 cm apart, using the recommended fertilizer and crop-management practices. The irrigation treatments were created with the line-source sprinkler system and the amount of water received by treatment plots was measured in calibrated catch-cans. The crop received first pre-sowing (75 mm) and second post-sowing irrigation (50 mm) at 7 days after sowing, which were equal and common to all the plots to establish the crop stand. Subsequently, 4 irrigations providing differential amounts of water to each treatment plot were given until crop maturity. The I_1 received 46.3, 50.3, 42.8 and 48.4 mm; I_2 , 40.7, 45.9, 24.4 and 25.6 mm; I_3 , 29.2, 39.5, 18.7 and 21.7 mm; and I_4 , 18.1, 18.7, 11.3 and 9.8 mm differential irrigations at 30, 104, 114 and 126 days after sowing respectively. A well-distributed and above-normal seasonal rainfall (43 mm in June, 164 mm in July, 404 mm in August and 468 mm in September) was received, but there was no rain after 8 September until crop maturity.

Soil-water retention in the 150 cm root zone was monitored with the neutron-probe regularly from sowing to crop maturity at weekly intervals, and in addition immediately before as well as 24–48 hr after each irrigation. Water-use efficiency (WUE) for seed and straw yield was calculated by using the relationship:

$$\text{WUE (kg/ha/mm)} : \frac{\text{Seed or straw (kg/ha)}}{\text{Total water-use (mm)}}$$

Total water-use during growth season of the crop was obtained by adding depletion of root-zone soil moisture between successive sampling intervals. Soil-water retention at each soil moisture sampling is given by:

$$\text{Root-zone water retention} : \sum_{i=1}^n D_i$$

where i , soil-depth interval (0–15, 15–30, 30–60, 60–90, 90–120 and 120–150 cm); and D_i , depth of water retained in the respective soil-depth intervals.

To compute soil-water use by the crop due to evapotranspiration, the difference in soil-water retention between the 2 successive samplings was taken as soil-water use by the crop, assuming that no deep drainage (or percolation) occurred below the root zone. From the date of each irrigation to the day of next soil moisture sampling the daily ac-

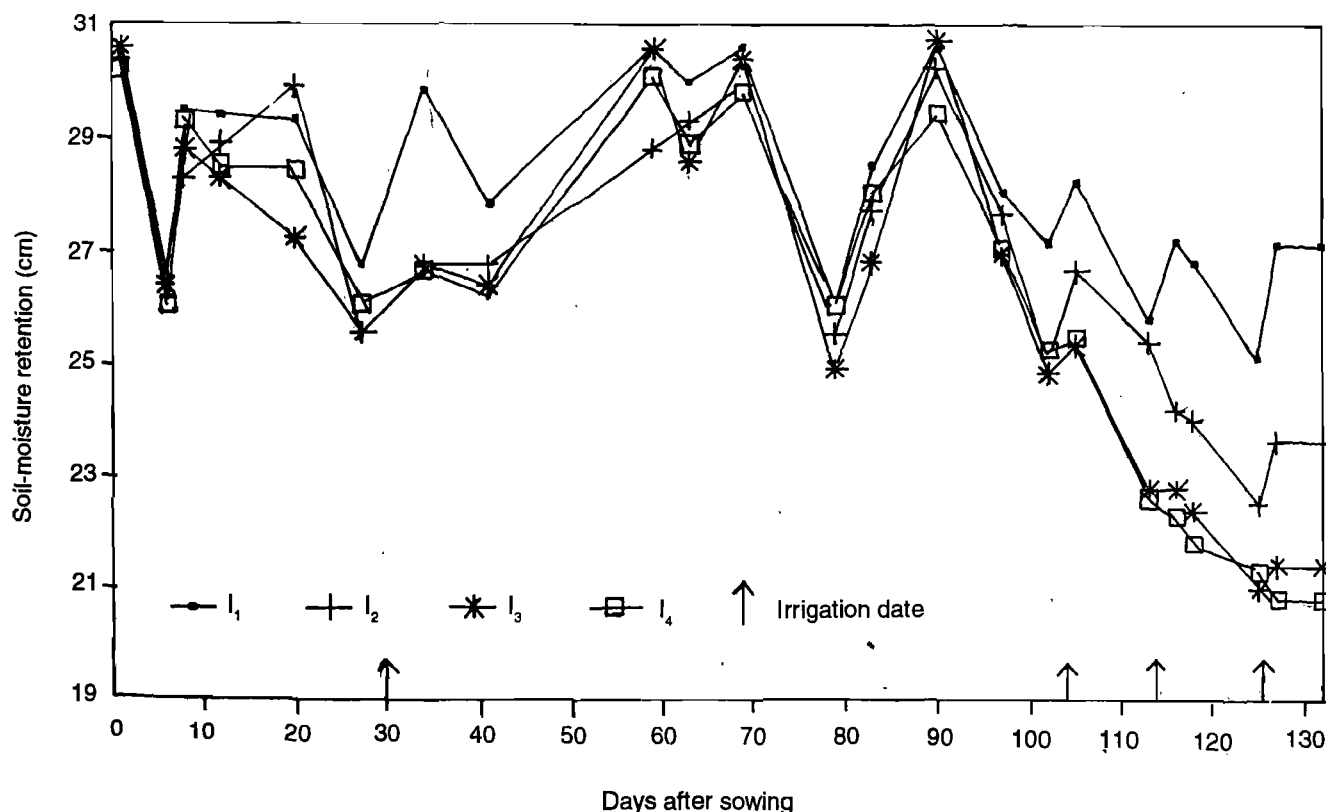


Fig 1 Soil-water retention in 0–150 cm profile in soybean under 4 water regimes

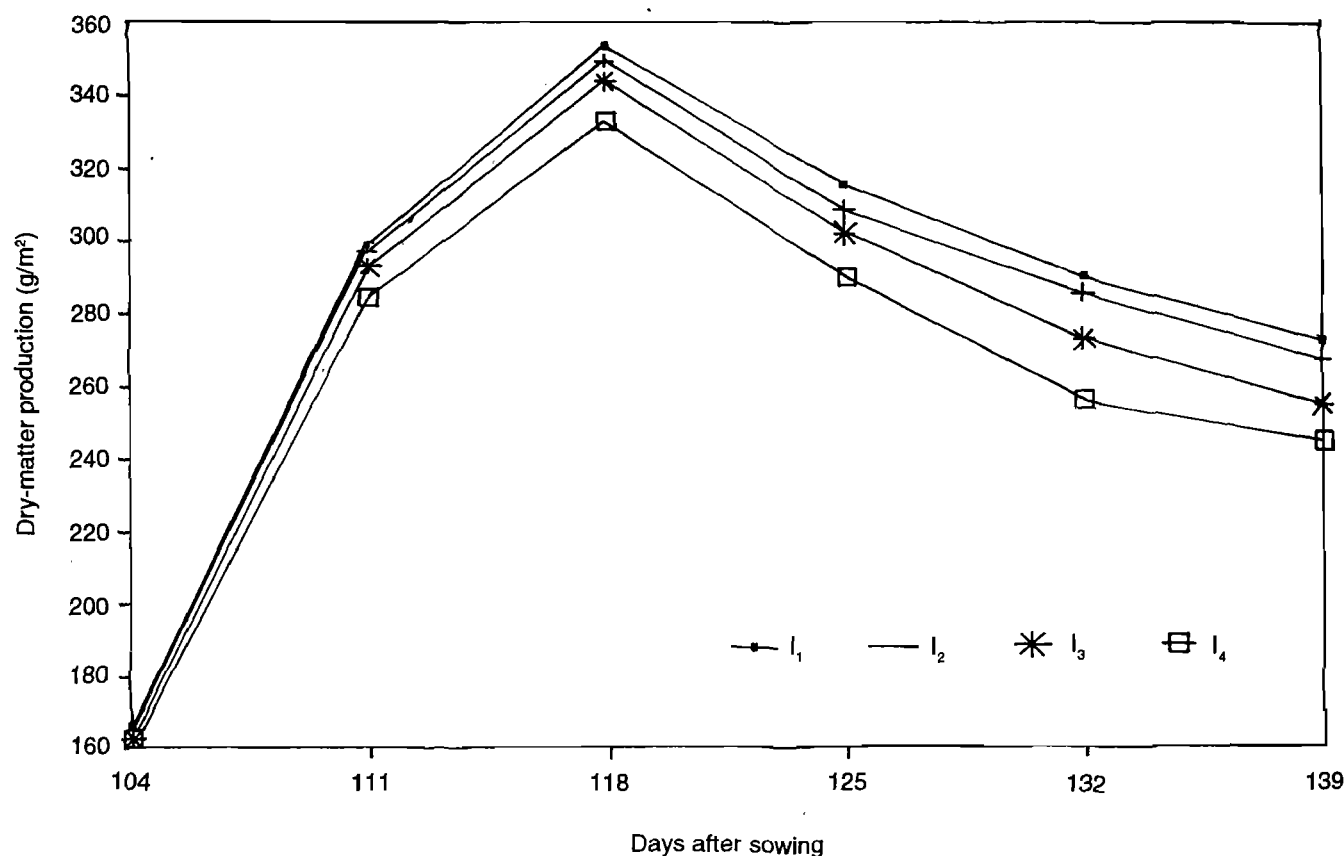


Fig 2 Total dry-matter production in soybean under 4 water regimes

tual evapo-transpiration was assumed to be 0.7–1.0 times the open-pan evaporation, based on the extent of crop-canopy development.

Dry-matter accumulation was recorded at periodic intervals starting at 27 days after sowing. Straw and grain yields were recorded at harvest from a net plot of 8 m x 1.8 m. Regression analysis was done between cumulative water-use and dry-matter accumulation.

RESULTS AND DISCUSSION

Soil-moisture retention

Since the crop was sown after a uniform pre-sowing irrigation, the water storage in the profile was similar at sowing for all the treatments (Fig 1). The soil-moisture retention was highest in the I₁ treatment after differential irrigation at 104 days after sowing. From 104 days after sowing to maturity, the profile soil-moisture retention remained highest in I₁, followed by I₂, whereas I₃ and I₄ treatments showed the lowest moisture retention. During this post-monsoon period higher amounts of water received by the I₁ provided better growth environment by avoiding moisture stress for the crop.

Soil-moisture extraction

The periodic losses in soil moisture due to evaporation and transpiration under different water-regime treatments indicate that during the growth season of the crop, the total crop water use amounted to 661, 654, 644 and 571 mm for I₁, I₂, I₃ and I₄ treatments respectively (Table 1).

Relationship between soil-moisture extraction and dry-matter production

The periodic dry-matter production showed little differences under different water regimes before applying differential irrigations (Fig 2). Rate of increase in dry-matter accumulation at initial growth stages was slow, but from 83 days after sowing onwards the increase in dry-matter accumulation was rapid up to 118 days after sowing and thereafter it declined. The decline in dry-matter accumulation at terminal stage was due to leaf senescence and consequent reduction in the rate of net photosynthesis.

With the start of differential irrigations, the dry-matter accumulation remained highest under the I₁ and lowest under the I₄ treatment. Huck *et al.* (1986) also observed that the above-ground dry-matter production and seed yield were directly dependent on the availability of water during criti-

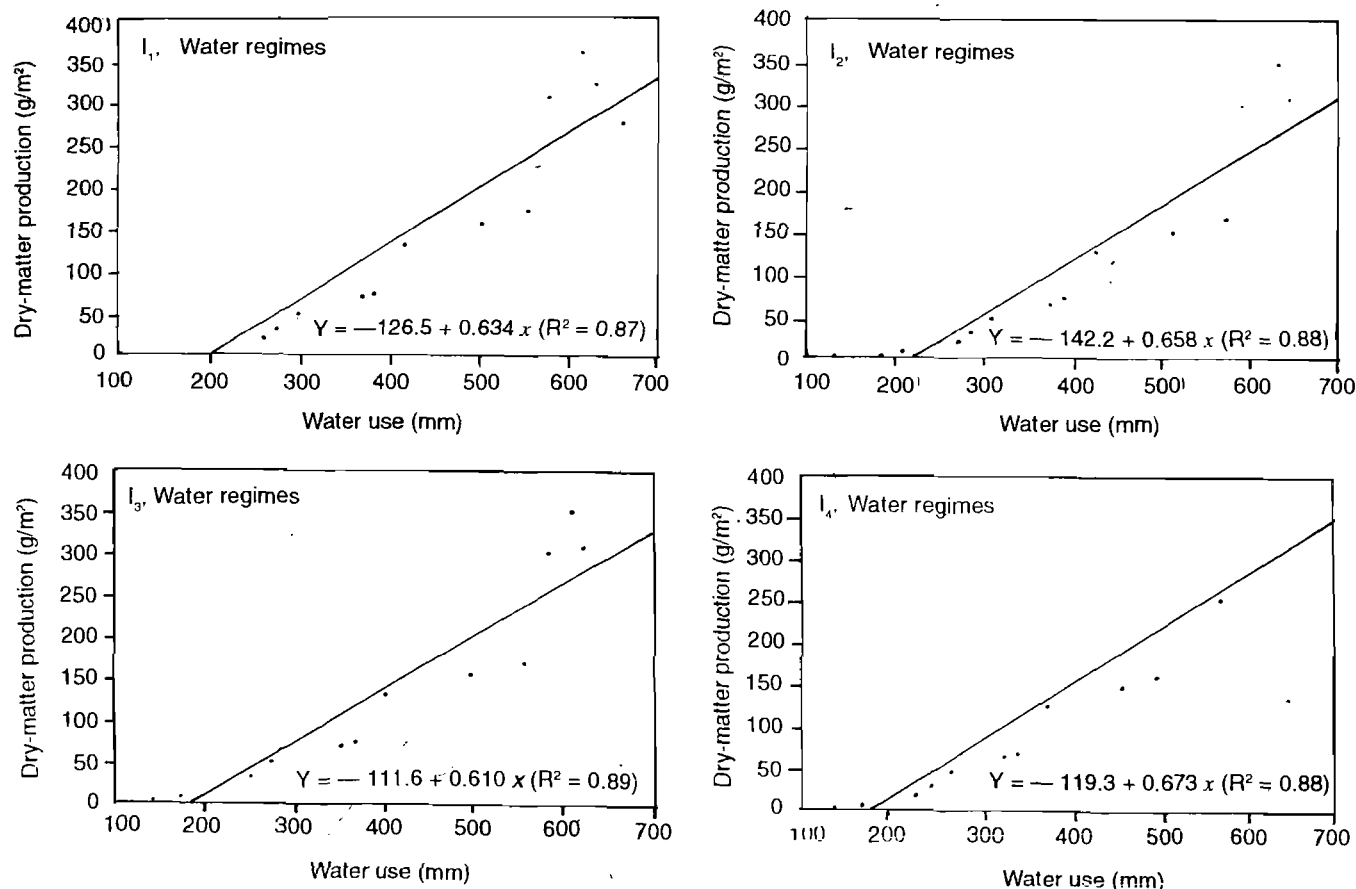


Fig 3 Relation between water use and dry-matter production of soybean under 4 water regimes

Table 2 Water-use efficiency of soybean under different water-regime treatments

Treatment	Total water use (mm)	Straw yield (kg/ha)	Seed yield (kg/ha)	Water-use efficiency (kg/ha/mm)	
				Straw	Seed
I ₁	661.3	1 640	546	2.48	0.826
I ₂	654.1	1 608	468	2.46	0.716
I ₃	644.0	1 507	443	2.34	0.688
I ₄	571.0	1 406	406	2.46	0.711

cal reproductive stages. Al-ithawi *et al.* (1980) also observed that consumptive water-use, seed yield of soybean and total dry matter increased under high soil-moisture levels when compared with low levels.

Relationship between water use and dry-matter production was observed using regression analysis (Fig 3). The linear regression equations between the 2 parameters gave good estimates ($R^2 = 0.86-0.89$) under all the treatments.

The linear regression equations developed between these parameters for the 4 water-regime treatments were:

$$I_1 : Y = -126.6 + 0.636 x (R^2 = 0.87)$$

$$I_2 : Y = -142.2 + 0.658 x (R^2 = 0.86)$$

$$I_3 : Y = -111.6 + 0.610 x (R^2 = 0.89)$$

$$I_4 : Y = -119.3 + 0.673 x (R^2 = 0.88)$$

The pooled regression for all the 4 treatments was :

$$Y = -121.6 + 0.636 x (R^2 = 0.87)$$

where Y, dry matter (g/m^2); and x, water use (mm).

Water-use efficiency

For straw yield the water-use efficiency was 2.48, 2.46, 2.34 and 2.46 kg/ha/mm for I₁, I₂, I₃, and I₄ water regimes respectively. Similarly, for seed yield it was 0.826, 0.716, 0.688 and 0.711 kg/ha/mm for I₁, I₂, I₃ and I₄ treatments respectively (Table 2).

The water-use efficiency for straw yield was nearly similar for I₁, I₂ and I₄ treatments, indicating that the efficiency of production of dry matter was comparable irrespective of the amount of water applied after the crop approached the maximum leaf-area stage. However, the trend was reverse with respect to water-use efficiency for seed yield, which was higher for I₁. This indicated that seed yield was the highest under higher amounts of differential water application. The lower water-use efficiency for the other treatments revealed that the seed yield was adversely affected by lower amounts of water availability during terminal growth stages.

Daniels and Scott (1991) also obtained higher water-use efficiency for irrigated soybean compared with non-irrigated soybean. The result of this study revealed that soybean crop may face soil-water stress in the post-rainy season, and irrigation during this period would be favourable to increase dry-matter production and seed yield.

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Production of virus-free garlic (*Allium sativum*) plants by thermotherapy and meristem-tip culture

D K GHOSH¹, Y S AHLAWAT² and M DUTTA GUPTA³

Indian Agricultural Research Institute, New Delhi 110 012

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Key words: garlic, *Allium sativum*, virus-free plants, heat therapy, meristem-tip culture

Virus indexing of garlic (*Allium sativum* L.) collections or cultivars destined for field planting in India showed the presence of viral infection in all the 115 germplasm collections tested (Ghosh and Ahlawat 1997). Bos (1982) reported similar situation in various countries. In garlic virus infections mainly produce chlorotic streaking of leaves, which varies from light-green to bright-yellow mosaic (Fig 1) and reduced bulb size. These infections are usually found in a combination with 2 or more viruses belonging to carla and poty virus groups (Walkey *et al.* 1987, Van Dijk *et al.* 1991). In India garlic crop is infected with GLV (garlic latent carla virus), SLV (shallot latent carla virus), CLV (carnation latent carla virus), OYDV (onion yellow-dwarf poty virus) and possibly an unidentified Rymo virus (Ahlawat 1974, Ghosh and Ahlawat 1997). These viruses perpetuate through vegetative propagation. This paper deals with raising virus-free plants of local selection of garlic ('Pusa Selection 10') by thermotherapy combined with meristem-tip culture.

The experiment was conducted at New Delhi during 1991–93. Modified media B5 (Gamborg *et al.* 1968) and MS (Murashige and Skoog 1962) were used for meristem-tip culture of garlic. B5 medium was supplemented with 2-isopentenyl adenine @ 0.5 mg/litre and naphthalene acetic acid (NAA) @ 0.1 mg/litre, whereas MS medium was supplemented with indole acetic acid (IAA) @ 0.1 mg/litre and kinetin @ 0.1 mg/litre.

Virus-infected cloves of 'Pusa Selection 10' garlic were subjected to thermotherapy with hot air at different temperatures and durations. Nine sets of garlic each containing 60 cloves were kept separately in a heat-therapy chamber at 35, 40 (both for 2, 4 and 6 weeks) and 45° C (1, 2 and 4 weeks). In addition, 1 untreated set was kept at room temperature (20–25°C) as the control.

Meristem was isolated aseptically under a stereomicroscope in a laminar air-flow hood with sterilized dis-

secting instruments. The cloves were separated from the bulb and their scales were removed. It was then surface sterilized in 95% ethanol for 10 min followed by dipping in sodium hypochlorite solution (5%) for 20 min, and then washed in sterilized water and dried with sterilized filter-paper. A 0.5 mm-long meristem tip was excised from each sterilized clove under the microscope and planted in separate tubes (7.5 cm x 1 cm) containing 1 ml B5 medium supplemented with 2-isopentenyl adenine (0.5 mg/litre) and NAA (0.1 mg/litre).

The meristems were subcultured 18–20 days after excision. The newly developed shoots after 30–35 days were transplanted to hormone-free B5 medium for rooting. Eight weeks after the initiation of growth, small plantlets with well-developed root system were washed in tap water to remove the material attached with roots, dried in blotting-paper and finally transferred in 10 cm pots containing sterilized soil in an insect-proof glass-house. The plants were covered with alkathene bags for 10 days to restore proper humidity. The plants thus obtained were tested for the presence of viruses by double-antibody sandwich-enzyme-linked immuno sorbent assay (DAS-ELISA) and immunosorbent electron microscopy (ISEM). The plants showing negative response in ELISA and ISEM were grown in the glass-house. The bulbs from these plants were planted and the plants were retested the following year.

Modified B5 medium provided better growth of meristems than MS (Fig 1). However, in MS-supplemented medium 19 meristems out of 50 could not survive, and the survived ones had a poor growth. Therefore subsequently all the meristem tips were grown on B5 basal medium supplemented with 2-isopentenyl adenine and NAA.

The plants were regenerated by meristem-tip culture both in the treated and control or untreated cloves. Hot-air treatment of cloves at 35, 40 and 45°C for 2, 4 and 6 weeks however did not show any significant effect on regeneration except marginal reduction with increase in temperature.

Out of 371 meristems regenerated, only 285 survived, and in the indexing of 266 plants in ISEM and ELISA only 15 were found free from viruses (carla and poty) in the first generation. However, among the plants raised from virus-free bulbs in the next season in glass-house only 3 out of 117 plants remained virus free, because of very low concen-

*Short note

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¹ Scientist, National Research Centre for Citrus, Nagpur, Maharashtra 440 010

² Professor of Virology, ³ Senior Scientist (Plant Pathology)

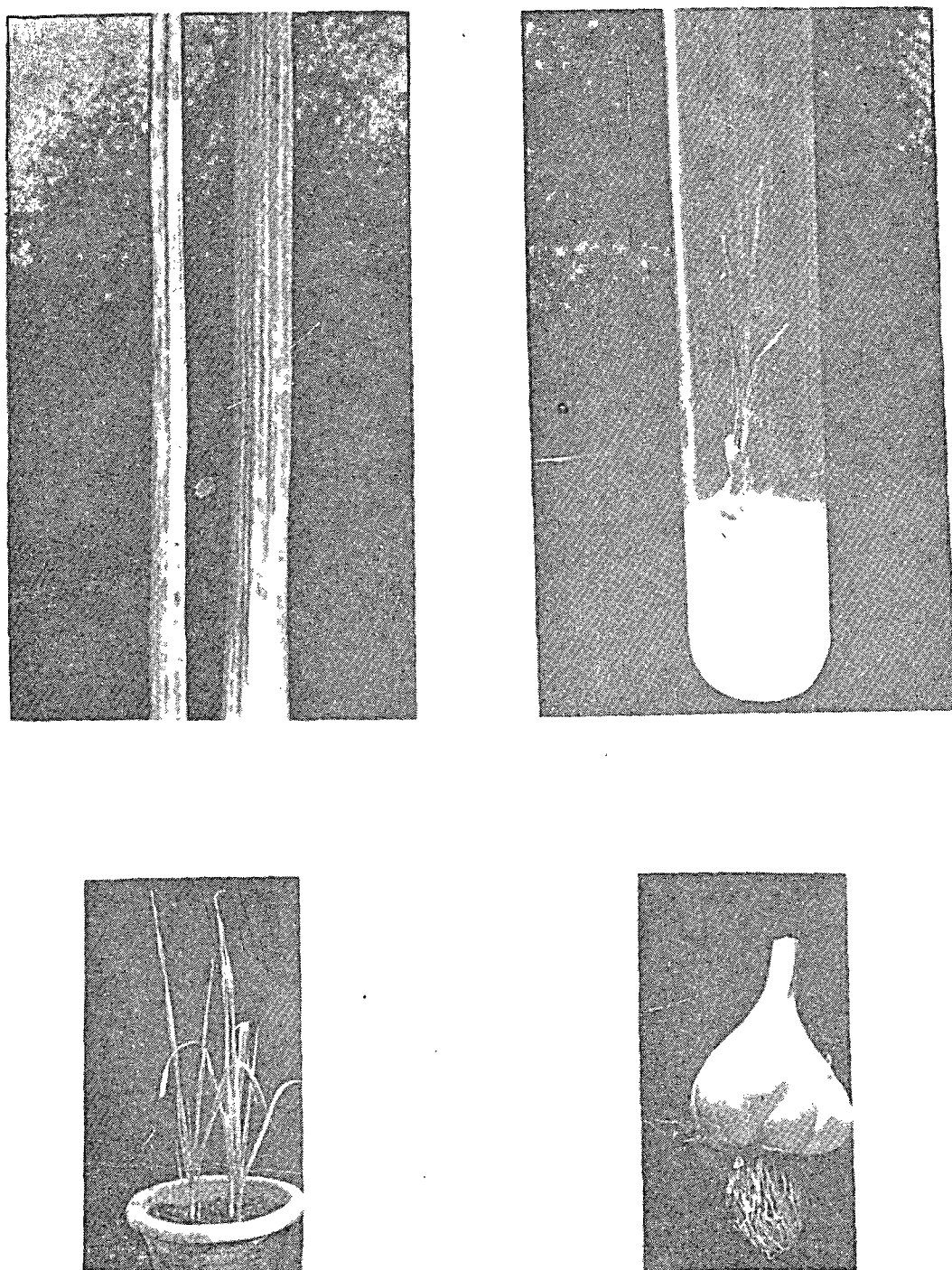


Fig 1 Effect of yellow stripe on garlic and virus-free plants produced through meristem-tip culture. *Top left*, Garlic leaves showing symptoms of yellow stripe; *top right*, development of garlic plantlets through meristem-tip culture in B5 medium; *bottom left*, garlic plants derived from meristem-tip in pot in glass-house; *bottom right*, garlic bulb obtained from plant derived from meristem tip grown in glass-house.

tration of virus in the regenerated plants. The concentration of the virus increased in the second generation to the detectable level by ELISA and ISEM.

To obtain virus-free plants many workers used shoot-tip culture (Wan and Huang 1974, Ayuso and Pena-Iglesias

1981, Pena-Iglesias and Ayuso 1982), whereas others used meristem-tip culture (Mori 1971, 1977, Havranek 1972, Wei and We 1992). However, heat therapy before shoot-tip excision or meristem-tip excision gave higher percentage of disease-free plants (Lin 1985, Ding *et al.* 1988, Conci and

Nome 1991). In our study viruses were eliminated from the infected garlic cloves of 'Pusa Selection 10' but with very little success (2.56%). In heat therapy greater mortality of explants was observed, due to the combined effect of high temperature and traumatic meristem excision. Conci and Nome (1991) expressed similar opinion. The chance of obtaining virus-free plants by meristem-tip culture depends on initial size of the meristem and the number of viruses present. We could obtain fewer virus-free plants either owing to the survival of any of the 5 viruses within the excised meristem, or due to insufficient temperature and duration of exposure of garlic cloves that could not completely inactivate the virus present in meristematic regions. Conci and Nome (1991) and Conci *et al.* (1992) also reported similar findings. In our experiment the percentage of virus-free plants was apparently less than presumed, but it certainly raises the hope of getting virus-free nucleus material for commercial exploitation.

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Increase in clonal propagation of 'Arka Neelamani' grape (*Vitis vinifera*) through induction of axillaries in *in-vitro* layering technique*

PIOUS THOMAS¹

Indian Institute of Horticultural Research, Bangalore, Karnataka 560 089

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Key words : grape, clonal propagation, *in-vitro* layering, microcutting, *Vitis vinifera*

In grapes (*Vitis vinifera* L.) the response of different cultivars to *in-vitro* multiplication varies (Barlass and Skene 1980, Boti *et al.* 1993) and this necessitates the optimization of protocols for different cultivars. Preliminary studies for the rapid propagation of the newly bred black seedless hybrid 'Arka Neelamani' showed that multiple shoot proliferation approach using N6-benzyl amino purine (BA) in the medium as reported for other genotypes (Grenan 1992) was not suitable for this one. Another approach is *in-vitro* layering, wherein the shoot tip and nodal micro cuttings produce a shoot often along with rooting, and is increasingly used now as a safe method of micropropagation (George 1993) with the advantages of easy operation, healthy plantlets, normal *ex-vitro* plants and clonal stability (Cao 1990). The main drawback is the slow rate of multiplication. The present study was taken up during 1993–95 to increase the multiplication rate through *in-vitro* layering technique with the recovery of normal plants.

Tender sprouts (5–10 cm) from cuttings of 'Arka Neelamani' planted in the glass-house after October pruning served as the source of explant for culture establishment. The sprouts were severed, leaves were trimmed off, and then each were segmented to shoot tip and single node microcuttings (1.5–2 cm) and then were treated with a disinfectant stock containing 1 000 ppm carbendazim 50% wp (Bavistin) + 1 000 ppm chlorothalonil 75% wp (Kavach) for 15 min, followed by 1 000 ppm HgCl₂ (5 min). The disinfectants contained 2 drops of Tween 20/100 ml. After 6 washings in sterile distilled water, the exposed ends were trimmed off and the micro cuttings were planted in culture tubes (15 cm x 2.5 cm) containing 15 ml medium. Murashige and Skoog (1962) medium containing 3.0% sucrose, 1.0 µM indole-3-acetic acid (IAA) and 0.1 µM gibberellic acid (GA₃) was used for culture establishment, multiplication and rooting based on preliminary results. The pH of the medium was adjusted to 5.8 and it was gelled with 0.25% phytagel. The cultures were incubated at 26 ± 2°C with 16 hr light

(20–30 µMol / m /sec) and the responding healthy ones were then subcultured at 6–8 weeks (unless mentioned otherwise).

Various approaches for induction of axillary branching namely: T₁, pruning the main shoot at 4 weeks and again the freshly formed sprouts at an interval of 2–3 weeks, leaving the basal node; T₂, extended undisturbed incubation of cultures up to 6 months; T₃, detipping the shoot at 4-week stage; or T₄, incorporation of a small quantity of BA (0.1, 0.5, or 1.0 µM) in the medium together with 1 µM IAA and 0.1 µM GA₃ were tried to increase the multiplication rate. Three types of microcutting, viz shoot tip, leaf-bearing node and leafless node, obtained from 3–4-month-old cultures in T₂ were evaluated for their growth and rooting. The experiment were laid out in completely randomized design using 6 or more replicates, depending on the number of treatments in a trial. Culture bottles (12.5 cm height, 6.5 cm diameter and 5 cm mouth with screw caps) with 50 ml medium and 4 shoot-tip or nodal microcuttings formed 1 replicate in multiplication trials and with 12 micro cuttings in rooting trials. Plantlets at 4–5 weeks with 3–5 nodes and at least 1 root were used for *ex-vitro* establishment. Sachet technique as described by Ravindra and Thomas (1995) was followed for acclimatization.

Preliminary trials using BA in the medium showed the production of multiple shoots with poor elongation at 5 µM and condensed shoots or undifferentiated growth at 10–20 µM. These shoots showed poor rooting and many failed to develop properly. Trials using IAA (1, 5 or 10 µM) and GA₃ (0.1 µM) in the medium showed best response in the form of single shoots often accompanied by rooting at 1 µM IAA, whereas the higher levels reduced the response (%). The rooting (%) was poor in the original culture (20–30%), but the culture showed gradual adaptation to the *in-vitro* environment with each subculturing reaching 80–100% rooting with 4–6 subculturing at an interval of 4–8 weeks. Pruning the *in-vitro* formed shoots helped in bulking the culture during this initial period. With the advantage of an established root system, pruning led to the development of 1–2 vigorous sprouts from the basal node. Within 3 months, 3–4 repeated prunings could be practised, giving 4–5 micro

*Short note

¹ Scientist, Division of Biotechnology

cuttings each time. Retention of more basal nodes (3–4) resulted in delayed sproutings and weaker shoots compared with that of 1 node. This observation was made when the culture was originally initiated as well as with a fresh culture.

Extended incubation for 1–6 months showed that period up to 4 months was beneficial to increase the multiplication rate through the induction of axillaries from the original shoot. The shoot on reaching the top of the bottle in 4–8 weeks got coiled beneath the cap, leading to the production of primary branches from the lower nodes followed by secondaries (Fig 1 *top, bottom*). Maximum healthy branches and multiplication rate (which comprised healthy tips from the main shoot and the axillaries and subtending leaf bearing and leafless nodes/microcuttings planted) were recorded at 4 months (Table 1). The main advantage of extended incubation was that increased multiplication was achieved at no extra cost of labour and medium inputs. Beyond 4 months the rate declined due to depletion of medium and partial drying of plants. The cultures possessed high regeneration potential on subculturing up to 4 months; afterwards this too showed a decline.

Axillary branching in the previous instance was probably due to the disruption of apical dominance by the bending and coiling of shoot tip under the cap. Detipping was practised to break the apical dominance (Hillman 1984). There were 2–6 (av 3.9) potential nodes on the main stem for sprouting after the detipping. However, in a majority (80%) of the cases, only 1 immediate lower node showed, but the practice of delayed sprouting and this practice did not offer any advantage.

Incorporation of traces of BA in the medium resulted in better growth response, axillary branching and multiplication at 0.1 μM compared with no-BA control or 0.5 μM BA, but there was no significant difference between the 3 treatments. Concentration of 1.0 μM significantly reduced the response (%), vigour of plantlets and root growth, and favoured callus formation. Growth response of the plantlets at 0, 0.1, 0.5 or 1.0 μM BA was 83.2, 95.8, 85 and 54% respectively and the multiplication rate/microcutting at 3 months in these treatments was 12, 15.9, 9.2 and 7 respectively.

Among the 3 types of micro-cuttings, shoot tip was the best, giving maximum hardenable plantlets (83.3%) in 4 weeks, followed by leaf-bearing nodes (58%) and leafless nodes (25%). Thus a multiplication system giving more shoot tips was desirable, which was achieved with simple extended incubation.

Use of sachet technique of acclimatization led to establishment of 80–100% *in-vitro* rooted plantlets. Acclimatization was completed in 4 weeks and the plants were shifted to partial shade. These plants grew 15–30 cm tall with 6–10 expanded leaves in 2 months from *ex-vitro* planting, and they showed distichous phyllotaxy and tendril production, which are considered adult characteristics (Mullins *et al.*



Fig 1 *In vitro* propagation in 'Arka Neelamani' grape. *Top*, 4-month-old culture; *bottom*, 3-month old plantlets showing axillaries

Table 1 Effect of extended incubation on induction of axillary branches and yield of shoot tip and nodal microcuttings in grape

Incubation period (months)	Healthy axillary branches (no)		Recovery per cultured microcutting				
	Primary	Secondary	st*	lbn (average)	ln	Total	
						Range	(Average)
1	0.16	0	0.95	1.78	0.17	0-6	3.20
2	1.58	0.25	2.58	4.25	0.50	2-10	6.50
3	3.54	1.33	5.50	4.16	1.25	2-30	10.75
4	5.16	8.0	11.5	7.25	2.25	4-41	21.03
5	3.58	5.83	10.1	6.33	1.50	0-51	17.90
6	1.50	2.33	3.41	2.00	1.00	0-8	6.16
SEm $\pm$	0.655	0.964	1.05	0.97	0.46		1.48
CD ($P=0.05$)	1.89	2.784	3.04	2.82	1.34		4.28

st, Shoot tip lbn, leaf-bearing node; ln, leafless node

*Includes tips from original shoot

1979). Thus the plants raised through *in-vitro* layering did not have a long juvenile phase. The plants put in the field are showing normal growth.

In conclusion, pruning *in vitro* was beneficial for rapid bulking of a new culture. Extended incubation up to 3-4 months in culture bottles increased the multiplication rate through natural induction of axillaries at no extra cost of major inputs, whereas detipping *in vitro* or use of traces of BA in the medium was not effective in promotion of axillaries.

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Varietal performance under soil-moisture stress in sugarcane (*Saccharum officinarum*)

R P SRIVASTAVA¹, D JOHARI² and G P SINGH³

Uttar Pradesh Council of Sugarcane Research, Shahjahanpur 242 001

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Key words : sugarcane, moisture stress, varietal performance

Abnormal water balance in plant tissues reduces the growth and yield of sugarcane (*Saccharum officinarum* L.) (Bowyer and Bowen 1970, Singh and Singh 1974, Srivastava *et al.* 1994, 1995, 1996, Singh and Reddy 1976). In northern India, particularly in Uttar Pradesh, sugarcane plants are grown under extreme drought conditions caused by high temperature, low relative humidity and high soil-moisture stress. Among the 3 types of drought, i.e. soil, atmospheric and physiological, the first is most important, which is caused by a deficiency of soil moisture.

Sugarcane requires large amount of water for maximum growth and development of the plant. The water required by this crop to produce 1 g dry substance ranges from 148 to 300 g under different situations (Singh 1974). The most dominant factor governing the drought resistance is variety (Dillewijn 1952). It was considered desirable to find out the drought resistance of promising varieties for general cultivation. Therefore an experiment was planned with 12 promising sugarcane varieties at Shahjahanpur.

The field experiment was conducted with 12 sugarcane varieties, viz 'CoS 88216', 'CoS 86218', 'CoS 88230', 'CoS 767', 'CoS 8436', 'CoS 90265', 'CoS 90269', 'CoS 91269', 'CoS 92254', 'CoS 92263' and 'UP 39' along with 'Co 1148' as the standard, in spring planting season at the research farm at Shahjahanpur. Three-budded setts were planted in the cropping years 1992–93 (7 February 1992), 1993–94 (9 February 1993) and 1994–95 (9 February 1994) in strip-plot design 90 cm apart, replicated thrice. Urea was given in 2 equal splits @ 150 kg N/ha, half basal and the rest half before the onset of monsoon. Two moisture levels, i.e. normal (5 irrigations) and deficient (2 irrigations), were maintained during the formative stage of the crop. The 2 common irrigations were given to both normal and deficient plots, which were completed up to 60 days of the crop by maintaining 50% available soil moisture. In normal plots 40–50% available soil moisture was kept by giving 3 more irrigations, whereas the deficient plot did not receive any more till the break of monsoon. The intensity of drought was measured at 15–20% available soil moisture during the moisture-stress phase. The crop was harvested in March for

estimation of yield. Sucrose (%) in juice was analysed at 10 months by following traditional laboratory method.

Pooled data of 3 years (1992–93, 1993–94 and 1994–95) (Table 1) indicated that the effect of moisture stress on different attributes was statistically significant. Moisture levels affected the shoot population significantly, but the magnitude differed with the variety. The deficient moisture level produced less shoots than normal soil moisture. Although the varieties could not show a significant response at the same level of moisture, 'CoS 91269' gave higher number at shoots at both normal and deficient irrigational levels compared with the other varieties. Interactions between variety $\times$ treatment and treatment $\times$ variety were statistically not significant in respect of shoot production. Production of millable canes was adversely affected due to moisture stress. Varieties responded significantly in respect of millable cane number due to moisture level. Although interactions between variety $\times$ treatment and treatment $\times$ variety were non-significant, the maximum number of millable canes were found in 'CoS 91269' followed by 'Co 1148', 'CoS 767' and 'CoS 92263' under normal soil-moisture condition, but under deficient moisture condition varieties 'CoS 91269', 'CoS 767' and 'CoS 92263' gave higher number. A significant depression in cane yield was noted due to soil-moisture tension. Higher cane yield was recorded in 'CoS 91269', 'Co 1148', 'CoS 92263' and 'CoS 767' under normal soil moisture, and in 'CoS 91269', 'CoS 92263', 'UP 39', 'Co 1148' and 'CoS 88216' under deficient soil moisture. Mean data of both the moisture levels showed that varieties 'CoS 91269', 'CoS 767' and 'CoS 92263' responded better than the standard variety 'Co 1148' for cane yield. 'CoS 91269' and 'CoS 92263' proved superior to 'Co 1148' and 'CoS 767', which are in extensive cultivation. Sucrose (%) in juice at 10 months also decreased significantly under soil-moisture tension, which varied with the varieties.

Singh and Srivastava (1992) and Srivastava *et al.* (1994, 1995, 1996) reported the utility of stomatal studies for the selection of drought-resistant varieties, whereas Chen and Bor (1966) and Dwivedi (1988) laid stress on osmotic potential and epidermal bulliform cell for rapid selection of varieties for deficient moisture condition. Gill (1962) reported that tillering and growth were adversely affected by deficient irrigation, but the cane quality was not greatly

*Short note

^{1,2} Scientific Officer, Department of Physiology, ³ Director

Table 1 Effect of moisture stress on growth, yield and juice quality of sugarcane (pooled data of 1992–93, 1993–94 and 1994–95)

Variety	Shoots/ha (‘000/ha)		Mean	Millable cane (‘000/ha)		Mean	Cane yield (tonnes/ha)		Mean	Sucrose (%) in juice at 10 months		Mean	Reduction in cane yield (%)
	N	D		N	D		N	D		N	D		
‘CoS 88216’	162.6	134.8	148.7	87.8	70.7	79.3	64.8	55.2	60.0	16.44	16.40	16.42	14.81
‘CoS 88230’	146.3	114.1	130.2	72.2	56.3	64.3	60.7	48.9	54.8	17.58	17.32	17.45	19.44
‘CoS 86218’	148.1	116.3	132.2	72.2	58.5	65.4	52.2	41.5	46.9	16.91	16.76	16.84	20.50
‘CoS 90265’	150.0	122.6	136.3	72.6	57.0	64.8	51.1	43.7	47.4	17.64	17.24	17.44	14.48
‘CoS 90269’	150.7	124.4	137.6	78.9	67.0	73.0	57.3	47.4	52.4	16.96	16.90	16.93	17.28
‘Co 1148’	173.0	140.4	156.7	89.3	73.0	81.2	68.9	56.7	62.8	16.68	16.41	16.55	17.71
‘CoS 767’	161.5	135.6	148.6	88.1	77.8	83.0	67.0	61.5	64.3	16.98	16.52	16.75	8.21
‘CoS 8436’	134.4	111.9	123.2	67.8	53.3	60.6	63.0	48.9	56.0	17.75	17.39	17.57	22.38
‘CoS 91269’	175.6	154.4	165.0	94.8	83.0	88.9	73.3	61.5	67.4	16.51	15.97	16.24	16.10
‘CoS 92254’	140.0	126.3	133.2	71.1	61.5	66.3	53.3	47.0	50.2	17.11	16.91	17.01	11.82
‘CoS 92263’	161.5	140.0	150.8	88.1	76.7	82.4	68.9	59.2	64.1	16.05	15.84	15.95	14.08
‘UP 39’	166.3	138.5	152.4	81.1	74.1	77.6	65.2	57.0	61.1	16.22	16.11	16.17	12.58
Mean		155.8	129.9		80.3	67.4		62.14	52.4		16.90	16.65	
CD ($P = 0.05$)													
Irrigation			30.22			9.59			6.10			0.30	
Varieties			12.17			6.27			6.20			0.39	
Interaction V x I			NS										

influenced by the frequency of irrigation. Singh *et al.* (1984) observed that the third order of tillering required irrigation necessarily. Omission of this irrigation reduced the sugarcane yield. In the present study deficient plots did not receive more than 2 irrigations during formative stage, leading to decrease in cane yield in those plots. Mongelard (1969) emphasized that for the selection of drought-resistant varieties plant-water potential is more important than soil-water potential for growth of cane. Srivastava *et al.* (1994) stated that ‘CoS 91269’, ‘CoS 92263’ ‘CoS 767’ and ‘UP 39’ possessed higher stomatal diffusive resistance and leaf-water potential along with lower reduction of leaf-water potential during their stress phase, proving that these are relatively tolerant to moisture stress. Hence the varieties ‘CoS 91269’, ‘CoS 92263’ and ‘UP 39’ are similar to the standard varieties like ‘Co 1148’ and ‘CoS 767’ in respect of cane yield under moisture-deficient condition. Hence these 3 varieties could be of value for cultivation under water-stressed agricultural situation.

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Effect of foliar application of sulphur on yield and uptake by sugarcane (*Saccharum officinarum*)

N P S YADUVANSHI¹ and D V YADAV²

Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh 22 6002

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Key words : sugarcane, sulphur, foliar application, *Saccharum officinarum*

Sulphur, the fourth major nutrient after nitrogen, phosphorus and potassium (Tandon 1991), is becoming deficient in Indian soils. The areas of its deficiency are wide-spread because of the use of relatively sulphur-free fertilizer and intensive cropping system. Its deficiency leads to chlorosis and development of anthocyanin pigment in the affected leaves, which can be corrected by foliar application of sulphur (Dutt 1962). Yaduvanshi and Yadav (1995) reported highest yield of sugarcane (*Saccharum officinarum* L.) with 60 kg S/ha through basal application. The present study was undertaken to assess the effect of different times and levels of sulphur on growth, yield and uptake of sulphur by sugarcane.

In a field experiment 'Co 1148' sugarcane was planted during 1988 on sandy-loam soil (Ustifluvents) to study the effect of sulphur dose, viz S₀, without sulphur; S₁, 30 kg S/ha through 2 % ammonium sulphate solution; and S₂, 60 kg S/ha through 4 % ammonium sulphate solution mixed with

1% urea solution, at an interval of 15 days during different stages of crop foliage. Subsequently first ratoon was raised during 1989. For each S dose the treatments were : T₁, 4 sprays at tillering ; T₂, 4 sprays at elongation ; T₃, 2 sprays each at tillering and elongation; and T₄, 1 spray at tillering combined with 3 sprays at elongation. Treatment combinations used were: S₀T₁, S₀T₂, S₀T₃, S₀T₄, S₁T₁, S₁T₂, S₁T₃, S₁T₄, S₂T₁, S₂T₂, S₂T₃ and S₂T₄. Nitrogen @ 50 kg/ha, P @ 26.4 kg/ha and K @ 33.2 kg/ha were applied through urea, diammonium phosphate and muriate of potash respectively, below the setts. The remaining nitrogen was applied at tillering and at different times of foliar sprays, keeping nitrogen doses uniform in all the treatments including that added by ammonium sulphate. The soil had pH (1 : 2) 7.6, electrical conductivity (1 : 2) 0.48 ds/m, available SO₄-S 24.6 kg/ha, available N 221 kg/ha and Olsen's P 37.0 kg/ha. Plant samples were taken 15 days after spraying at tillering and elongation stages and at harvest. Sulphur in the leaves 3–6 from the top of the plant up to the elongation stage and in the whole plant tops at harvest were determined by digestion in a mixture of HNO₃ and HClO₄ and also by turbidity method (Jackson 1978).

Application of S increased the plant height and girth of millable cane significantly compared with the control.

*Short note

¹ Scientist Senior Scale, Division of Soil and Crop Production, Central Soil Salinity Research Institute, Karnal, Haryana 132 001

² Head and Principal Scientist, Division of Soil Science and Agricultural Chemistry

Table 1 Effect of level and time of S spray on yield (tonnes/ha) of sugarcane plant and ratoon crop

Treatment	Time of spray									
	Plant					Ratoon				
	T ₁	T ₂	T ₃	T ₄	Mean	T ₁	T ₂	T ₃	T ₄	Mean
S (kg/ha)										
0	58.3	58.6	57.7	58.1	58.2	58.9	60.3	61.3	60.5	60.3
30	59.7	60.3	62.7	67.1	62.5	68.9	72.1	74.7	76.3	73.0
60	59.1	61.6	62.9	69.0	63.2	72.1	73.9	75.8	76.8	74.7
Mean	59.0	60.2	61.1	64.7		66.6	68.8	70.6	71.2	
CD (P = 0.05)										
Level of sulphur (S)		3.69				1.83				
Time of spray (T)		3.20				1.59				
Interaction (S x T)		NS				NS				

T₁, 4 sprays at tillering stage; T₂, 4 sprays at elongation stage; T₃, 2 sprays each at tillering and elongation stage; T₄, 1 spray at tillering and 3 sprays at elongation stage

Table 2 Effect of level and time of S spray on S content (%) and uptake (kg/ha) at harvest of sugarcane (mean values of plant and ratoon crops)

Treatment	Time of spray									
	S content					S uptake				
	T ₁	T ₂	T ₃	T ₄	Mean	T ₁	T ₂	T ₃	T ₄	Mean
<i>S</i> (kg/ha)										
0	0.09	0.12	0.10	0.11	0.11	19.9	25.9	22.1	23.9	23.0
30	0.19	0.18	0.21	0.20	0.20	43.4	52.5	50.1	54.1	50.2
60	0.17	0.20	0.21	0.23	0.20	40.1	54.9	52.3	58.2	51.4
Mean	0.15	0.18	0.17	0.18		34.5	44.1	41.7	45.4	
CD (<i>P</i> = 0.05)										
Level of sulphur (S)		0.023				8.22				
Time of spray (T)		NS				7.12				
Interaction (S × T)		NS				NS				

Details of treatments are given with table 1

Maximum height and girth of millable cane were observed in S₂T₄ treatment, which was at par with S₁T₄. The variation in the time of spray was non-significant in both the characters but the interaction was significant. Application of S increased the yield of plant and ratoon cane by 15.7 and 21.5% respectively compared with the control (Table 1). The S₁T₄ treatment gave the cane yield in plant and ratoon crops more or less equal to that of S₂T₄. Therefore foliar application of 60 kg S/ha gave the maximum cane yield of plant and ratoon cane (69.0 and 78.8 tonnes/ha).

Foliar application of sulphur through S₁T₄ or S₂T₄ gave yield of millable cane equal to that of treatments S₁T₃ or S₂T₃ but superior to spray of sulphur at tillering stage (Table 1). The increase in yield under sulphur spray was due to continuous supply of S and N through ammonium sulphate and 1% urea solution up to elongation stage, as also found beneficial for higher productivity of sugarcane crop.

Sulphur content and uptake of plant at harvest of crop increased significantly with foliar application of S up to 60 kg/ha compared with the control (Table 2). Maximum sulphur content and uptake in leaves was found at harvest in the treatment S₂T₄. Sulphur removal at different stages of sugarcane from 60 kg S/ha was approximately equal to that from 30 kg S/ha.

The foliar application of sulphur increased the cane yield of plant and ratoon by 15.7 and 21.5% respectively compared with the control. More or less equal cane yield obtained under 30 kg S/ha and 60 kg S/ha indicates that the use of 30 kg S/ha through 2% solution of ammonium sulphate with 1% urea applied as foliar spray 2 each at tillering and elongation stage (S₁T₃) could increase the sugarcane production.

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Effect of seed *Rhizobium*-pelleting treatment and addition of coir-pith compost to soil on growth and nodulation of fluoride-water-irrigated blackgram (*Phaseolus mungo*)

M JAYAKUMAR¹, MEYINI² and R VELMURUGAN³

Virudhunagar Hindu Nadar's Senthikumara Nadar College, Virudhunagar, Tamil Nadu 626 001

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Key words : blackgram, fluoride water, nodulation, *Rhizobium*, pelletting, coir-pith compost

Fluoride above a threshold concentration may be toxic to plants, affecting photosynthesis, respiration and other plant processes (Treshow 1970, McCune and Weinstein 1971), leading to chlorosis and necrosis (Khoshoo 1988). Dahiya and Laura (1988) reported that salinity-induced reduction in yield and retardation in growth of crop plants can be overcome by the application of inorganic and organic substances. Jayakumar *et al.* (1992, 1993) observed the effect of biogas slurry in alleviating the effect of salinity stress in sunflower (*Helianthus annuus* L.) plants. Increased growth and yield due to the application of coir-pith compost were observed in groundnut (*Arachis hypogaea* L.) (Mayalagu 1983) and maize (*Zea mays* L.) (Jayakumar and Shaji 1993). This study was undertaken to compare the effect of seed-pelleting treatment with *Rhizobium phaseoli* and coir-pith compost application to the soil on growth and nodulation of blackgram (*Phaseolus mungo* L.) plants irrigated with fluoride water.

The experiment was conducted during May–July 1992 at Virudhunagar. It comprised 4 treatments with 3 replication. 'T 9' blackgram was grown in pots (30 cm diameter, 45 cm height) containing red soil, clay and farmyard manure (containing 1% N, 1% P and 1.3% K on dry-weight basis) in 2 : 1 : 1 ratio. The plants were irrigated throughout with sodium fluoride water (10 ppm), which was equivalent to that of the ground-water containing fluoride used for irrigation at Periyamayakipuram village near Virudhunagar.

The plants irrigated with sodium fluoride water were segregated into 4 sets and were given the following treatments, viz T₁, plants raised from uninoculated seeds (the control); T₂, plants raised from uninoculated seeds with 250 g/pot coir-pith compost (equivalent to 10 tonnes/ha); T₃, plants raised from *Rhizobium*-inoculated and lime-pretreated seeds and T₄, plants raised from *Rhizobium*-

inoculated and lime-pretreated with 250 g/pot coir-pith compost (equivalent to 10 tonnes/ha).

Coir-pith compost was applied to plants twice during their growth period (at 15 and 45 days after sowing). Mushroom [*Pleurotus sajor caju* (Fr.) Sing] spawn and urea were used for the preparation of coir-pith compost (Theradimani and Marimuthu 1993). The plants were grown in the botanical garden-house at Virudhunagar. The day temperature was 32 ± 2°C and the night temperature was 27 ± 1°C. Natural photoperiod was 10–12 hr. *Rhizobium phaseoli* strain was maintained and cultured by yeast-extract mannitol agar medium (Subba Rao 1977). The pellets were prepared following the method of Roughley *et al.* (1966). The seeds were inoculated with *R. phaseoli* and were allowed to dry in shade. After drying, the seeds were pretreated with lime. These seeds were used for raising the plants in the third and fourth treatments.

All the plants in each treatment were uprooted at 65 days after sowing. Shoot length, root length, dry weight of plant and nodule number were recorded on 15 plants in each treatment. Total nitrate (Cataldo *et al.* 1975), leghaemoglobin (Wilson and Reisnauer 1963) and nitrate-reductase activity (Jaworski 1971) were determined at 15 days after sowing, and thereafter at an interval of 10 days till flower initiation. Leghaemoglobin content of nodule was measured initially at 25 days after sowing. The third leaf of each plant was used for all the experiments.

The plants irrigated with fluoride water had minimum shoot length, root length, dry weight and less nodules than those receiving coir-pith compost or those raised from *Rhizobium* inoculated and lime-pelleted seeds. Application of coir-pith compost increased the root length more than the shoot length compared with the control. *Rhizobium* inoculation with lime-seed pelletting increased both root and shoot lengths by 45%. The effect increased when both the treatments were combined (Table 1).

Dry weight of plants irrigated with fluoride water increased by 36% after application of coir-pith compost. Treatments T₃ and T₄ increased the dry weight of plants by 120 and 165% respectively.

The number of nodules/plant showed a significant correlation with the dry weight of plants. The nodule number/

* Short note

¹ Senior Lecturer, Research Department of Botany; ² Senior Lecturer, Research, Department of Botany, Thiagarajar College, Madurai, Tamil Nadu 625 009; ³ Post-graduate Assistant (Botany), Kshatriya Vidhyasala Matriculation School, Sulakarai, Virudhunagar, Tamil Nadu 626 002

Table 1 Effect of coir-pith compost and lime-seed pelleting on growth and yield components of blackgram plants irrigated with sodium fluoride water

Treatment	Shoot length (cm)	Root length (cm)	Dry weight of plants (g/plant)	Nodules
T ₁	16.0 ± 1.0	12.5 ± 1.1	9.1 ± 1.0	14.0 ± 1.2
T ₂	17.0 ± 1.1	16.3 ± 1.2	12.4 ± 1.0	23.0 ± 2.0
T ₃	23.1 ± 2.0	18.0 ± 1.7	19.2 ± 2.0	28.0 ± 1.9
T ₄	24.8 ± 1.9	23.1 ± 2.0	24.2 ± 1.9	33.0 ± 3.1
CD (P=0.05)	5.45	2.58	10.5	12.0

Values are mean ± SE of 3 replicates
Details of treatments are given in text

Table 2 Effect of coir-pith compost and lime-seed pelleting on some biochemical parameters in 65-day-old *Phaseolus mungo* plants irrigated with sodium fluoride water

Parameter	T ₁	T ₂	T ₃	T ₄
Total nitrate (mg/g fresh weight)	0.65 ± 0.03	0.89 ± 0.03	1.51 ± 0.09	1.69 ± 0.1
Nodule leghaemoglobin content (mg/g fresh weight)	0.75 ± 0.04	1.10 ± 0.09	2.20 ± 0.1	2.60 ± 0.08
Nitrate reductase activity (mg NO ₂ produced/hr/g fresh weight)	0.65 ± 0.05	0.89 ± 0.06	1.51 ± 0.09	1.69 ± 0.1

Values are mean ± SE of 3 replicates each with 15 plants

plant increased by 64, 100 and 135% in T₂, T₃ and T₄ treatments respectively compared with the control.

The coir-pith compost makes available the soil phosphorus, potassium and stimulates the activity of potassium nodule (Sprent 1979). Coir-pith compost improved the growth of blackgram plants by increasing the rate and activity of nodulation. But the superior performance of plants raised from *Rhizobium*-inoculated lime-pelleted seeds indicated that plant growth depends mainly on the survival of rhizobia under adverse soil conditions, as ensured by lime pelleting (Iswaran *et al.* 1970). In the combined treatment the coir-pith compost and *Rhizobium* inoculation with lime pelleting produced synergistic effect on nodulation and plant growth.

As *Rhizobium* improves the plant growth under stress (Nataraju *et al.* 1990), ensuring its survival by pelleting the seeds with lime and increasing the availability of potassium and phosphorus by coir-pith compost led to an increase in total nitrate content, nodule leghaemoglobin content and leaf-nitrate reductase activity, resulting in increased dry weight and subsequent yield of plants (Table 2).

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Effect of phosphorus level and cutting interval on forage yield and quality of berseem (*Trifolium alexandrinum*)*

S K MANI¹ and M M SINGH²

Narendra Deva University of Agriculture and Technology, Faizabad, Uttar Pradesh 224 229

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Key words : forage berseem, phosphorus, cutting interval

Berseem (*Trifolium alexandrinum* Juslen.) provides succulent, palatable and energy-rich nutritious forage to livestock. Being a leguminous crop it fulfills its major part of nitrogen requirement through root nodules by biological nitrogen fixation. Hence an adequate supply of phosphorus is necessary for proper root development and functioning of the nodules. Keshikar *et al.* (1991), Rana *et al.* (1991), Sheoram *et al.* (1992) and Taneja *et al.* (1994) observed good response of berseem to P fertilization. Cutting management is also an important management practice for obtaining high forage yield of better quality. Lal (1981), Singh *et al.* (1982) and Desai *et al.* (1986) highlighted that forage yield and quality of berseem was greatly influenced by the cutting-management practices. The present investigation was therefore carried out to find out the optimum dose of phosphorus and duration of subsequent cut for increasing the forage yield and quality of berseem.

*Short note

Based on complete information of M Sc (Agriculture) thesis submitted to Narendra Deva University of Agriculture and Technology, Faizabad, Uttar Pradesh in 1995 (unpublished)

¹M Sc (Agriculture) student, ²Agronomist (Forage Crops), Department of Agronomy

The experiment was conducted during winter season of 1993-94 at Faizabad with 4 P levels (0, 17.6, 35.2 and 52.6 kg P/ha) and 3 cutting intervals (20, 30 and 40 days after first cut) in randomized block design with 4 replications. The soil was sandy loam with pH 7.6, low available N (232 kg/ha) and P (7.8 kg/ha) and high K (242 kg/ha). 'Wardan' berseem was sown on 12 November 1993 using 25 kg seed/ha by broadcast method under wet condition. The crop was fertilized with a common dose of 25 kg N/ha along with P as per treatment. Urea and single superphosphate were taken as the source of N and P respectively and the entire quantity of both the fertilizers was applied basal before puddling. The first cutting was taken at 60 days after sowing and subsequently as per the cutting schedule. Five, 4 and 3 cuttings were obtained at intervals of 20, 30 and 40 days respectively. Observations were recorded at each cut and the average data on plant height, number of shoots/plant, number of nodules/plant and dry root weight were taken, and nutrient uptake and the yields of green forage, dry matter and crude protein were pooled.

Plant height, number of shoots/plant, number of nodules/plant, dry-root weight/plant, N and P uptake, green-forage, and the dry-matter and crude-protein yields increased

Table 1. Plant height, shoots, nodules, dry root weight, nutrient uptake, green forage, dry matter and crude protein of berseem as affected by P and cutting interval

Treatment	Plant height (cm)	Shoots/plant	Nodules/plant	Dry-root weight (g/plant)	N uptake (kg/ha)	P uptake (kg/ha)	Green-forage yield (tonnes/ha)	Dry-matter yield (tonnes/ha)	Crude-protein yield (tonnes/ha)
<i>P (kg/ha)</i>									
Control	48.0	4.4	159.5	0.33	156.0	6.9	46.6	6.4	0.9
17.6	60.8	6.0	179.8	0.48	278.6	13.2	65.2	10.4	1.7
35.2	76.8	6.9	208.1	0.59	536.5	28.8	82.6	15.4	3.3
52.8	78.1	7.3	210.0	0.61	538.2	29.0	83.2	15.5	3.3
CD (<i>P</i> = 0.05)	2.0	1.8	2.3	0.02	12.5	1.5	1.8	0.3	0.1
<i>Cutting interval (days)</i>									
20	63.2	4.3	189.1	0.49	340.0	17.2	61.7	10.3	2.0
30	66.1	5.9	189.1	0.50	404.0	21.2	74.1	12.8	2.5
40	68.5	8.2	189.0	0.50	398.2	20.3	72.4	12.7	2.4
CD (<i>P</i> = 0.05)	1.8	1.6	NS	NS	10.8	1.3	1.5	0.2	0.1

significantly with increase in P level from 0 to 35.2 kg/ha. Further increase in P level did not show significant response. The result confirms the findings of Rana *et al.* (1991), Sheoram *et al.* (1992) and Taneja *et al.* (1994). The increase in growth characters, forage and crude protein yields in this investigation might be attributed to increased cell expansion and various metabolic processes because of greater nutrient uptake in the presence of abundant available phosphorus.

The plots harvested at an interval of 40 days produced significantly taller plants with more number of shoots/plant. Cutting interval did not influence the number of nodules/plant and dry-root weight/plant significantly. Maximum uptake of N and P and yield of crude protein were recorded under cutting interval of 30 days. Significantly higher green-forage yield was recorded when the crop was harvested at interval of 30 days compared with that of 40 and 20 days, but for dry-matter yield the cutting intervals of 30 and 40 days (both at par) were better than of 20 days (Table 1). The interval of 30 days in subsequent cuts gave 16.6 and 19.6% more green-forage and dry-matter yields compared with that of 20 days. The result confirms the findings of Lal (1981) and Desai *et al.* (1986). The increase in growth and yield of green forage, dry matter and crude protein under 40-day interval might be attributed to increased photosynthetic activity of the plant, because of longer duration.

It was concluded that for getting higher quantity and quality of forage, berseem crop should be fertilized with

35.2 kg P/ha and subsequent cuttings should be made at an interval of 30 days.

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Phenotypic-stability analysis in open-pollinated varieties of sunflower (*Helianthus annuus*) in north-west and south-east Madhya Pradesh during winter season

V S KANDALKAR¹

Zonal Agricultural Research Station, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Khargone, Madhya Pradesh 451 001

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Key words : sunflower, phenotypic analysis, open pollinated, winter season

Sunflower (*Helianthus annuus* L.) as an edible oilseed crop has recently become popular in Madhya Pradesh. Since it is a day-neutral plant, farmers of rice (*Oryza sativa* L.)-growing areas in south-east Satpura valley of Madhya Pradesh have started growing sunflower after harvesting rainy-season rice during late winter season under assured irrigation. Therefore identification of stable high-yielding varieties of sunflower for this region is important. Various open-pollinated sunflower varieties have been developed and tested for yield performance during rainy season (Singh and Yadav 1983, Shinde *et al.* 1992). But such an information for winter season is meagre. Therefore an attempt was made to study the stability parameters of sunflower during winter season.

Open-pollinated promising genotypes of sunflower were tested for stability of kernel-yield performance under different dates of sowing at 2 locations during winter season of 1991-92 at Kailash Nath Katju College of Agriculture, Mandsaur (16 genotypes) and of 1992-93 at Regional Agricultural Research Station, Waraseoni (15 genotypes). The environments were 4 sowing dates, ie 15 October, 1 and 20 November and 12 December, at Mandsaur (north-west Madhya Pradesh) and 6 sowing dates, ie 1, 10 and 20 De-

cember and 1, 15 and 30 January, at Waraseoni (south-east Madhya Pradesh). The crop was raised in randomized complete block design with 3 replications. The plot size for each entry was 2.4 m x 3 m. The plants were spaced 60 cm and 15 cm apart between rows and within row respectively. Observations were recorded on 5 randomly selected plants in each plot. Since error variances were homogeneous for different sowing dates and heterogeneous for different locations, the stability analysis was made for sowing dates separately for each location using the method of Eberhart and Russell (1966).

Pooled analysis of variance revealed highly significant variation for kernel yield among the varieties and in the sowing dates at both the locations (Table 1). Significant variances due to genotypes x environments (linear) interaction and pooled deviation indicated that both predictable and unpredictable components of genotype (G) x environments (E) interaction were important in the expression of kernel yield of sunflower at Mandsaur, whereas only unpredictable components of G x E interaction were important at Waraseoni. Thus prediction of yield performance of individual genotypes should be made on stability parameters. Seetharam *et al.* (1980), Singh and Yadav (1983) and Shinde *et al.* (1992) also reported similar findings.

All the 3 stability parameters ($\bar{X}$, S^2_{di} and b_i) estimated for kernel yields showed that the mean kernel yield of 'Surya', 'GAU SUF-14', 'GAU SUF 15', 'EC 68414' and

*Short note

¹ Junior Scientist (Plant Breeding and Genetics), All India Co-ordinated Project on Pulses

Table 1 Pooled analysis of variance for kernal yield of sunflower

Source of variation	Mean squares			
	df	Mandsaur (1991-92)	df	Waraseoni (1992-93)
Varieties (V)	15	77.69**	14	100.10**
Environment (E)	3	116.31**	5	627.29**
V x E interaction	45	25.66**	70	40.96**
E + (V x E)	48	33.41**	75	79.54**
E (linear)	1	348.95**	1	3136.24**
V x E (linear) interaction	15	46.10**	14	26.91
Pooled deviation	32	14.47**	60	40.93**
Pooled error	64	6.61	84	15.02

** P = 0.01

Table 2 Stability parameters for kernel yield of sunflower at different dates and locations of sowing during winter season in Madhya Pradesh

Variety	Mandsaur (1991-92)				Waraseoni (1992-93)			
	$\bar{X}$	b_i	$\bar{S}^2_{di}$	Days to maturity	$\bar{X}$	b_i	$\bar{S}^2_{di}$	Days to maturity
'TNAU SUF 7'	16.17	0.8891	6.52	105	12.56	0.4721	43.38**	95
'EC 68415'	15.72	-0.1763	-4.34	114				
'TNAU SUF 8'	21.15	-0.3404	10.78	115	15.19	1.1563	20.68	115
'SS 104'	18.54	1.8558	-5.72	100	13.23	0.7650	26.74	102
'GAU SUF 15'	24.41	3.3802**	11.40	110	15.31	1.1188	53.22**	95
'JN SUF 2'	15.64	-0.7302	10.91	116	7.00	1.0376	5.81	105
'AK SF 9'	17.14	0.4247	-4.56	112	11.65	0.7045	5.29	100
'GAU SUF 14'	26.24	2.1022	26.66**	108	12.09	0.5415	34.66**	112
'Latur 917'	20.99	3.6719**	15.85**	115	12.44	1.1956	43.43**	118
'GAU SUF 13'	15.82	0.0809	40.79**	116	14.11	1.2450	9.93	115
'JN SUF 3'	14.60	-0.0737	-2.73	100	12.08	0.7203	21.09	102
'KBSP 3'	13.66	-0.3862	-1.45	116	11.37	1.3642	53.38**	115
'JN SUF 1'	16.60	0.4006	-1.67	95	19.55	1.0401	9.46	97
'Surya'	27.70	2.8966**	39.28**	103	11.82	0.9892	134.84**	97
'Morden'	15.86	-0.5554	4.88	90	12.43	0.7746	19.23	90
'EC 68414'	23.23	2.5597	5.81	112	13.34	1.8762	20.14	114
Location mean	18.97				12.81			
CD ($P = 0.05$)	2.57				3.02			

** $P = 0.01$

'TNAU SUF 8' were significantly higher than of other varieties (Table 2). Regression coefficient (b_i) values of 'GAU SUF-15', 'Latur 917' and 'Surya' were significantly more than 1 (>1), indicating that these varieties were responsive for yield performance in the better environments. Deviation from regression ($\bar{S}^2_{di}$) values of 'GAU SUF-14', 'Latur 917', 'GAU SUF-13' and 'Surya' were significant, indicating unstable performance under different dates of sowing. The remaining 12 varieties showed non-significant regression coefficient and $\bar{S}^2_{di}$ values. While considering mean performance along with b_i and $\bar{S}^2_{di}$ values, 'EC 68414' and 'TNAU SUF-8' under late-maturing group and 'Morden' and 'JN SUF-1' under early maturing group showed stable average response at different dates of sowing with higher yield performance.

Varieties 'JN SUF-1' followed by 'GAU SUF-15', 'TNAU SUF-8', 'GAU SUF-13', 'EC 68414', 'SS 104', 'TNAU SUF-7', 'Latur 917' and 'Morden' recorded significantly higher yield than other varieties at Waraseoni. Regression coefficient (b_i) values of all the varieties were not significantly different from 1, indicating that all the varieties showed average response at different dates of sowing. Significant $\bar{S}^2_{di}$ values of 'TNAU SUF-7', 'GAU SUF-15', 'GAU SUF-14', 'Latur 917', 'KBSP 3' and 'Surya' indicated unstable performance under different dates of sowing and their performance cannot be predicted. The remaining 9 varieties showed non-significant $\bar{S}^2_{di}$ values. While considering all 3 stability

parameters, 'Morden' and 'JN SUF-1' in early-maturing group and 'TNAU SUF-8', 'GAU SUF-13' and 'EC 68414' in late-maturing group showed average response and stability under different dates of sowing with higher yield performance.

Results at both the locations revealed that all the varieties showed average response at different dates of sowing, except 'GAU SUF-15', 'Latur 917' and 'Surya' which were highly responsive under better (normal) sowing dates. 'TNAU SUF-8', 'EC 68414', 'Morden' and 'JN SUF-1' showed stable higher mean performance and average response at different dates of sowing during winter season at both the locations. Thus these promising varieties could be used for general cultivation or may be utilized in future breeding programme.

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Persistence of carbendazim on apple (*Malus domestica*) in Himachal Pradesh*

I D SHARMA¹, A NATH² and S K PATYAL³

Dr Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh 173 230

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Key words : apple, carbendazim, persistence

Apple (*Malus domestica* Borkh) is grown in Himachal Pradesh at altitudes of 1 200 –2' 700 m above mean sea-level. It is attacked by a number of diseases including apple scab [*Venturia inaequalis* (Cke)], cankers [*Botryobasidium salmonicolor* (Berk. & Br.) Venkatrayan] and *Nectria galligena* Bres. collar rot [*Phytophthora cactorum* (Lebert & Cohn) Schroet] and crown galls [*Agrobacterium tumefaciens* (E.F.Sm & Towns) Conn.]. These are controlled by spraying the plants with a number of fungicides, out of which carbendazim (2-methoxy carbomyl benzimidazole) is commonly used on fruits up to fruit-development stage and sometimes even close to harvest (YSPUHF, Nauni 1992). Since there are no proper data on its persistence in apple for fixing the spraying-time intervals for effective control of these diseases as well as for ensuring safety to consumer from its residual intake, an experiment was conducted at 2 locations to study the persistence of carbendazim in fruits and leaves.

To study the persistence of carbendazim in apple, an experiment was conducted in 2 orchards at Rajgarh (1 950 m above mean sea-level) and Nauni (1 200 m above mean sea-level), located in Sirmour and Solan districts of Himachal Pradesh respectively. Carbendazim was sprayed twice on

apple close to harvest at an interval of 20 days, commencing from 7 June 1994 at Nauni and 14 June 1994 at Rajgarh. Two concentrations, ie 1.5 kg and 3.0 kg ai/ha, of carbendazim, each replicated thrice were sprayed to run-off by a foot-sprayer. Details of application and sampling techniques were as described by Sharma and Nath (1992).

Total rainfall of about 280 and 222 mm was recorded at Rajgarh and Nauni respectively during experimental period. The range of minimum and maximum temperatures was 14.4–21.9°C and 19.8–28.0°C and that of relative humidity was 66.5 and 86.2% at the respective locations.

The residues of carbendazim were determined as per the method of Nath *et al.* (1993), which involved extraction of residues in ethyl acetate followed by cleaning through partitioning with dilute HCl and then neutralization of acidic phase with sodium bicarbonate, followed by repartitioning with ethyl acetate. Finally the residues were taken in 0.1 N HCl from organic (ethyl acetate) phase by liquid-liquid partitioning and carbendazim was estimated by recording absorbance in spectro-photometer (Shimadzu-UV-VIS) at 280 nm in comparison with ethyl acetate saturated 0.1 N HCl as reference.

The initial deposits of carbendazim were lower in fruits than in leaves (Table 1). However, the rate of degradation was similar on fruits and leaves up to the last day of analysis. The variation in initial deposits of carbendazim on fruits and leaves depends on different factors like structure and texture of plant material. Initially up to 5 days the residues degraded at faster rate, as more than 50% carbendazim dis-

*Short note

Based on study of a part of the All-India Coordinated Research Project on Pesticide Residues

^{1,3} Assistant Scientist, ² Senior Scientist, Department of Entomology

Table 1 Persistence of carbendazim at 1.5 and 3.0 kg/ha on apple fruits and leaves after treatment

Sampling interval (days)	Residue level (mg/kg)							
	Fruit				Leaves			
	Rajgarh		Nauni		Rajgarh		Nauni	
Day								
0	5.12	(9.38)	4.96	(8.10)	225.09	(398.41)	210.96	(352.62)
1	4.73	(6.33)	4.25	(5.52)	202.15	(288.19)	181.32	(235.12)
3	3.20	(4.81)	2.92	(3.45)	131.42	(179.85)	84.54	(116.38)
5	2.50	(3.10)	1.68	(2.15)	67.85	(78.63)	48.75	(59.38)
7	1.80	(2.30)	0.95	(1.25)	36.85	(38.28)	20.68	(24.32)
10	0.83	(1.05)	0	(0.65)	20.45	(24.85)	8.72	(10.64)

Figures in parentheses are @ 3.0 kg ai/ha

sipated from fruits and leaves at 2 locations. Dissipation during the subsequent 5-day intervals declined steadily with progress in time. On fruits the residues could be detected up to 10 days, whereas on leaves these even persisted beyond this period. At Rajgarh, 10 days after the treatment the residues were twice than at Nauni in fruits as well as leaves. The half-life of carbendazim at Nauni (2.0–2.9 days) was comparatively less than that at Rajgarh (2.4–3.9 days), both in fruits and leaves. This indicates that the rate of dissipation of carbendazim depends on temperature, as suggested by Sharma and Nath (1992).

The safe waiting period of the treated apples compared with the established tolerance limit of carbendazim 5.0 mg/kg was worked out to be 3 and 1.7 days at Rajgarh and Nauni respectively. These values were considerably lower than those considered acceptable by the World Health Organization (Monico-Pifarre and Xirau-Vayreda 1987). It was concluded that carbendazim at the recommended dose involves low health risk at post-harvest stage, with a safe waiting period of 3 days.

ACKNOWLEDGMENT

The authors are thankful to the M/s BASF (India) Ltd for supplying free sample of Bavistin 50 WP.

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Influence of herbicides on microbial population and enzyme activity in potato (*Solanum tuberosum*) - field soil*

A K SHUKLA¹ and R R MISHRA²

North-Eastern Hill University, Shillong, Meghalaya 793 022

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Key words : bacteria, enzyme, fungi, herbicide, potato, soil

Micro-organisms occupy a unique position in biological cycles in terrestrial habitats, as they are essential for maintenance of soil fertility and plant growth. In agriculture weeds often pose a major threat to crop yield. The purpose of the present study was to assess the influence of herbicides on microbial populations and enzymatic activities, dehydrogenase, urease and phosphatase in potato (*Solanum tuberosum* L.) soils.

The study was carried out at the farm of Central Potato Research Station, Shillong. The top soil was sandy loam.

* Short note

¹ Lecturer, Department of Botany, Arunachal University, Itanagar, Arunachal Pradesh 791 112

² Professor, Department of Botany

Disease-free tubers of 'Kufri Jyoti' were sown in the last week of March 1995. Five 30 m² randomized plots were taken for each treatment along with the control. The herbicides were used as per recommendation for potato in the region. The herbicides used were thiobencarb, S (4-chlorobenzyl)-N, N diethyl thiocarbamate (3.0 litres/ha); 2, 4-D, 2,4-dichlorophenoxy acetic acid (1.2 litres/ha); fluchloralin, N propyl-N (2'chloroethyl)-2, 6 dinitro-n-trifluoromethyl aniline (1.7 litres/ha). Initial soil sampling was done 20 days after emergence of the plants and on the same day herbicides were sprayed. Subsequent samples were collected on 15-day intervals. Soil-plate method was used to assess fungal propagules developing on rose bengal agar medium, and dilution plate method was used to estimate

Table 1 Influence of herbicides on fungal population (x 1 000), bacterial population (x 100 000), dehydrogenase activity (µg triphenyl formazan 24 hr), urease activity (µg NH₄⁺/ 3 hr) and phosphatase activity (µg p-nitrophenyl/ hr) in potato-growing soil (per gram dry soil)

Treatment	Fungi	Bacteria	Dehydrogenase	Urease	Phosphatase
<i>Control</i>					
<i>Period (days)</i>					
0	52.0	43.7	48.0	131.0	270.0
15	57.6	51.3	67.5	156.0	278.5
30	62.5	75.0	102.0	181.5	296.6
45	89.8	180.7	193.6	209.0	317.9
60	78.9	173.6	170.5	190.5	301.0
<i>2,4-D</i>					
15	49.5	15.3	66.0	135.8	280.0
30	90.1	23.8	103.7	170.7	305.9
45	94.8	130.0	192.8	200.2	323.7
60	75.0	125.0	178.6	195.6	300.0
<i>Thiobencarb</i>					
15	23.7	14.8	37.7	130.0	267.8
30	37.6	45.0	40.6	132.7	269.6
45	60.4	140.0	57.6	178.6	270.9
60	53.2	126.0	79.7	177.9	257.8
<i>Fluchloralin</i>					
15	40.2	13.9	47.5	139.7	270.0
30	60.0	23.6	50.6	160.7	283.1
45	96.8	98.7	72.7	187.8	285.7
60	78.1	97.3	100.7	185.5	271.2
CD (<i>P</i> =0.05)	13.6	21.2	29.8	34.6	41.2

bacterial populations on nutrient agar medium (Johnson and Curl 1972). Petri-dishes for fungi were incubated at 25 °C for 5 days and for bacteria at 30°C for 24 hr. Dehydrogenase, urease and phosphatase activities were estimated by the methods of Casida (1977), McGarity and Meyers (1967) and Tabatabai and Bremner (1969) respectively.

Herbicides generally inhibited the fungal populations; however, slight stimulation occurred for a short period in soils treated with 2, 4-D at 30 and 45 days after application (Table 1). In the plots treated with thiobencarb and fluchloralin, fungal population remained less than the control throughout the period of study. Bacterial population also dropped after herbicide application in all the sets. There was not much variation in the population of bacteria among the 3 herbicidal treatments. Dehydrogenase activity tended to decrease on thiobencarb and fluchloralin application, but they had no marked variation in the set treats with 2, 4-D. The urease activity was not affected by herbicides. Phosphatase activity was also affected by herbicides and the trend was similar to that of dehydrogenase activity. Stimulation of the fungal population in the soil treated with 2, 4-D might be due to the partial sterilization effect. Davies and Greaves (1981) found that herbicides at prescribed dose might cause temporary changes in the dehydrogenase activity. Urease, being the urea-degrading enzyme, does not mediate the degradation pathway of the herbicides and probably therefore remained unaffected by the herbicides. Davies and Greaves (1981) also reported similar result. Phosphatase activity is an index of the activity of microflora involved in the soil-organic phosphate decomposition. The reduction in the enzyme activity in this study was due to the

direct effect of herbicides on the fungal and bacterial populations. Correlation coefficient values (r) for fungal and bacterial population with dehydrogenase, urease and phosphatase activity were found significant at the 0.001 *P* level. A significant positive correlation was observed between microbial population and the enzymatic activities, confirming the report of Shukla *et al.* (1989) in potato soils. Although the herbicides had some effect on microbial population and enzymatic activities, recovery was rapid.

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BOOK REVIEWS

Indian Journal of Agricultural Sciences 67 (12) : 612, December 1997

Allelopathy : Field Observations and Methodology. 1996. Narwal S S and Tauro P (Eds). Scientific Publishers, 5-A New Pali Road, PB 91, Jodhpur 342 001. xxviii + 342 pp. 22.5 cm x 14.5. Rs 750. ISBN 81-7233-130-4.

The book under review is a complete mess of ideas on a very important and emerging field of allelopathy. In the book, the senior editor has tried to project more about his achievements in quantitative terms. The book starts with a preface wherein it has been stated that this book covers the lectures and presentations made during Sessions I and II concerning Field Observations and Methodology respectively, but page xiv shows Session II dealing with Allelopathy in Pest Management. For the conference, all the invited lectures (56) were given to understand that these will be published in the form of proceedings. The organisers or editors, however, have published only 14 of these in this volume, omitting many more important lectures from eminent scientists (*see* summary of presentations for Session I, page xi; and Session iv; page xviii) but including 9 contributory routine papers in Section III. The book is without any foreword and inaugural address and key-note lectures delivered during the conference.

Section I consisting of 7 chapters should have better been named Allelopathy in Agroecosystems instead of Field observations. Interestingly, ch 1 is the longest of all (229 references), being more of a confusion and poorly presented based on earlier reports rather than on self-generated data and field observations. Dr R A Willis in ch 2 gives an excellent account of *Eucalyptus* allelopathy. Ch 3, 4, 5 and 7 are also well presented with good information but ch 6 is misfit in this section.

In Section II only paper 9 on chemical analysis of allelopathic compounds by Drs G R Waller and M-C Feng is a comprehensive treatise in elaborating various allelopathic techniques, with latest developments in the discipline. This chapter will be of great use to all engaged in allelopathy research. The title of paper 10 is not commensurate with the information presented. Ch 8 and 11 are out of place, being theoretical and ch 12 does not involve anything relating to methodologies as such.

Ch 13 on bioassays depicts stray thoughts of the author without any experience in the discipline. The chapter is poorly presented without any clarity about the basics of bioassays and extraction procedure, eg on p 257 under Section 2.1.2 (growth stage) a sweeping statement about all

annual and perennial plant-phenological stages is incorrect. The methodology of drying and extraction is misleading and the author has tried to confuse it with isolation and characterization instead of bioassay methods. There is lot of repetition and contrary statements. In Section 3.2 the statement that the solutes from the plant sample are released into the solvent through plasmolysis or diffusion shows poor knowledge of the editor about these physiological processes. The phrases like 'may be mentioned', 'should be mentioned', 'can be done', 'may be prepared' etc appear as if some instructions have been imparted to a laboratory technician. In essence, this chapter on one of the most important aspects of allelopathy should have been assigned to a specialist in the discipline.

Section III on contributory papers without any coherence with the former 2 consists of 9 chapters starting from 14 onwards. In ch 14 the comparison of the allelopathic effect of C_3 and C_4 weeds was intended, but is without any clear-cut conclusions. Ch 15 deals with the inhibitory effect of boiled cyperaceous weed extracts on rice-seedling growth, which now is against the norms of methodology of allelopathy. With unboiled extracts here is hardly any significant effect on all the parameters studied. Ch 16 and 17 are well presented and informative. Ch 18 was intended to study the effect of *Prunus cornuta* bark allelochemicals on wheat, but actually presents the effect on radish for the reasons best known to the editors or referees, if any. In ch 19 the labeling of extracts at 100% is erroneous and it should come out to be around 400%. Ch 20-22 are well presented.

In Sections I and II although there is almost uniformity in presentation with conclusions, only a few chapters have future areas of research at the end. It would have been better to select a few review papers from eminent scientists for quality publication. The book, however, contains some valuable information for the benefit of researchers but suffers greatly from poor editing, which has resulted in bringing down the quality and utility of the book.

A price of the book is very high.

G L BANSAL

Hd, Dep Pl Physiol, HPKV, Palampur 176 062

Land Resources and their Management for Sustainability in Arid Regions. 1996. Kolarkar A S, Joshi D C and Kar, Amar (Eds). Scientific Publishers, 5-A New Pali Road, Jodhpur 342 001. xiii + 316 pp. Rs 750. ISBN 81-7233-125-8.

Arid regions are wide-spread all over the world. These regions are characterized by low rainfall, high temperature and evaporation, saline and scarce ground waters, shifting sand dunes, low density of population, poor road and communication system etc. More attention is needed to conserve the land and water resources in these regions. The present publication is based on the lectures delivered during 1993 in a training course at Central Arid Zone Research Institute, Jodhpur. The book contains 26 chapters, which deal mainly with constraints in development of arid regions, concept of watershed as a unit of development, ground-water assessment, water-harvesting techniques, problems of salinization and their amelioration, dryland farming, nutrient management, alternate land-use systems, simulation of crop yield and water balance, and technology transfer for sustainable development. Chapters on remote sensing, land-livestock interaction, social aspirations and evaluation of sustainable development have also been included.

Chapters on water harvesting, anthropogenic factors, problems of salinization, simulation on crop yields and land-management alternatives are written well and contain sufficient up-to-date information.

However, some gross deficiencies have been observed :

(1) In the beginning of the book, a chapter should have been on the nature and extent of arid-land problem. There

should have been a table showing chemical, physical and mechanical composition of a few representative soil profiles of arid regions. (2) In arid regions one of the important problems is that the ground water is generally saline. There should have been a separate chapter on use of saline ground waters including the modern concepts of water-quality appraisal. (3) The second chapter on land as a resource should have been written in relation to arid-land problem. However, there is not even a single reference to the arid-land problem. Similarly, ch 6 on remote sensing does not provide any information on arid regions. (4) The chapters have not been arranged subject wise. For example, ch 3, 5, 7 and 8 should have been arranged one after the other so as to maintain continuity of the subject. (5) During the recent years canal irrigation has been introduced in arid regions. Though it has led to increase in crop production in many areas, it has also created waterlogging and salinity problems in some regions of the command area. This important aspect is also missing. (6) A chapter on micro-irrigation should have been included. (7) Subject index is missing.

If the editors had applied more time and mind, they could produce much better publication than what it is in the present form.

K K MEHTA

P Soil Sci, CSSRI, Karnal 132 001

Indian Journal of Agricultural Sciences 67 (12) : 614, December 1997

Crop Production in Acid Soils. 1996. Somani L L. Agrotech Publishing Co., 1-G-24, Sector 5 (Gayatri Nagar), Hiran Magri, Udaipur (Rajasthan) 313 001. xvi + 224 pp. 22.5 cm x 14.5 cm. Rs 400. ISBN 81-85680-18-3.

To provide more food, fodder and fiber, additional land is to be brought under cultivation. Potential acid soils can be utilized for this purpose. Publication of this book is very timely. Dr Somani has provided the latest research findings in a concise form, presenting the available information under 8 chapters. These chapters provide sufficient information about the nature and extent of acid soils, their formation, diagnostic characteristics and harmful effects, especially toxicity of iron and aluminium. Management practices including reclamation by liming of acid soils, crop production, growing of tolerant crops and their genotypes have been dealt with sufficiently. Management of acid sulphate soils has also been included. In coastal areas of

India there are many soils that are acidic and saline. A separate chapter on this aspect could provide better information. The eco-system in these areas is very fragile due to high rainfall and intense chemical weathering. Therefore sufficient care has to be taken while bringing these lands under crop cultivation, as it can increase soil erosion. More information could be provided to maintain the eco-system. Similarly, the subject index could be enlarged for easy reference. The author has done a good job and it is expected that information contained in this book will be useful for the students, teachers and scientists.

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Information for readers

INDIAN JOURNAL OF AGRICULTURAL SCIENCES

GUIDELINES FOR REGISTRATION OF PLANT GERMPLASM

Need for registration of plant germplasm has been under the consideration of the Indian Council of Agricultural Research for sometime. Due recognition is accorded to the scientists who develop improved varieties, as per the release procedure available for the purpose. Unlike the developers of released cultivars, scientists associated with the development of improved germplasm and genetic stocks (new resources of resistance male sterility, varied types of mutants, cytogenetic stocks etc) have no mechanism for recognition. Lack of formal recognition of such useful materials and the role of scientists in development of these materials, discourages them from sharing the valuable materials with other works. Consequently, most of such valuable material remain under utilized or get lost. With the recent developments concerning Intellectual Property Rights and other related issues, due recognition of these materials has become all the more important.

Keeping these considerations in view, the ICAR constituted a Committee to suggest guidelines for identification and registration of value-added germplasm. The recommendations of the Committee have been approved by the ICAR for implementation. National Bureau of Plant Genetic Resources (NBPGR) has been identified as the nodal agency for implementation. The relevant procedure is specified in Annexure I, II and III for identification and registration of germplasm of crop plant, to encourage better sharing of genetic materials among the scientists.

GUIDELINES FOR IDENTIFICATION AND REGISTRATION

- 1 Nature of material to be registered
Material will constitute genetic stock or germplasm that has the potential attributes of scientific or commercial value.
- 2 Crop to be covered
The guidelines would operate on the following crops to start with
 - (a) Cereals Rice, wheat, maize, barley
 - (b) Millets Sorghum (*Jowar*), pearl millet (*bajra*), finger millet (*ragi*)
 - (c) Pulses Gram or chickpea, lentil, pigeonpea (*arhar*), greengram or moogbean, blackgram or urdbean, fieldpea
 - (d) Oilseeds Rapeseed-indian mustard, groundnut, safflower, soybean, linseed, sunflower, castor, sesame
 - (e) Commercial Crops Cotton, jute, sugarcane, tobacco
 - (f) Forage Crops Oat, berseem
 - (g) Vegetables Tomato, brinjal, chillies, french bean, cabbage, cauliflower, onion, cucumber, melon, pumpkin, watermelon, vegetable pea
 - (h) Root and tuber crops Cassava, potato, sweet potato
 - (i) Spices Black pepper, turmeric, ginger
 - (j) Fruits Banana, mango, citrus, grapes, guava, aonla, jujube (*ber*), pomegranate
 - (k) Ornamentals Rose, gladiolus, bougainvillea
 - (l) Any other material not listed above and of agricultural or commercial value may be considered at the discretion of the Committee.
- 3 Criteria for eligibility for registration
All the claims concerning the material submitted for registration would be subject to one or more of the following validation criteria:
 - (a) Publication in standard peer-reviewed journal (a copy of reprint to be submitted); and or
 - (b) Evaluation under All India Co-ordinated Research Project trial or nursery tests to be supported by relevant extracts of the documents/verification by the concerned project director or Project Co-ordinator; and/or
 - (c) One year of validation tests of the claimed attribute by the NBPGR.
- 4 Registration committee
 - (a) The material to be registered would be put up for consideration to the Registration Committee, the proposed constitution of which is as follows:

(i) DDG (CS)	Chairman
(ii) DDG (Hort.)	Member
(iii) Director, NBPGR	Member
(iv) ADG (FC)	Member
(v) One representative from SAUs	Member
(vi) Representative of DAC	Member
(vii) Need based 3 specialists with reference to the material under consideration (to be identified by the Chairman)	Member
(viii) A senior level scientists of NBPGR	Member-Secretary
 - (b) The material required to be registered would be proposed using the proformae enclosed at Annexures II and III.
 - (c) The proposals submitted as per the prescribed proforma would be summarily screened by the Member-Secretary of the committee in consultation with the Chairman to decide about the situation that holds true for it, as given under Item 3, including the need for validation by the NBPGR.
 - (d) After the validation, if required, the proposal would be put up for consideration to the registration committee.

5 Nodal agency

- (a) The NBPGR would be the nodal agency for registration of material, which will receive applications, process them and carry out the validation (if required).
- (b) Date of receipt of the proposal and material would be duly acknowledged by the Director, NBPGR, within a week of its receipt.
- (c) The NBPGR will maintain a permanent register, in which the materials approved for registration would be listed.

6 Time schedule

- (a) The decision of the committee must be finalized within 1 year of the submission of the proposal.
- (b) If the validation test by the NBPGR is required, the proposal would be received at least 2 months before the normal crop sowing season, ie winter season (*rabi*) and rainy season (*khari*) so that validation tests are made during the first crop season.

7 Notification of registered materials

All the materials approved for registration would be notified along with brief description in the subsequent issue of the following journals:

- (a) Indian Journal of Genetics and Plant Breeding
- (b) Concerned crop Newsletter if any and ICAR reports
- (c) Indian Journal of Plant Genetic Resources
- (d) The Indian Journal of Agricultural Sciences
- (e) Annual reports of the ICAR

8 Maintenance of registered material

In addition to long term storage of the registered material by the NBPGR, working stock for supply to users would be maintained by the institution associated with the development of the material.

9 Procedure for submission of application or material

- (a) All genetic stocks or germplasms proposed to be registered would be submitted to the NBPGR at the following address:

The Director
National Bureau of Plant Genetic Resources
Pusa Complex, New Delhi 110 012

- (b) The material must be accompanied by properly filled-in Form the registering A (Annexure II) duly signed by the depositor and the head of the institution. Separate application is required for the registration of each germplasm or genetic stock.
- (c) Form A must be accompanied by complete description of the material, using standard descriptors as per the requirement of the concerned crop AICRP or NBPGR.
- (d) A minimum of 1 000 seeds from freshly harvested crop well cleaned, must be submitted without any obvious physical change and with potential viability. For vegetatively propagated crops and horticultural species, the size may be determined in consultation with the Director, NBPGR

FORM A : APPLICATION FOR REGISTRATION

Registration Form for Plant Germplasm
(To be submitted to the Director, NBPGR, New Delhi)

Application No and date

(to be filled by NBPGR on receipt of application alongwith the seed or planting material and intimated to the depositor as acknowledgement)

- 1 Crop species (botanical name):
- 2 Name/designation of the genetic stock/germplasm:
- 3 Specific feature/characteristic for which registration is to be made:
- 4 Basis of eligibility:
 - (i) Name of the journal, if published
(please attach a copy of reprint)
 - (ii) If AICRP tests indicate years of testing
(enclose extract of test reports)
 - (iii) Any other particulars (please specify with justification)
- 5 Original source of the material and pedigree:
 - (i) Source
 - (ii) Pedigree
- 6 If developed, give
 - (a) Pedigree
 - (b) Breeding method used
- 7 Name of the depositor :
- 8 Name of scientists responsible for developing the material :
- 9 Name of the Institution/Organization where developed :
- 10 Chief descriptive morphological/botanical characters
(attach complete description using standard descriptors
as per AICRP/NBPGR requirements) :
- 11 Amount of seed deposited (minimum 1 000 seeds
or in consultation with the Director, NBPGR) :
- 12 Year of seed generation :
Certified that a viable stock would be maintained by the Institute for supply to those indenting the same.

(Name and signature of the depositor)
Institution address

(Signature of Head of
the Institution/VC

FORM B : (VALIDATION AND REGISTRATION)

- 1 Application No. : Crop
- 2 Specific feature/characteristic claimed :
- 3 Basis for acceptance of the claim as per preliminary decision on item 4 of application :
- 4 NBPGR validation (if required)
 - (a) Year of testing :
 - (b) Location/locations where tests were carried out :
 - (c) Person/persons conducting the test :
 - (d) Results of tests :
 - (e) Do the test results confirm the specific claim made ?
(records to be shown to the Registration Committee)
 - (f) Does the description conforms to that given in the application ?
 - (g) If not, in what way does it differ ?
 - (h) Is there a need to reconfirm any of the above-mentioned observations ?
- 5 Proposed Registration No.
- 6 Long-term germplasm storage index No.

Signature of Director, NBPGR

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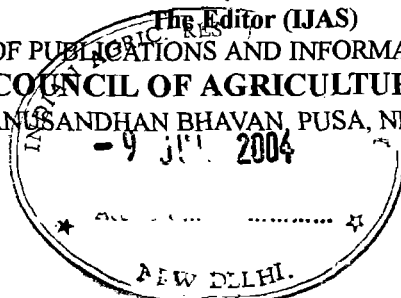
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