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Productivity, stability and efficiency of different cropping sequences in Maharashtra

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ABSTRACT

An experiment to identify efficient cropping sequences for 3 major zones of Maharashtra was conducted through cropping systems research centres located at Akola, Parbhani and Rahuri. Based on 11 years study at Akola (1987–88 to 1997–98) representing Vidharbha zone, cropping scquence involving upland cotton (*Gossypium hirsutum* L.)–groundnut (*Arachis hypogaea* L.) was identified to be most suitable and efficient with highest grain-equivalent yield (10 079 kg/ha/year), productivity (43.82 kg wheat grain equivalent/day/ha), profitability (Rs 49 539/ha/year), economic efficiency (Rs 135.7/day/ha) and land-use efficiency (90.0%) with reasonably good benefit : cost ratio (Rs 16.57) and stability (0.68). However, in terms of energetics, soybean [*Glycine max* (L.) Merr.]–groundnut sequence was distinctly better than others. Similarly, in Central Maharashtra Plateau Zone also, cotton–groundnut sequence was identified to be more efficient based on 8 years study at Parbhani (1990–91 to 1997–98) with highest production (12 060 kg/ha/year of wheat grain equivalent), productivity (50.04 kg/day/ha), profitability (Rs 62 053/ha/year), economic efficiency (Rs 170.0/day/ha) and land-use efficiency (85%) with moderate system stability (0.59). But, in terms of energetics soybean–indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] sequence was better than rest of the sequences compared. At Rahuri, representing western Maharashtra scarcity zone, raising of single sugarcane crop in a year was undoubtedly a profitable choice with the highest net return of Rs 93 429/ha/year, economic efficiency of Rs 255.9/ha/day and benefit : cost ratio of Rs 19.96. The equally good alternate choice was the sequence involving sorghum [*Sorghum bicolor* (L.) Moench.]–cabbage [*Brassica oleracea* L. var *capitata* (L.) f.]–cowpea [*Vigna unguiculata* (L.) Walp.] for fodder with production of 22 793 kg/ha/year wheat grain equivalent, productivity of 94.2 kg/day/ha, profitability of Rs 81 733/ha/year, economic efficiency of Rs 223.9/day/ha and carbohydrate production of 4.69 g 10^6/ha. In general, the soil fertility could be maintained or slightly improved over years with the use of recommended doses of nutrients under different cropping systems in 3 major zones of Maharashtra.

Keywords: Efficient cropping systems, Productivity, Stability, Soil fertility, Profitability, Energetics

The increasing future demand of food can probably be achieved with more intensive crop production. The cultivated area is inelastic. In fact, we have to produce needed quantity of food to feed the teeming population on one hand and sustain production taking due care on soil health on the other hand. To achieve the targets, we have to think for more productive, more efficient and remunerative cropping systems. For identifying most suitable crop sequences for a particular situation, the analysis of productivity, stability, land-use efficiency and production efficiency are considered important. The performance of a crop sequence is generally judged in terms of productivity and profitability. However, understanding of yield stability, energetics and land-use efficiency may provide an additional base for identification of a better and efficient crop sequence for a particular area. Therefore, present attempt was made for comparative study of stability, productivity, profitability, energetics and efficiency of various crop sequences under irrigated condition of semi-arid ecosystem of Maharashtra to identify efficient cropping systems for 3 major zones of the state.

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MATERIALS AND METHODS

An experiment to identify need-based crop sequences was conducted at Akola, Parbhani and Rahuri centres of All-India Co-ordinated Research Project on Cropping Systems from 1987–88 to 1997–98, 1990–91 to 1997–98 and 1990–91 to 1993–94 respectively. Twelve crop sequences, viz sorghum [*Sorghum bicolor* (L.) Moench.]–wheat (*Triticum aestivum* L. emend. Fiori & Paol.), cotton (*Gossypium hirsutum* L.)–groundnut (*Arachis hypogaea* L.), sorghum–indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]–groundnut, sorghum–chickpea or gram (*Cicer arietinum* L.), sorghum–sunflower (*Helianthus annuus* L.), cotton–wheat, cotton–chickpea, pigeonpea (*Cajanus cajan* (L.) Millsp.]–chickpea, pigeonpea–groundnut, soybean [*Glycine max* (L.) Merr.]–

wheat, soybean–chickpea, soybean–groundnut and greengram (*Phaseolus mungo* L.)–chilli (*Capsicum annuum* L.), were tried at Akola in different years. At Parbhani, 9 crop sequences, viz soybean–wheat, soybean–indian mustard, soybean–chickpea, soybean–safflower (*Carthamus tinctorius* L.), soybean–sunflower, soybean–sorghum, soybean–groundnut, cotton–chilli and cotton–groundnut, were tried in different years. However, at Rahuri 8 crop sequences, viz pigeonpea–wheat, sorghum–greengram–chilli, sorghum–groundnut, sorghum–cabbage [*Brassica oleracea* L. var *capitata* (L.) f.]–fodder cowpea [*Vigna unguiculata* (L.) Walp.], groundnut–sorghum, groundnut–wheat, cotton–wheat and sugarcane (single crop), were tried. The characteristics of experimental sites are given in Table 1. For reasonable comparison purpose, the average yield over years form the base for calculation of yield equivalent and system productivity in terms of wheat grain equivalent using prevailing market prices of different crop commodities in final years of experimentation.

The stability index for individual crops and sequences was computed using the following formula (SI) as per Singh *et al.* (1990).

$$SI = \frac{Y - S}{Y_{max}}$$

where Y is the average yield of a crop in sequence over a period of years n and s is the standard deviation of yield over a period of years. Y_{max} is the maximum yield of a crop in a certain year.

The economic efficiency in terms of Rs/day/ha was worked out by dividing the net returns of the sequence by 365 days in an agricultural year (Patil *et al.* 1995). The productivity of the system was calculated after converting the produce in wheat equivalent yield divided by 365 days.

Table 1 Characteristics of experimental sites in Maharashtra

Characteristics	Location (NARP Zone)		
	Akola (Vidharbha Zone)	Parbhani (Central Maharashtra Plateau Zone)	Rahuri (Western Maharashtra Scarcity Zone)
Latitude	19° 32' N	19°N	19°47' to 19°57' N
Longitude	74°03' E	76°E	74°18' to 74°19' E
Altitude (m)	307.4	408	435 to 459
Annual rainfall (mm)	788.0	717.9	726.4
Temperature (°C)			
Maximum	36.2	40.0	37.9
Minimum	9.6	5.0	17.2
Soil type	Fine clayey soils	Deep black soils	Medium black soils
Soil taxonomic class	Vertic Ustochrept	Chromustert (deep 90 cm depth)	Chromustert (60–90 cm depth)

The land-use efficiency (LUE) was calculated by dividing the total duration of different crops in a sequence by 365 days expressed in percentage (Tomar and Tiwari 1990). The energetics of different crops and cropping systems were calculated using the figures as provided by Gopalan *et al.* (1978). Recommended varieties were used. Also recommended doses of fertilizers were applied (Table 3) and management practices followed for raising different crops in the cropping systems.

RESULTS AND DISCUSSION

Productivity

At Akola, of the 12 crop sequences evaluated, cotton–groundnut gave the highest wheat-grain equivalent of 10 079 kg/ha/year, with system productivity of 43.82 kg/day/ha, followed by sorghum–indian mustard–groundnut which yielded 7 857 kg/ha/year grain equivalent with production efficiency of 25.59 kg/ha/day. The third best sequence was sorghum–chickpea with wheat-equivalent yield of 7 588 kg/ha/year and better productivity of 33.14 kg/ha/day in the order of merit. At Rahuri, among the 8 crop sequences tried sorghum–cabbage–cowpea (fodder) system was found distinctly better than others, giving maximum wheat-grain-equivalent yield of 22 973 kg/ha/year with productivity of 94.19 kg/ha/day, followed by single crop of sugarcane giving wheat grain equivalent of 12 348 kg/ha/year with productivity of 33.46 kg/ha/day. In terms of crop productivity, groundnut–wheat sequence was also better, giving 39.23 kg grain/day/ha. At Parbhani, among the 9 crop sequences tried, cotton–groundnut was distinctly better than other sequences which gave maximum wheat-grain-equivalent yield of 12 060 kg/ha/year, with productivity of 58.04 kg/ha/day. The next best sequence was cotton–chilli which gave 8 847 kg/ha/year wheat-grain equivalent with productivity of 30.93 kg/ha/day. But, in terms of productivity sorghum–wheat system was also a good sequence, giving 33.41 kg/day/ha wheat-grain equivalent yield.

Stability

At Akola, among the 4 crops (sorghum, cotton, pigeonpea and soybean) tried during the rainy season in 12 crop sequences, the pigeonpea showed the highest stability (0.84) when grown in sequence with groundnut (Table 2), while it was only 0.48 when sequenced with chickpea, clearly showing the appropriate choice of crop in a sequence is important for higher stability and productivity. This could also be seen in other crops, as stability of soybean varied from 0.55 to 0.76 in different sequences when raised as rainy season crop. Similarly, stability of sorghum varied from 0.41 to 0.75 and that of cotton from 0.41 to 0.61. The lower stability in cotton was mainly due to more fluctuation in yield over the years. In winter season, wheat, chickpea, groundnut and sunflower are the better choice in the order of merit considering the yield stability of these crops in different sequences. Only in 1

Table 2 Productivity and stability of various crops and cropping systems in Maharashtra

Cropping system (duration of crops in days)	Yield (kg/ha) Rainy season	Winter season	Summer	Wheat equivalent (kg/ha/year)	System productivity (kg/ha/day)	Stability Rainy season	Winter season	Summer	System
				Akola					
Sorghum–wheat (113) (109)	3 760	3 459		6 131	27.61	0.75	0.62		0.64
Cotton–groundnut (120) (110)	1 803	2 149		10 079	43.82	0.61	0.65		0.68
Sorghum–indian mustard–groundnut (115) (87) (105)	3 487	487	1 416	7 857	25.59	0.41	0.32	0.60	0.80
Sorghum–sunflower (113) (99)	3 806	1 206		5 183	24.45	0.72	0.63		0.55
Cotton–wheat (137) (109)	1 104	3 516		6 423	26.11	0.44	0.68		0.67
Sorghum–chickpea (113) (116)	3 713	3 588		7 588	33.14	0.71	0.68		0.42
Cotton–chickpea (137) (116)	955	1 383		5 561	21.98	0.51	0.48		0.49
Pigeonpea–chickpea (120) (90)	882	1 801		5 365	25.55	0.48	0.35		0.35
Pigeonpea–groundnut (120) (123)	868	1 935		6 599	27.16	0.84	0.59		0.80
Soybean–wheat (103) (109)	1 435	3 640		5 994	28.27	0.76	0.86		0.80
Soybean–chickpea (103) (116)	1 470	1 642		5 533	25.26	0.55	0.48		0.87
Soybean–groundnut (103) (125)	1 423	1 555		5 708	25.04	0.68	0.52		0.91
				Parbhani					
Sorghum–indian mustard (103) (87)	2 104	982		5 600	29.47	0.95	0.40		0.66
Sorghum–wheat (103) (114)	2 423	3 039		7 250	33.41	0.70	0.69		0.70
Sorghum–safflower (103) (118)	1 921	1 736		6 705	30.34	0.66	0.38		0.50
Soybean–chickpea (103) (139)	1 931	1 280		5 606	23.26	0.82	0.36		0.81
Cotton–groundnut (192) (120)	1 963	3 100		12 060	50.04	0.48	0.36		0.59
Soybean–sunflower (103) (106)	2 253	1 011		6 040	28.90	0.82	0.34		0.87
Soybean–sorghum (103) (125)	2 128	2 095		4 956	21.74	0.83	0.23		0.78
Soybean–groundnut (103) (127)	2 120	1 750		7 118	30.95	0.74	0.31		0.56
Cotton–chilli	2 277	3 509		8 847	30.93	0.87	0.49		0.70
				Rahuri					
Pigeonpea–wheat (122) (118)	2 083	3 313		7 615	31.73	0.71	0.87		0.83
Sorghum–gram–green chilli (102) (111) (120)	3651	580	5 267	6 649	19.97	0.52	.76	0.77	0.46
Sorghum–groundnut (113) (142)	4 115	3 433		9360	36.71	0.54	0.73		0.42
Soroghum–cabbage–cowpea (F) (113) (78) (51)	4 362	33 144	28 466	22 793	94.19	0.66	0.74	0.84	0.53
Groundnut–sorghum (94) (118)	2 006	3 440		6 681	30.23	0.74	0.70		0.88
Groundnut–wheat (94) (118)	1 951	3 511		8 316	39.23	0.83	0.86		0.86
Cotton–wheat (168) (118)	2 021	3 377		9 423	32.95	0.47	0.88		0.59
Sugarcane (369)			109 011	12 348	33.46			0.83	0.75

treatment groundnut was raised during summer after harvest of indian mustard with moderate stability of 0.60 showing that raising of crops in summer in assured irrigated situation is possible. As far as whole system is considered, the sequence involving soybean–groundnut was more stable (0.91), followed by soybean–chickpea (0.87) while soybean–wheat, pigeonpea–groundnut and sorghum–indian mustard–groundnut were equally stable (0.80). The other systems tried were comparatively less stable.

At Rahuri, among the crops compared single crop of sugarcane in an agricultural year was found more stable (0.83), followed by groundnut with stability ranging from 0.74 to 0.83 during the rainy season. Pigeonpea was also a good choice with stability of 0.71. In winter season, crops like wheat with stability ranging from 0.86 to 0.88 was found to be the best choice based on yield stability. It was followed by gram, cabbage and groundnut with stability of 0.76, 0.74 and 0.73, respectively, when grown in sequence with different crops. During summer only in 2 sequences cowpea (fodder) and green chilli crop were raised with respective stability of 0.84 and 0.77, showing that a good crop can be raised through selection of suitable crop sequence in the area under irrigated situation. While considering the stability of the cropping sequence as a whole, groundnut–winter sorghum was more stable (0.88), followed by groundnut–wheat (0.86) and pigeonpea–wheat (0.83) and single crop of sugarcane (0.75) in the order of merit.

At Parbhani, sorghum found to be more stable choice during the rainy season with stability ranging from 0.66 to 0.95, while soybean the next best choice with stability ranging from 0.74 to 83. The stability of cotton remained highly fluctuating from 0.48 to 0.87 showing that choice of the crop in the sequence is important for the stability. In winter season, wheat showed the highest stability (0.69) while other crops like chilli, indian mustard, groundnut, safflower, chickpea, and sunflower are the alternate choice with stability ranging 0.31 to 0.49. Comparatively lower stability of all these crops during the winter season was mainly due to climatic limitations and management resulting more fluctuations in yield over years. The system stability was the highest (0.87) in soybean–sunflower sequence, followed by soybean–chickpea (0.81), soybean–sorghum (0.78), cotton–chilli (0.70) and sorghum–wheat (0.70) in the order of merit.

Land-use efficiency

In cotton–groundnut system at Akola, the land remained

Table 3 Land-use efficiency, energy equivalents and profitability of different crop sequences of different centres of AICRP on cropping system

Crop sequence (NPK dose, kg/ha)	Field remained occupied (days/year)	Land-use efficiency (%)	Energy equivalents: Carbohydates (g 10^6)	Energy equivalents: Proteins (g 10^6)	Energy equivalents: Energy (K cal 10^6)	Profitability: Net returns (Rs/ha)	Profitability: Economic efficiency (Rs/ha/day)	Profitability: Benefit : cost ratio
			Akola					
Sorghum–wheat (100:50:40) (120:60:60)	222	61	2.46	0.41	11.97	29 433	80.6	6.91
Cotton–groundnut (100:50:50) (25:50:0)	330	90	0.56	0.54	12.18	49 539	135.7	16.57
Sorghum–indian mustard–groundnut (100:50:40) (50:250:25) (25:50:0)	307	84	.6.24	0.74	20.53	30 024	82.3	7.71
Sorghum–sunflower (100:50:40) (40:60:0)	212	58	5.25	0.81	14.20	25 021	68.6	7.86
Cotton–wheat (50:25:0) (25:50:0)	246	67	3.69	0.66	18.75	33 661	92.2	18.70
Sorghum–chickpea (100:50:40) (25:50:0)	229	63	2.98	0.64	20.78	31 308	85.8	10.77
Cotton–chickpea (50:25:0) (25:50:0)	253	69	0.84	0.24	4.98	26 132	71.6	14.55
Pigeonpea–chickpea (25:50:0) (25:50:0)	310	85	1.10	0.31	6.48	22 546	61.8	11.08
Pigeonpea–groundnut (25:50:0) (25:50:0)	243	67	0.51	0.49	10.97	27 037	74.1	13.29
Soybean–wheat (120:60:60) (120:60:60)	212	58	2.89	1.05	18.79	26 843	73.5	5.67
Soybean–chickpea (30:60:0) (25:50:0)	219	60	1.31	0.92	12.26	24 045	65.9	10.74
Soybean–groundnut (30:60:0) (25:50:0)	228	62	0.70	6.54	70.29	25 700	70.4	11.48

Table 3 *continued*

Crop sequence (NPK dose, kg/ha)	Field remained occupied (days/year)	Land-use efficiency (%)	Energy equivalents			Profitability		
			Carbohydates (g 10^6)	Proteins (g 10^6)	Energy (K cal 10^6)	Net returns (Rs/ha)	Economic efficiency (Rs/ha/day)	Benefit : cost ratio
			Parbhani					
Soybean–indian mustard (30:60:30) (30:30:35)	190	52	2.70	1.41	21.13	25 162	68.9	1 015
Soybean–wheat (30:60:30) (120:60:60)	217	59	0.47	0.95	9.40	32 625	89.4	2.50
Soybean–safflower (30:60:30) (60:40:40)	221	60	1.18	1.05	12.95	28 394	77.8	9.78
Soybean–chickpea (30:60:30) (25:50:15)	242	66	0.48	0.87	8.87	24 197	65.3	9.26
Cotton–groundnut (100:50:50) (25:50:25)	312	85	0.65	1.17	16.00	62 053	170.0	19.41
Soybean–sunflower (30:60:30) (25:50:15)	209	57	1.97	1.14	16.50	26 696	73.1	10.22
Soybean–sorghum (30:60:30) (80:40:40)	228	62	0.90	1.36	19.08	22 253	61.0	7.30
Soybean–groundnut (30:60:30) (25:50:15)	230	63				33 004	90.4	12.64
Cotton–chilli (100:50:50) (100:50:50)	286	78	0.81	0.78	17.58	40 644	111.4	10.30
			Rahuri					
Pigeonpea–wheat (20:20:25) (120:60:60)	240	66	2.36	0.39	11.46	35 287	96.7	9.92
Sorghum–gram–green chilli (120:60:60) (25:50:0) (100:75:50)	333	91	2.65	3.79	12.42	22 187	60.8	3.84
Sorghum–groundnut (120:60:60) (25:50:0)	255	70	3.88	0.43	33.82	49 055	134.4	14.49
Sorghum–cabbage–cowpea (F) (120:60:60) (100:80:80) (15:90:30)	242	66	4.69	1.30	24.17	81 733	223.9	11.75
Groundnut–sorghum (25:50:0) (120:60:60)	221	61	3.04	0.87	23.38	31 080	85.2	8.63
Groundnut–wheat (25:50:0) (120;60:60)	212	58	3.00	0.91	23.21	36 608	100.3	10.82
Cotton–wheat (80:40:40) (120:60:60)	286	78	2.40	0.40	11.68	47 976	131.4	12.16
Sugarcane (250:115:115)	360	99	108.36		4.25	93 429	256.0	19.96

occupied by crops for maximum number of days (330) resulting highest land-use efficiency (90%). It was followed by pigeonpea–chickpea and sorghum–indian mustard–groundnut sequence with respective land-use efficiency of 85 and 84% (Table 3). However, in other sequences the land-use efficiency ranged from 58 to 67% showing that land remained vacant for considerable time during agricultural year offering scope to raise crops during summer.

At Rahuri, the highest land-use efficiency (99%) was experienced when sugarcane crop was raised, as it could be harvested in 360 days. The land-use efficiency in sorghum–gram–green chilli sequence was also very high (91%), as the field remained occupied for 333 days in a year. At Parbhani, the land-use efficiency was the highest (85%) under cotton–groundnut sequence, followed by cotton–chilli (78%). While in other sequences the land-use efficiency varied from 52 to 66% showing that the possibility of improving land-use efficiency needs to be explored in the irrigated area.

Energetics

Energy equivalents are considered better indicator of the performance of a cropping system for comparison purpose, as it is not affected by market prices. Highest carbohydrate could be produced in the rice–indian mustard–groundnut sequence (6.24 g 10^6), followed by sorghum–sunflower sequence (5.25 g 10^6) at Akola. In terms of protein production, soybean–wheat sequence was identified to be the highest producer (1.05 g 10^6). It was followed by sorghum–sunflower (0.81 g 10^6) in the order of merit. The energy equivalents were interestingly highest (70.29 Kcal 10^6) in the system involving soybean–groundnut, clearly showing superiority of this system to others (Table 3).

At Rahuri, the highest production of carbohydrate could be recorded in sorghum–cabbage–cowpea (fodder) sequence (4.69 g 10^6), followed by sorghum–groundnut sequence (3.88 g 10^6). In terms of protein production, sorghum–gram–green chilli was distinctly better (3.79 g 10^6) than others. However, in terms of energy equivalents (33.82 cal 10^6), sorghum–groundnut was found better, followed by sorghum–cabbage–cowpea fodder system (24.17 Kcal 10^6), while groundnut followed by wheat or winter sorghum was almost equal in energy production (Table 3). At Parbhani, sequence involving soybean–indian mustard was the highest producer of carbohydrate (2.70 g 10^6), protein (1.41 g 10^6) and energy (21.13 Kcal 10^6), clearly showing superiority to other sequences tried, Such systems can be the appropriate choices on efficiency considerations.

Table 4 Final soil status at different centres (kg/ha)

Treatment	Organic carbon (%)	N	P	K
Akola				
Initial	0.50	172.0	14.9	417.0
T_1 Sorghum–wheat	0.48	362.0	47.0	336.0
T_2 Cotton–groundnut	0.47	326.0	53.0	327.0
T_3 Sorghum–indian mustard–groundnut	0.46	357.0	56.0	322.0
T_4 Sorghum–sunflower	0.46	382.0	54.0	327.0
T_5 Cotton–wheat	0.46	368.0	56.0	347.0
T_6 Sorghum–chickpea	0.46	345.0	48.0	344.0
T_7 Cotton–chickpea	0.53	276.0	46.3	347.0
T_8 Pigeonpea–chickpea	0.62	314.0	48.1	381.0
T_9 Pigeonpea–groundnut	0.60	301.0	50.0	386.0
T_{10} Soybean–wheat	0.58	307.0	38.0	336.0
T_{11} Soybean–chickpea	0.61	376.0	49.2	358.0
T_{12} Soybean–groundnut	0.55	288.0	41.0	336.0
Parbhani				
Initial	0.55	163.4	24.3	451.3
T_1 Soybean–indian mustard		167.9	25.4	456.1
T_2 Soybean–wheat		176.6	27.5	467.5
T_3 Soybean–safflower		173.7	26.2	462.4
T_4 Soybean–chickpea		168.7	25.4	457.7
T_5 Cotton–groundnut		178.1	28.5	471.5
T_6 Soybean–sunflower		169.0	25.7	458.7
T_7 Soybean–sorghum		170.5	25.8	460.0
Rahuri				
Initial	0.58	195.0	18.0	432.0
T_1 Pigeonpea–wheat	0.44	181.9	15.6	560.0
T_2 Sorghum–gram–green chilli	0.51	203.8	17.3	537.6
T_3 Sorghum–groundnut	0.50	197.6	13.4	512.2
T_4 Sorghum–cabbage–cowpea (F)	0.47	188.2	11.2	504.0
T_5 Groundnut–sorghum	0.48	194.4	15.6	526.4
T_6 Groundnut–wheat	0.48	188.2	13.4	548.8
T_7 Cotton–wheat	0.45	169.3	6.7	470.4
T_8 Sugarcane–ratoon	0.48	178.8	8.9	492.8

Profitability

Choice of a cropping system in a area is mainly guided by the profitability. Under the prevailing market prices of different crop commodities in recent years, the sequence involving cotton–groundnut with net return of Rs 49 539/ha/year, economic efficiency of Rs 135.7/ha/day and benefit : cost ratio of Rs 16.57 was more profitable at Akola (Table 3). The next choice was cotton–wheat with net return of Rs 33 666/ha/year), economic efficiency of Rs 92.2/day/ha and benefit : cost ratio of Rs 18.70. At Rahuri, raising of sugacane in an agricultural year was more profitable giving average highest return of Rs 93 429/ha/year, economic efficiency of Rs 256.0/ha/day and benefit : cost ratio of Rs 19.96. The next profitable choice was sorghum–cabbage–cowpea fodder with net profit of Rs 81 733/ha/year, economic efficiency of Rs 22.6/day/ha and relatively low benefit : cost ratio of Rs 11.75. The third choice was sorghum–groundnut sequence with net return of Rs 49 055/ha/year, economic efficiency of Rs 134.4/ha/day and benefit : cost ratio of Rs 14.49. At Parbhani, the sequence involving cotton–groundnut was identified to be the distinctly better choice with net profit of Rs 62 053/ha/year, economic efficiency of Rs 170.0/ha/day and benefit : cost ratio of Rs 19.41.

Soil fertility

On perusal of initial and final status of soil fertility, in general the fertility status could be maintained with the use of recommended doses of nutrients in different crops and cropping systems (Table 4). At Akola, improvement in nitrogen and phosphorus content could be observed while there was decline in K content showing that the recommended dose of potash needs to be enhanced for maintaining the K in the soil at initial level. At Rahuri, growing of different crops in sequences over a period of 11 years showed slight decline in organic carbon, nitrogen and phosphorus content. This trend clearly favours enhancement in the dose of nitrogen and phosphorus while buildup of K in the soil under different treatments reveals that some quantity of potash can be saved. At Parbhani, there was slight increase in all the 3 nutrients (NPK) in the soil clearly showing that the recommended doses applied to different crops in the cropping systems are sufficient to maintain and sustain the system. Clearly, the higher productivity and profitability with sustained soil fertility can be obtained with suitable choice of crops or cropping systems and use of required doses of plant nutrients.

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Effect of phosphate-solubilizing bacteria on efficiency of Mussoorie rockphosphate in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was carried out at the Indian Agricultural Research Institute, New Delhi, during 3 crop cycles (1996–97 to 1998–99), to study the effect of phosphorus fertilization on grain and straw yields and NPK uptake of rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system and organic C, available P and available K content of soil. Application of Mussoorie rockphosphate had no significant effect on grain and straw yields of rice, however, when it was inoculated with phosphate-solubilizing bacteria, it increased grain yield by 0.9–1.8 tonnes/ha, straw yield by 0.8–2.1 tonnes/ha, N uptake by 18–38 kg/ha, P uptake by 2.7–6.6 kg/ha and K uptake by 16–41 kg/ha of rice–wheat cropping system. These increases were similar to those obtained with diammonium phosphate. Application of Mussoorie rockphosphate with and without phosphate-solubilizing bacteria significantly increased organic C by 0.02–0.06% and available P by 4.1–15.3 kg/ha in soil, whereas diammonium rockphosphate increased only available P by 3–4.7 kg/ha in soil.

Keywords: Phosphorus fertilization, NPK uptake, Diammonium phosphate, Mussoorie rock phosphate, phosphate-solubilizing bacteria

Rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system occupies about 12 million ha in India and contributes about 31% of total grain production (Kumar *et al.* 1998). In this cropping system, rice gives low response to applied P compared to wheat, primarily due to increased availability of native soil P, specially the occluded P (Patrick and Mahapatra 1968). This led to recommendation that in rice–wheat cropping system rice can be grown on residual P if wheat is adequately fertilized (Meelu and Rekhi 1981). However, no application of P to rice could be partly responsible for declining yields in rice in rice–wheat cropping system. Attempts have been made to use Mussoorie rockphosphate directly in soils of *p*H 7 and above (Sharma *et al.* 1983, Sharma and Prasad 1996), it is still not widely used due to unavailable form of P in Mussoorie rockphosphate. The introduction of efficient P solubilizers (*Pseudomonas striata, Bacillus polymaxa* etc) in the rhizosphere of crops and soils increases the availability of P from insoluble sources and a variety of mechanisms such as production of aliphatic and aromatic acids, phytases and phospholipases etc are responsible for this (Chhonkar and Tilak 1997). Benefits of phosphate-solubilizing bacteria in terms of increased yield have been equated with 13 kg P/ha as ordinary superphosphate (Gaur 1990).

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An attempt was, therefore made to assess the relative availability of P from diammonium phosphate and Mussoorie rockphosphate in the rice–wheat rotation as influenced by phosphate-solubilizing bacteria on above parameters.

MATERIALS AND METHODS

The field experiment was conducted during 3 crop years (July–June) from 1996–1997 to 1998–99 at the Indian Agricultural Research Institute, New Delhi. The soil was a sandy clay loam in texture with *p*H 8.2 (1:2.5 soil to water). It contained 0.67 % organic C, 0.065 % Kjeldahl-N, 15 kg/ha available P and 321 kg/ha available K.

The experiment was laid out in randomized block design with 3 replications. The treatments were: no phosphorus, 26 kg P/ha as diammonium phosphate, 26 kg P/ha as Mussoorie rockphosphate and 26 kg P/ha as Mussoorie rockphosphate + phosphate-solubilizing bacteria (*Pseudomonas striata*). These treatments were applied to both rice and wheat.

Phosphorus fertilizer

Commercial grade granulated diammonium phosphate (18 % N and 20 % P) and Mussoorie rockphosphate (8 % P) were used. Of the total P in Mussoorie rockphosphate, 12% was soluble in neutral ammonium citrate. Mussoorie rockphosphate was ground to pass 2 mm size sieve.

Phosphate-solubilizing bacteria

The culture *Pseudomonas striata* was obtained from the Division of Microbiology, Indian Agricultural Research Institute, New Delhi. In rice, 500 g bacterial culture was mixed with 1 000 ml jaggery solution, which was diluted to 10 litres with water and inoculation was done by dipping the roots of rice seedling in the solution. For wheat 500 g bacterial culture was mixed with 1 000 ml of jaggery solution, which was mixed with wheat seeds and dried in shade before sowing.

Field study

The field experiment was started with rice crop (July to October). The field was flooded and puddling was done with a tractor-drawn disc harrow. Just before final puddling, P as per treatment, 33 kg K/ha as muriate of potash and 4.5 kg Zn/ha as zinc sulphate hepta hydrate were applied to each plot each year. Nitrogen as urea at 120 kg N/ha was applied in 2 splits, half 10 days after transplanting and the remaining at panicle initiation. 'Pusa Basmati 1' rice of 140 days duration was transplanted in the first week of July, using 2–3 seedlings of 21–25 days/hill at a spacing of 20 cm × 10 cm. Rice was harvested in the last week of October.

The field was irrigated after the harvest of rice crop and at optimum soil-moisture condition, field was ploughed in with disc plough, followed by double-discing and planking. Before final discing 60 kg N/ha as urea, P as per treatment and 33 kg K/ha as muriate of potash were applied to each plot. Second dose of 60 kg N/ha as urea was given 30 days after sowing. 'HD 2329' wheat was sown in the third week of November and harvested during the second week of April.

Sampling and analysis

Prior to start of the field experiment a composite soil sample was drawn from 0–25 cm soil layer and analysed for organic C (Walkley and Black 1934), total Kjeldahl's N (Prasad 1998) and available P (Olsen *et al.* 1954) and available K (Jackson 1958). At rice and wheat maturity grain and straw samples were analysed for total P (Prasad 1998) and NPK uptake was calculated by multiplying NPK concentration in grain and straw with their respective dry weights. At the harvest of each crop, soil samples were drawn from 0–25 cm layer and analysed for organic C, available P and available K content. Data of each character were statistically analysed (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Grain yield

Application of Mussoorie rockphosphate inoculated with phosphorus-solubilizing bacteria and diammonium phosphate were equally effective and increased the grain yield of both rice and wheat significantly (Table 1). The increase in the grain yield of rice due to diammonium phosphate over the control was 0.5 tonne/ha in the first year, 0.9 tonne/ha in the second year and 0.5 tonne/ha in the third year. The respective increases in grain yield of wheat were 1.0, 0.9 and 0.4 tonne/ha in first, second and third year respectively. Similarly, Mussoorie rockphosphate increased grain yield over control by 0.6, 0.8 and 0.5 tonne/ha in rice and by 1.1, 1.0 and 0.4 tonne/ha in wheat in first, second and third year, respectively. These results clearly show that in rice–wheat cropping system both rice and wheat responded well to phosphorus.

Application of Mussoorie rockphosphate without phosphorus-solubilizing bacteria inoculation did not increase the grain yield of rice or wheat. As regards Mussoorie rockphosphate these results are in accordance with those of Sharma and Prasad (1996) who suggested the use of Mussoorie rock phosphate–pyrite mixture and also with those of Sharma *et al.* (1983), Dubey (1996) and Dubey *et al.* (1997), who suggested use of Mussoorie rockphosphate with phosphate-solubilizing bacteria for its higher efficiency.

Table 1 Effect of P fertilization on grain and straw yield (tonnes/ha) of rice–wheat cropping system

Treatment	1996–97			1997–98			1998–99		
	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total
				Grain yield					
Control (no P)	4.1	3.6	7.7	3.5	3.6	7.1	3.7	3.9	7.6
DAP	4.6	4.6	9.2	4.4	4.5	8.9	4.2	4.3	8.5
MRP	4.4	4.3	8.7	3.9	4.1	8.0	3.9	4.0	7.9
MRP + PSB	4.7	4.7	9.4	4.3	4.6	8.9	4.2	4.3	8.5
LSD ($P = 0.05$)	0.24	0.51	0.51	0.40	0.42	0.50	0.34	0.24	0.42
				Straw yield					
Control (no P)	6.6	5.8	12.4	5.6	6.4	12.0	7.2	4.7	11.9
DAP	7.6	7.3	14.9	6.4	7.4	13.8	7.9	5.2	13.1
MRP	6.8	6.4	13.2	6.0	6.6	12.6	7.4	4.7	12.1
MRP + PSB	7.7	6.8	14.5	6.4	7.4	13.8	7.6	5.1	12.7
LSD ($P = 0.05$)	0.75	0.32	0.81	0.42	0.61	0.75	0.45	0.43	0.77

DAP, Diammonium phosphate; MRP, Mussoorie rockphosphate; PSB, phosphorus-solubilizing bacteria

Table 2 Effect of P fertilization on N, P and K uptake (kg/ha) of rice–wheat cropping system

Treatment	1996–97			1997–98			1998–99		
	Rice	Wheat	Total	Rice	Wheat	Total	Rice	Wheat	Total
				Nitrogen					
Control (no P)	80	75	155	72	79	151	98	82	180
DAP	93	96	189	88	97	185	112	92	204
MRP	87	88	175	80	88	168	103	84	187
MRP + PSB	95	96	191	89	100	189	109	89	198
LSD ($P = 0.05$)	4.2	7.6	7.7	6.39	6.9	8.2	5.87	4.2	9.1
				Phosphorus					
Control (no P)	10.1	11.7	21.8	8.9	12.5	21.4	9.9	13.2	23.1
DAP	12.4	15.3	27.7	11.4	16.0	27.4	11.9	15.3	27.2
MRP	11.4	14.6	26.0	10.3	14.4	24.7	10.8	13.9	24.7
MRP + PSB	12.4	16.1	28.5	11.6	16.4	28.0	11.8	14.8	26.6
LSD ($P = 0.05$)	0.73	1.61	1.81	0.97	1.41	1.52	0.78	0.87	1.62
				Potassium					
Control (no P)	100	105	205	101	116	217	105	84	189
DAP	117	132	249	117	136	253	117	92	209
MRP	107	116	223	110	123	233	110	86	196
MRP + PSB	120	126	246	117	134	251	115	90	205
LSD ($P = 0.05$)	10.4	6.2	12.2	7.3	6.3	11.7	7.9	6.3	13.5

DAP, Diammonium phosphate; MRP, Mussoorie rockphosphate, PSB, phosphate-solubilizing bacteria

Straw yield

Both diammonium phosphate and Mussoorie rockphosphate + phosphate-solubilizing bacteria were equally effective and increased straw yield of both rice and wheat significantly (Table 1). Diammonium phosphate increased the straw yield of rice over control by 1.0 tonne/ha in the first year, 0.8 tonne/ha in the second year and 0.5 tonne/ha in the third year and straw yield of wheat by 1.5 tonne/ha in the first year, 1.0 tonne/ha in the second year and 0.5 tonne/ha in the third year. Similarly, Mussoorie rockphosphate + phosphorus solubilizing bacteria increased straw yield over the control by 1.1, 0.8 and 0.4 tonne/ha in rice and by 1.0, 1.0 and 0.4 tonne/ha in wheat in first, second and third years, respectively. Application of Mussoorie rockphosphate, on the other hand, had no significant effect on straw yield of both rice and wheat.

Nutrient uptake

Phosphorus fertilization increased N, P and K uptake by both rice and wheat (Table 2). Inoculated Mussoorie rockphosphate with phosphorus-solubilizing bacteria was as effective as diammonium phosphate and significantly increased N uptake over the control by 15–18 kg/ha in rice and by 7–21 kg/ha in wheat. Mussoorie rockphosphate + phosphorus-solubilizing bacteria also increased P uptake over the control by 1.9–2.7 kg/ha in rice and by 1.6–4.4 kg/ha in wheat. The increase in K uptake by Mussoorie rockphosphate + phosphorus-solubilizing bacteria over the control ranged from 10 to 20 kg/ha in rice and from 6 to 21 kg/ha in wheat. Although Mussoorie rockphosphate did not significantly increase rice or wheat grain or straw yield, its application had positive effect on N, P and K uptake by rice and wheat and increased N, P and K uptake over the control by 5–8, 0.9–1.4 and 5–9 kg/ha, respectively, in rice and by 2–13, 0.7–2.9 and 2–11 kg/ha, respectively, in wheat. These data again show the

Table 3 Effect of P fertilization on soil fertility under rice–wheat cropping system

Treatment	1996–97	1997–98	1998–99
	Organic C (%)		
Control (no P)	0.61	0.69	0.70
DAP	0.62	0.70	0.73
MRP	0.64	0.75	0.74
MRP + PSB	0.63	0.75	0.75
LSD ($P = 0.05$)	NS	0.06	0.05
	Available P (kg/ha)		
Control (no P)	15.3	20.1	20.2
DAP	20.0	23.9	23.2
MRP	17.5	27.3	32.8
MRP + PSB	19.4	32.1	35.5
LSD ($P = 0.05$)	NS	2.0	1.9
	Available K (kg/ha)		
Control (no P)	304	311	356
DAP	313	315	343
MRP	308	335	350
MRP + PSB	323	342	345
LSD ($P = 0.05$)	NS	NS	NS

DAP, Diammonium phosphate; MRP, Mussoorie rockphosphate; PSB, phosphate-solubilizing bacteria need for adequate P fertilization of both rice and wheat in rice-wheat cropping system.

Soil fertility

Application of Mussoorie rockphosphate with or without phosphorus-solubilizing bacteria increased organic C in soil and the difference was significant in the second year onward (Table 3). Organic C content in soil was, however, not increased due to diammonium phosphate application and inoculation of phosphorus-solubilizing bacteria.

As regards available soil P, a significant increase was noted in the second and third year of study when Mussoorie rockphosphate + phosphorus-solubilizing bacteria recorded the highest available P in soil, significantly more than Mussoorie rockphosphate, which in turn, was significantly superior to diammonium phosphate. Phosphorus fertilization of rice–wheat cropping system did not affect available K content of soil in all the 3 years of study.

These results show that Mussoorie rockphosphate inoculated with phosphorus-solubilizing bacteria is a better source of P than diammonium phosphate from point of view of soil fertility. This could be owing to the presence of other elements (such as micronutrients) as impurity in Mussoorie rockphosphate which benefitted the soil microorganisms.

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Effect of nitrogen and phosphorus fertilization on growth and yield of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) as influenced by inclusion of forage cowpea (*Vigna unguiculata*) in rice–wheat system

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ABSTRACT

A field experiment was conducted during 1997–98 to 1999–2000 on Typic Ustochrept soil of Modipuram (29^{0}4' N, 77^{0}46' E, 237 m above mean sea-level), Meerut, Uttar Pradesh, to evaluate the effect of fertilizer nitrogen and phosphorus on the growth and yield of rice (*Oryza sativa*) and wheat (*Triticum aestivum* L.emend. Fiori & Paol.) in rice–wheat system, with or without inclusion of summer cowpea [*Vigna unguiculata* (L.) Walp.] (forage) crop. Growth parameters, viz dry-matter accumulation, leaf-area index, crop-growth rate and net assimilation rate measured at different stages increased significantly with balanced NP fertilization. The yield attributes, viz ears/m^2, grains/ear and grain weight/ear, measured at maturity in rice and wheat revealed a significant increase of 5.5 to 10.9%, 9 to 10% and 13.1 to 19.4%, respectively, with 120 kg N and 26 kg P/ha compared to 120 kg N alone. The crop-growth rate, averaged across treatments, was highest 45–60 days after transplanting in rice (10.9 g/m^2/day) and 70–90 days after sowing in wheat (7.4 g/m^2/day) in all treatments, indicating that these were the stages of peak physiological activity. Inclusion of forage cowpea in summer did not affect the yield of subsequent rice, but increased the yield of wheat, when both rice and wheat crops received recommended doses of N and P fertilizers. Skipping of either nutrient caused significant yield loss in both the crops. The magnitude of yield reduction was, however, greater (0.9–3.1 tonnes/ha in rice and 1.48–3.63 tonnes/ha in wheat) in forage cowpea treatments than in summer fallow (0.5–3.0 tonnes/ha in rice and 0.9–3.11 tonnes/ha in wheat).

Keywords: Rice, *Oryza sativa*, wheat, *Triticum aestivum*, Forage cowpea, *Vigna unguiculata*, N, P, Crop growth, Yield

Rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) rotation practised in 10.5 m ha in the Indo-Gangetic Plain region, is the most important agricultural production system for food security of India, mainly because of its higher productivity and greater ecological adaptability. The rice–wheat system shares 23% of the national foodgrain production (Yadav *et al.* 1998). Since both the component crops, ie rice and wheat, have a very high nutrient demand, a high productivity of the system can not be attained and sustained unless adequate nutrient supply is ensured (Hegde and Dwivedi 1992, Timsina and Connor 2001). Inclusion of legumes, particularly green-manure legumes, to complement chemical fertilizers is an established agro-technique in augmenting nutrient supply and restoration of soil fertility in rice–wheat system (Singh *et al.* 1991, Yadav *et al.* 2000). Information on inclusion of a forage legume and its possible role in modifying the response of rice and wheat to chemical fertilizers in rice–wheat system is, however, scanty. The present investigation was, therefore, undertaken to study the effect of fertilizer N and P application on growth and productivity of crops in rice–wheat system, managed with or without forage cowpea [*Vigna unguiculata* (L.) Walp.] during summer season.

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MATERIALS AND METHODS

A field experiment with rice–wheat cropping system was conducted at the Project Directorate for Cropping Systems Research Farm, Modipuram, Meerut, Uttar Pradesh, located at 29^0 4 N, 77^{0}46 E, 237 m above mean sea level, from 1997–98 to 1999–2000. The soil of experimental site was sandy loam, having *p*H 8.13, electrical conductivity 0.32 dS/m, organic carbon 0.43%, NO_3-N 4.8 mg/kg, NH_4-N 14.3 mg/kg, available P 8.3 mg/kg, available K 0.19 me % and available S 15 mg/kg.

Eight treatments comprising 2 levels of N (0 and 120 kg/ha), and 2 of phosphorus (0 and 26 kg P/ha) with 2 summer crop options, viz summer fallow and summer cowpea were evaluated in factorial randomized block design, with 4 replications. Fertilizer N and P were applied as per treatment to both the crops through urea and single superphosphate respectively. Both rice and wheat crops received uniform application of K at locally recommended rates (33 kg K/ha) through muriate of potash. One-third of N, and entire amount of P and K were applied at transplanting or sowing, and remaining N was top-dressed in 2 equal splits, at maximum tillering and panicle emergence. During all 3 years, 'Russian Giant 2' cowpea was grown in respective plots during summer, ie before rice transplanting, in 45 cm apart rows without any fertilizer application. Cowpea was harvested for fodder purpose from ground level at 50-day growth. Thereafter, 25-day-old seedlings of 'Saket 4' rice were transplanted at 20 cm × 15 cm spacing during the first week of July in all the plots. After rice harvesting in the second week of October, 'UP 2338' wheat was sown in 20 cm apart rows on the same layout. Rice and wheat crops were harvested manually at maturity and the above-ground biomass was removed from the plots.

The tillers/m², green leaves/m², and leaf weight (g/m²) were measured 60 days after transplanting in rice and 90 days after sowing in wheat. The observations on dry-matter accumulation and leaf-area index were recorded up to 75 days after transplanting (at 15-day interval) in rice, and up to 110 days after sowing (at 20-day interval) in wheat. The crop-growth rate and net assimilation rate during crop growth were computed, following standard techniques (Leopold and Kriedemann 1975). At harvest grain and straw yields were recorded from a net-plot of 4 m × 5 m, and yield-attributes, viz ears/m², grains/ear, grain weight/ear and 1000-grain weight were recorded from representative plant samples. The results presented in this paper are based on pooled statistical analysis of data over 3 years, as per procedure suggested by Fisher (1949).

Table 1 Number of tillers/m², number of green leaves/m² and leaf weight (g/m²) of rice and wheat as influenced by nitrogen and phosphorus and inclusion of summer cowpea in rice–wheat system

Treatment	Rice (60 DAT)			Wheat (90 DAS)		
	Tillers/ m²	Green leaves (g/m²)	Leaf weight (g/m²)	Tillers/ m²	Green leaves (g/m²)	Leaf weight (g/m²)
Summer fallow						
N_0P_0	352	1 094	323.2	1 112	620	158.7
N_0P_{26}	360	1 138	320.0	1 220	692	176.6
Mean	356	1 116	321.6	1 166	656	167.7
$N_{120}P_0$	488	1 436	477.8	1 664	1 024	401.3
$N_{120}P_{26}$	547	1 518	552.2	1 744	1 104	426.2
Mean	518	1 477	515.0	1 704	1 064	413.8
Summer cowpea						
N_0P_0	364	1 080	313.6	1 075	528	133.1
N_0P_{26}	369	1 104	323.2	1 120	560	135.4
Mean	367	1 092	318.4	1 098	544	134.3
$N_{120}P_0$	532	1 438	492.8	1 616	976	396.6
$N_{120}P_{26}$	563	1 521	557.2	1 790	1 168	432.6
Mean	548	1 480	525.0	1 703	1 072	414.6
CD (P = 0.05)						
Nitrogen (N)	33.43	81.61	33.41	72.74	60.47	1.20
Phosphorus (P)	NS*	NS	33.41	72.74	NS	1.20
Cropping system (C)	NS	NS	NS	NS	NS	1.20

DAT, Days after transplanting; DAS, days after sowing

RESULTS AND DISCUSSION

Number of tillers

Fertilizer application increased significantly tillers/m² in rice at 60 days after transplanting and in wheat at 90 days after sowing (Table 1). Compared with N-skipped plots, number of tillers in 120 kg N/ha treatment was greater by 54 and 41% in rice, and 46 and 55% in wheat under summer fallow and fodder cowpea situations respectively. Fertilizer P applied at 26 kg/ha alone did not bring any significant increase in number of tillers over no-P plots, but when combined with 120 kg N the number of tillers increased by 5.8 and 12% in rice, and by 4.8 and 19.7% in wheat under summer fallow and summer cowpea plots respectively. The enhancement in tiller number with increase in fertilizer dose is attributed to the rapid conversion of synthesized carbohydrates into protein and consequent to increase in the number and size of growing cells, resulting ultimately in increased number of tillers (Singh and Agarwal 2001). Although summer crop treatments had no significant effect on the number of tillers when averaged over NP rates, the highest tiller count in rice (548/m²) and wheat (1 168/m²) was recorded in summer cowpea treatments, with combined use of N and P fertilizers.

Green leaves and leaf weight

The number of green leaves at 60 days after transplanting in rice and 90 days after sowing in wheat was significantly increased with 120 kg N/ha, being the highest in rice (1 521/m²) and wheat (1 168/m²) under summer cowpea plots (Table 1). Application of 26 kg P/ha alone did not show marked effect on the green leaf count in rice under summer fallow or summer cowpea treatments, but increased the same by 15% over no P in wheat under summer cowpea plots. A similar pattern was also registered with respect to leaf weight of rice and wheat crop. The increase in tiller count as well as leaf weight due to adequate NP nutrition is explainable in terms of possible increase in nutrient mining capacity of plant as a result of better root development and increased translocation of carbohydrates from source to growing points in well-fertilized plots (Singh and Jain 2000, Singh and Agarwal 2001).

Dry-matter accumulation

Application of 120 kg N/ha enhanced the dry-matter accumulation at maturity compared with no N by 55% in rice and 143% in wheat (Fig 1). Such increase in dry matter may be ascribed to the combined effect of increased tillers, leaves and leaf weight. In general, dry-matter accumulation increased

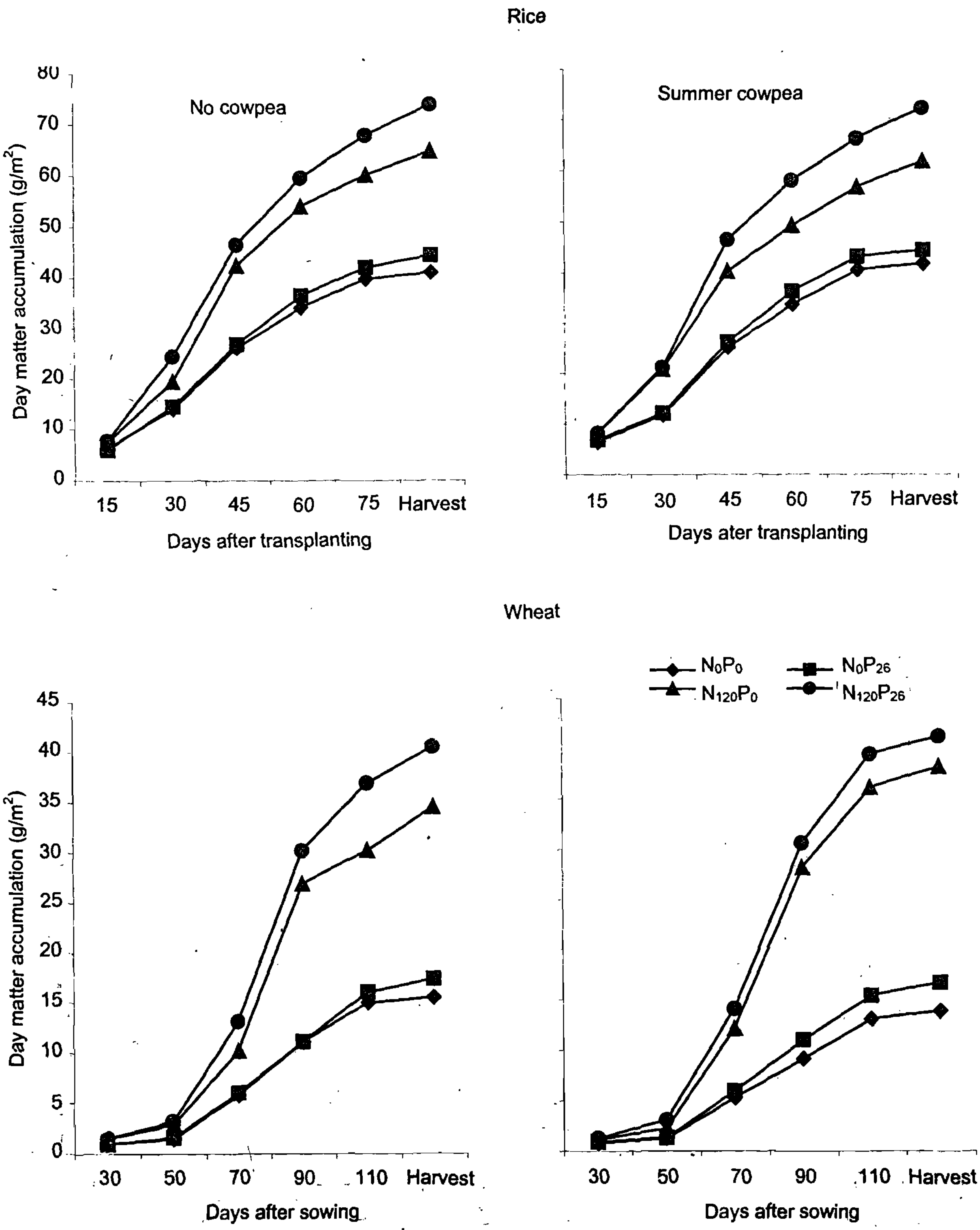

Fig 1 Effect of nitrogen, phosphorus and inclusion of summer cowpea on dry-matter accumulation of rice and wheat at different growth stages

at slow rate up to 15 days after transplanting in rice and 30 days after sowing in wheat, and thereafter increased at faster rate up to 75 days after transplanting in rice and 100 days after sowing in wheat, irrespective of treatments imposed. At later growth periods, senescence of leaves resulted in a decreased crop-growth rate, net assimilation rate and leaf-area index, and consequently the rate of dry-matter accumulation. These findings are in agreement with the results of Shrivastava and

Tripathi (1999). In absence of fertilizer N, application of 26 kg P/ha did not increase the dry-matter accumulation in rice or wheat, but combined use of 120 kg N and 26 kg P/ha resulted in the highest dry-matter yield of both crops. Compared to summer fallow, inclusion of forage cowpea in summer lowered the dry-matter production by both the crops, the magnitude of decrease being 2.5% in rice and 9.6% in wheat. Such effect of forage cowpea was more pronounced in P-skipped plots. On the other hand, inclusion of forage cowpea in the system did not cause any reduction in dry-matter production by either crop, when N and P fertilizers were applied at recommended rate.

Leaf-area index

Leaf-area index increased with time in different treatments, and was maximum at 60 days after transplanting in rice and 90 days after sowing in wheat (Table 2). Thereafter, the leaf-area index gradually declined. The leaf-area index measured at 15-day interval in rice up to 75 days after transplanting and at 20-day interval in wheat up to 110 days after sowing revealed a consistent and statistically significant increase due to 120 kg N/ha throughout the measurement period. Further, 120 kg N applied along with 26 kg P/ha proved superior to 120 kg N alone, and gave the highest leaf-area index at 60 days after transplanting in rice and at 90 days after sowing in wheat. On these dates, leaf-area index values in rice under N_0P_0 (control) were 1.68 and 1.38 in summer fallow and summer cowpea treatments, which were increased to 2.38 (42%) and 2.25 (63%), respectively, with recommended N and P fertilization. The corresponding increase in leaf-area index of wheat (90 days after sowing) was 218% under summer fallow and 239% under summer cowpea forage treatments. However, averaging over N and P fertilizer treatments, the leaf-area index did not differ significantly under fallow and summer cowpea plots. The advantageous effect of balanced N and P fertilization may be explained in terms of enhanced number and size of leaves of both crops. Squire *et al.* (1987) established that the main effect of N fertilizer is to increase the rate of leaf expansion, leading to increased interception of daily solar radiation by the canopy. Fertilizer P applied along with N possibly facilitated root proliferation and ultimately resulted higher nutrient and water uptake to growing cells, and manifested greater leaf area of the crops.

Crop-growth rate

The crop-growth rate during 30–45 days after transplanting in rice and 70–90 days after sowing in wheat was found highest, indicating major activity of plants relating to dry-matter accumulation during these stages (Fig 2). Subsequent decrease in crop-growth rate as noted with the advancement in crop age, irrespective of treatments, might be on account of onset of senescence. It is thus apparent that these growth stages (30–45 days after transplanting in rice and 70–90 days after sowing in wheat) represent peak growth period, and nutrient stress during this period may have averse effect on the crop growth. Application of 120 kg N/ha enhanced the values of crop-growth rate at all the growth stages in rice and wheat, but fertilizer P applied alone could not bring marked change in crop-growth rate. Combined use of 120 kg N and 26 kg P/ha, however, accelerated crop-growth

Table 2 Effect of fertilizer NP and summer cowpea on leaf-area index of rice and wheat at different growth stages

Treatment	Rice					Wheat				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	30 DAS	50 DAS	70 DAS	90 DAS	110 DAS
Summer fallow										
N_0P_0	0.67	1.41	1.58	1.68	1.45	0.19	0.36	0.81	1.02	0.65
N_0P_{26}	0.65	1.45	1.61	1.72	1.48	0.20	0.41	0.89	1.03	0.67
Mean	0.66	1.43	1.59	1.70	1.47	0.20	0.39	0.85	1.03	0.66
$N_{120}P_0$	0.88	1.60	2.04	2.30	2.05	0.24	0.64	2.66	2.99	2.24
$N_{120}P_{26}$	0.95	1.75	2.06	2.38	2.12	0.26	0.74	3.04	3.24	2.59
Mean	0.92	1.68	2.05	2.34	2.09	0.25	0.69	2.85	3.12	2.42
Summer cowpea										
N_0P_0	0.57	1.24	1.29	1.38	1.35	0.15	0.30	0.80	0.97	0.65
N_0P_{26}	0.62	1.29	1.38	1.45	1.38	0.14	0.32	0.92	1.03	0.71
Mean	0.60	1.27	1.34	1.42	1.37	0.15	0.31	0.86	1.00	0.68
$N_{120}P_0$	0.67	1.48	1.86	2.18	1.93	0.22	0.62	2.42	2.66	1.93
$N_{120}P_{26}$	0.70	1.64	2.09	2.25	2.02	0.22	0.75	2.93	3.29	2.55
Mean	0.69	1.56	1.98	2.22	1.98	0.22	0.69	2.68	2.98	2.24
CD (P = 0.05)										
N	NS	0.07	0.16	0.10	0.09	0.02	0.04	0.19	0.12	0.10
P	NS	NS	0.16	0.10	NS	NS	NS	NS	0.12	0.10
C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAT, Days after transplanting; DAS, days after sowing

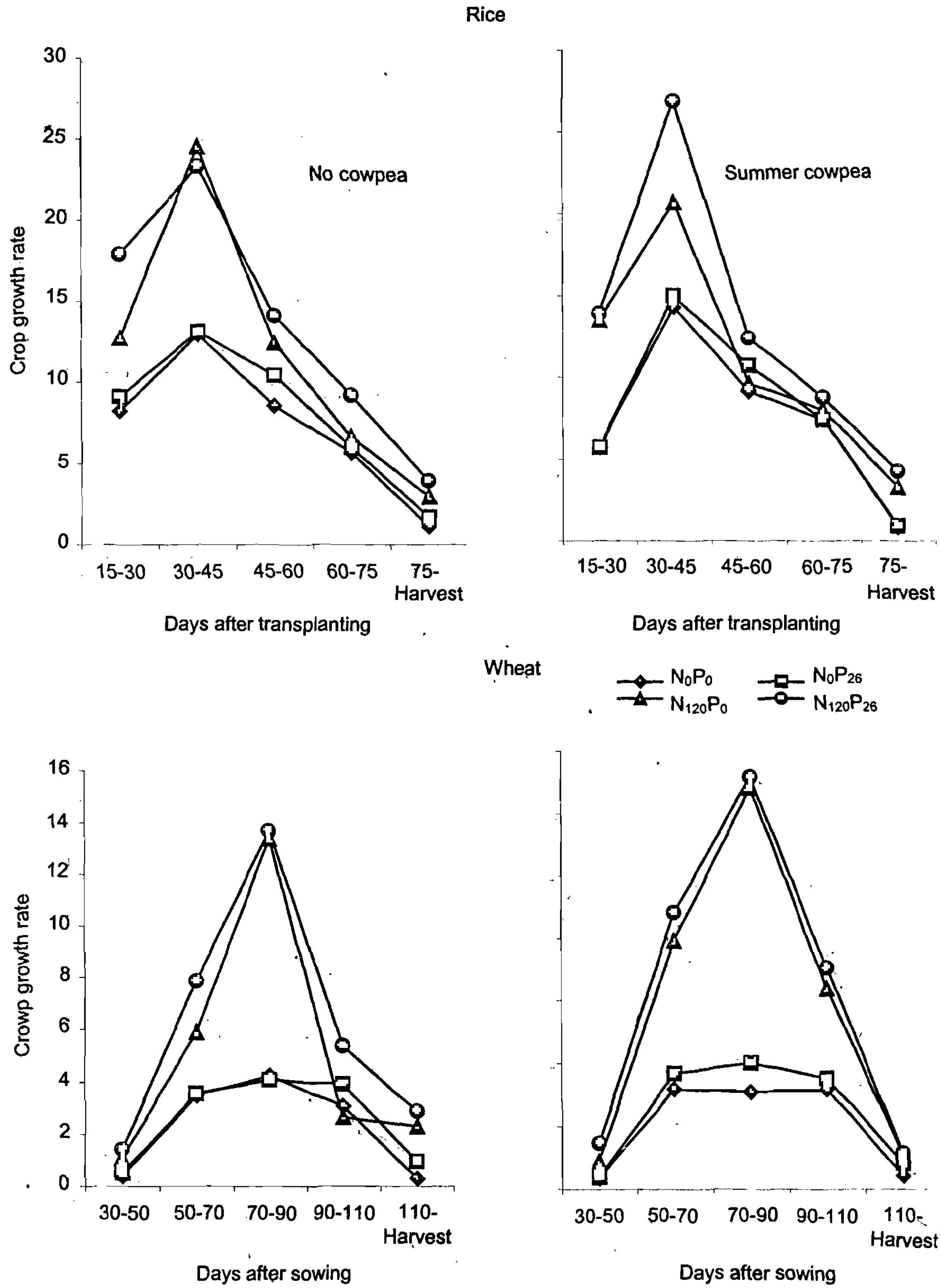

Fig 2 Effect of nitrogen, phosphorus and inclusion of summer cowpea on crop-growth rate (g/m^2/day) of rice and wheat

rate irrespective of summer crop options, ie summer fallow or forage cowpea, probably on account of increase in dry-matter yield owing to balanced N and P nutrition to the crops. The advantage of conjunctive use of N and P over fertilizer N or P alone may also be partly ascribed to greater photosynthesis via larger and sustained photosynthetically active leaf surface

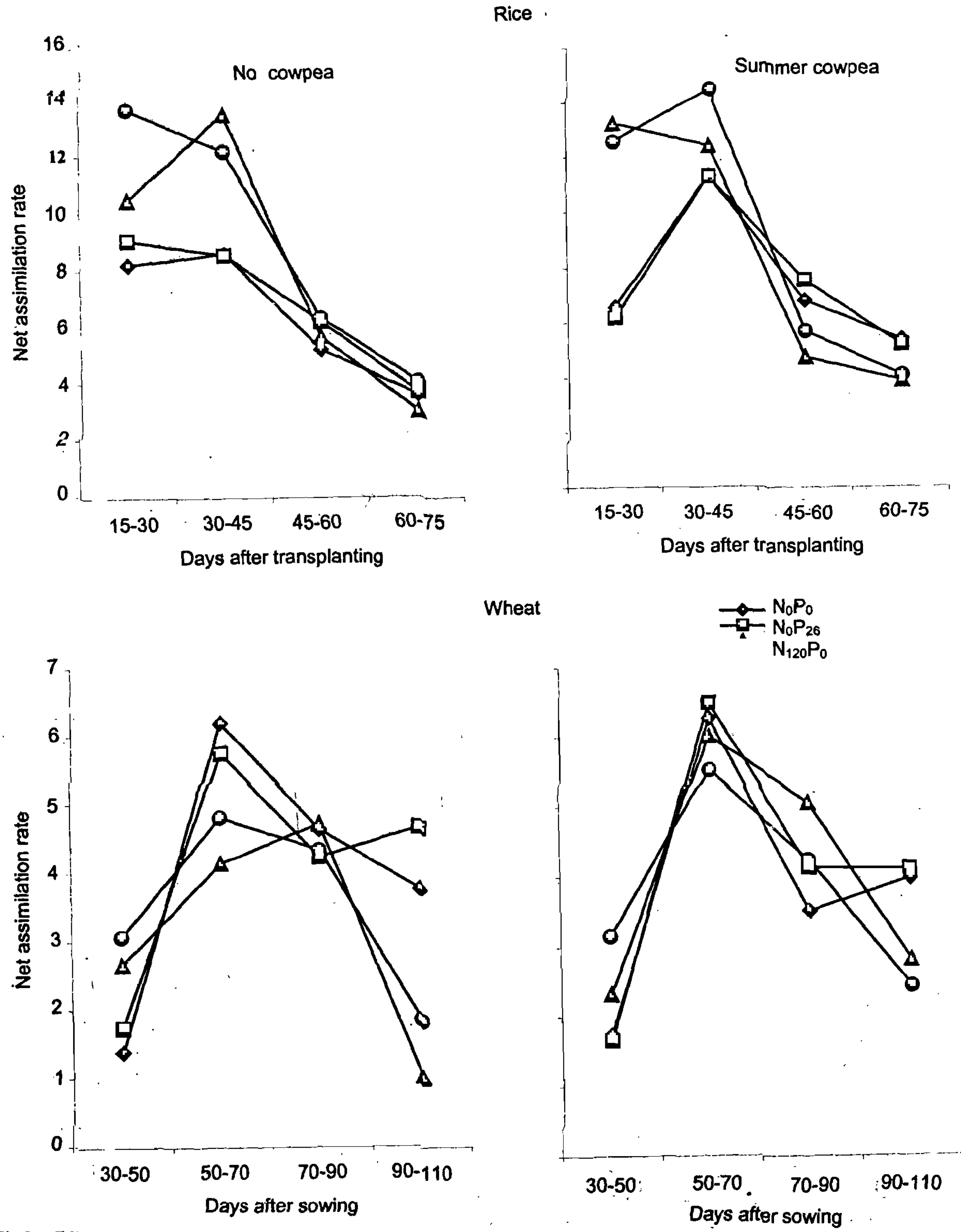

Fig 3 Effect of nitrogen, phosphorus and inclusion of summer cowpea in rice–wheat cropping system on net assimilation rate ($g/m^2/day$) of rice and wheat

on account of delayed leaf senescence, and prevention of chlorophyll degradation in the former case. The crop-growth rate values, averaged over N and P treatments, revealed that inclusion of forage cowpea in the system hardly influenced crop-growth rate in rice and wheat.

Net assimilation rate

In general, net assimilation rate increased up to 45 days after transplanting in rice and 70 days after sowing in wheat (Fig 3). Compared with no N, application of 120 kg N/ha increased the net assimilation rate in rice by 64% at 15–30

Table 3 Yield and yield attributes of rice and wheat crop as influenced by nitrogen and phosphorus and inclusion of summer cowpea

Treatment	Grain yield (tonnes/ ha)	Straw yield (tonnes/ ha)	Ear/ m²	Grains/ ear	Grain weight/ ear	1 000-grain weight (g)
			Rice			
Summer fallow						
N_0P_0	3.08	3.57	46	75	1.32	17.6
N_0P_{26}	3.24	3.82	42	79	1.29	16.3
Mean	3.16	3.70	44	77	1.31	17.0
$N_{120}P_0$	5.76	7.40	76	96	1.80	18.8
$N_{120}P_{26}$	6.29	7.93	78	104	1.96	18.8
Mean	6.03	7.67	77	100	1.88	18.8
Summer cowpea						
N_0P_0	2.80	3.31	36	70	1.29	18.4
N_0P_{26}	3.25	3.86	37	74	1.29	17.4
Mean	3.03	3.59	36.5	72	1.29	17.9
$N_{120}P_0$	5.28	6.87	70	95	1.72	18.1
$N_{120}P_{26}$	6.18	7.79	76	106	2.01	19.0
Mean	5.73	7.33	73.0	100.5	1.87	18.6
CD (P = 0.05)						
N	0.43	0.47	3.82	4.92	0.061	1.34
P	0.43	0.47	NS	NS	0.061	NS
C	NS	NS	3.82	NS	NS	NS
			Wheat			
Summer fallow						
N_0P_0	1.75	2.52	72	24	0.76	31.7
N_0P_{26}	1.95	2.76	84	26	0.82	31.5
Mean	1.85	2.64	78	25	0.79	31.6
$N_{120}P_0$	4.19	6.16	94	30	1.03	34.3
$N_{120}P_{26}$	5.06	6.58	100	33	1.24	37.6
Mean	4.63	6.37	97	31.5	1.14	36.0
Summer cowpea						
N_0P_0	1.52	2.17	64	22	0.59	26.8
N_0P_{26}	1.75	2.47	80	22	0.63	28.6
Mean	1.64	2.32	72	22	0.61	26.7
$N_{120}P_0$	3.90	5.73	90	30	0.93	31.0
$N_{120}P_{26}$	5.38	7.11	103	34	1.20	35.3
Mean	4.64	6.42	96.5	32	1.07	33.2
CD (P = 0.05)						
N	0.29	0.38	5.13	2.42	0.047	2.33
P	0.29	0.38	5.13	NS	0.047	2.33
C	NS	NS	NS	NS	0.047	2.33

days after transplanting and by 32% at 30–45 days after transplanting, and in wheat by 72% at 30–50 days after sowing. On the other hand, P fertilization at 26 kg/ha along with N had a marginal effect on net assimilation rate during peak growth period, i e 45 days after transplanting in rice and 70 days after sowing in wheat. The net assimilation rate values, however, remained practically unaffected due to inclusion of summer cowpea. Higher leaf-area index attained through adequate NP fertilization led to greater interception of solar radiation and consequently high photosynthetic efficiency, which ultimately resulted in greater net assimilation rate in rice and wheat compared to N or P-skipped plots.

Yield attributes

Use of N alone or in combination with P significantly increased ears/m², grains/ear, grain weight/ear and 1 000-grain weight in rice and wheat, over N_0P_0 (control) (Table 3). The highest values of different yield attributes were recorded in the plots receiving 120 kg N and 26 kg P/ha to both the crops, irrespective of summer crop treatments. In N_0P_0 (control), the measured yield attributes were generally greater under summer fallow compared with those under summer cowpea. However, such differences were masked, when both the crops received N and P at recommended rate. Relatively higher values of various yield attributes in adequately fertilized plots are ascribed to the special significance of P in the formation of reproductive organs, fertilization and grain development, and that of N in improving the translocation of carbohydrates from the source to sink. On the other hand, marked reduction in different attributes under the control may be explained in terms of possible breakdown of some of the conducting tissue in N and P deficient plants (Yan *et al.* 1992). By and large, adequate supply of N and P throughout growth period improved plant vigour as also the yield attributes.

Grain and straw yield

The pooled data of rice and wheat yields revealed that both the crops responded significantly to 120 kg N/ha, compared to no fertilizer N plots (Table 3). Application of 26 kg P/ha along with N increased the grain and straw yields significantly over treatments receiving N alone, but response to P was negligible in absence of N application. Averaged over summer crop options, highest yields of rice (6.24 tonnes/ ha) and wheat (5.22 tonnes/ha), were recorded with combined use of 120 kg N and 26 kg P/ha, indicating the significance of balanced fertilizer use. Compared with summer fallow, raising of forage cowpea in summer resulted in lower yield of succeeding cereal crops in the plots receiving N or P alone, or none of these nutrients; the magnitude of such yield loss in the control (N_0P_0) was 3.7% in rice and 2.9% in wheat. The summer cowpea-induced yield reduction was greater in P-skipped plots, ie 9% in rice and 10.5% in wheat, compared to summer fallow treatments. With N and P fertilization to rice and wheat at recommended rate, no such adverse effect of cowpea was observed. In plots fertilized with N and P, summer cowpea rather had an edge over summer fallow by raising wheat grain yield to the extent of 0.32 tonne/ha, though the yield differences owing to inclusion of cowpea were statistically not significant. In fact, cowpea grown without any fertilizer left soil depleted of its native nutrients, especially P, which in turn lowered the yield of subsequent crops (Dwivedi *et al.* 2000). The above-ground biomass of cowpea harvested from ground level for the fodder purpose removed more nutrients from the soil than recycled through roots and nodules. Legumes may even have a negative N balance in soil despite biological N fixation, when entire above-ground biomass is removed from the field (Peoples and Herridge 1990). The adverse effect of forage cowpea on the yield of subsequent rice and wheat crops grown without adequate nutrient supply is thus explainable.

Thus pre-rice summer season can be effectively utilized for raising summer legume (forage cowpea) crop, provided both rice and wheat are adequately fertilized. Skipping of either N or P to these crops may, however, lead to yield loss. Ensuring a stress-free condition at the stages of peak physiological activity in rice and wheat, as revealed by the highest values of crop-growth rate and net assimilation rate, may further enhance the crop yields.

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Preparation of phosphorus-enriched compost and its effect on yield and phosphorus uptake by soybean (*Glycine max*) grown in a Vertisol

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ABSTRACT

An investigation was carried out during 1998 and 1999 on the preparation of phosphorus-enriched compost (phospho-compost) and its effect on yield and uptake of phosphorus by 'JS 335' soybean [*Glycine max* (L.) Merr.]. The phospho-compost was prepared by mixing the organic waste materials, viz wheat (*Triticum aestivum* L. emend. Fiori & Paol.) stubble, soybean [*Glycine max* (L.) Merr.] straw and linseed (*Linum usitatissimum* L.) straw in equal proportion, cattle dung, soil and well-composed farmyard manure in ratio of 8 : 1 : 0.5 : 0.5, and finally charging these with low-grade Jhabua rockphosphate of 100 mesh (containing 20% P_2O_5) @ 12.5 and 25% of the total composting material. These 2 types of phospho-composts, each prepared in the pit of 3 m × 2 m × 1 m for 3½ months, were found significantly superior to the plain compost (with no incorporation of Jhabua rockphosphate) for NH_4^+-N (216 and 256 mg/kg), NO_3^--N (300 and 355 mg/kg), total N (1.09 and 1.17%), water-soluble P (370 and 520 mg/kg), citrate-soluble P (3.41 and 5.10 g/kg), total P_2O_5 (4.04 and 6.22%) and phosphate-solubilizing fungi (11.7 and 15.0 × 10^5 CFU/g) and were having a narrow C : N ratio of 19.59 and 16.89 respectively. Application of 60 kg P_2O_5/ha either as 12.5% Jhabua rockphosphate-charged phospho-compost (PC_1) @ 2.5 tonnes/ha or as 25.0% Jhabua rockphosphate-charged phospho-compost (PC_2) @ 1.5 tonnes/ha exhibited statistically identical performance for growth and yield parameters of soybean and were significantly superior to the control (without P application). Both the phospho-composts were as effective as the application of 60 kg P_2O_5/ha supplied through single superphosphate. The results showed that Jhabua rockphosphate-charged phospho-compost was a good source of P and can act as a substitute of single superphosphate, when applied to soil on equal P_2O_5-basis.

Keywords: P-enriched compost, Soybean yield, P uptake, Vertisols, *Glycine max*

Organic manures and composts have been used as a means of improving fertility and productivity of soils all along the farming history. Organic manures addition improves physical, chemical and biological properties of the soil and also improve nutrient-use efficiency. Despite known benefits of manures, low nutrient content, bulky nature, high transportation and handling costs and limited availability of organic manures restricts their use by the farming community. Effective and economically viable technologies have been developed in the recent past to hasten the process of composting of agricultural residues for reducing the period of decomposition through cellulolytic fungi (Bhardwaj and Gaur 1985). In order to upgrade nutrient content of compost, the use of fertilizer N, rockphosphate, feldspar, pyrite, N_2-fixing bacteria and phosphate-solubilizing microorganisms has been documented (Manna *et al.* 1997). Phosphorus enrichment of compost owing to addition of low-grade rock phosphates, available abundantly in various parts of India, in association with phosphate-solubilizing fungi (*Aspergillus awamori*) accelerates the process of composting as well as its quality (Singh *et al.* 1992, Singh, 2000). Insoluble P of rockphosphate could be transformed to plant-available form during composting and was efficiently utilized by crops in neutral and alkaline soils. The present study was therefore made to produce phosphorus-enriched compost (phospho-compost) using farm waste and low-grade indigenous rock phosphate from Madhya Pradesh State Mining Corporation, Jhabua, Madhya Pradesh and assess the performance of phospho-compost as an alternative source of P for soybean [*Glycine max* (L.) Merr.] with respect to symbiotic traits, yield and P-uptake in a Vertisol (Typic Haplustert) of Malwa Plateau in Madhya Pradesh.

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MATERIALS AND METHODS

Technique of phospho-compost production

The compost-mix comprising farm waste, viz wheat (*Triticum aestivum* L. emend. Fiori & Paol.) stubble, soybean straw and linseed (*Linum usitatissimum* L.) straw in 1 : 1 : 1 ratio, cattle dung, soil and well-decomposed farmyard manure in the ratio of 8 : 1: 0.5 : 0.5 was charged with 12.5 and 25.0% Jhabua rockphosphate (JRP) containing 20% P_2O_5. For effective transformation of JRP during composting, a slurry of cattle dung, soil, well-decomposed farmyard manure (FYM) and the calculated quantity of JRP (12.5 kg/100 kg of compost-mix) was prepared and added to the organic wastes by simultaneous mixing of the entire mass. The lignite-based inoculant of phosphate-solubilizing fungus, *Aspergillus awamori* procured from the Department of Microbiology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, and cellulose-decomposing inoculant of *Trichurus spiralis* from Division of Microbiology, Indian Agricultural Research Institute, New Delhi, were uniformly applied to the compostable material, each @ 0.5 kg inoculum/ tonne of material. In all, 10 layers, each of 100 kg compost-mix were arranged one over the other in a pit of 3 m × 2 m × 1 m size, lined with polyethylene sheet, keeping the moisture level at 70% in each layer. Finally, a thin layer of soil and cattle dung was coated on the top of the pit. Composting of the material was continued for a period of 3½ months, providing turning of contents at 20, 40 and 80 days. During the second turning at 40 days, the composting material was re-inoculated with a lignite-based inoculant of phosphate-solubilizing fungus *Aspergillus awamori*. Appropriateness of moisture level was checked at each turning.

In all, 4 types of experimental composts: (C_1) organic wastes (wheat stubble, soybean straw and linseed straw in the ratio of 1 : 1 : 1) (C_2) organic wastes + amendments (cattle dung + soil + FYM); each item in ratio of 8 : 1 : 0.5 : 0.5, (C_3) organic wastes + amendments + 12.5% JRP, and (C_4) organic wastes + amendment + 25.0% JRP, were prepared in separate pits as per procedure outlined above at the Agriculture College Research Farm, Indore, in February 1998. After 3½ months, the composted material from each treatment was thoroughly mixed and 5 random samples of the finished product drawn from each treatment were subjected to analysis for organic carbon (ignition method), total N (Bremner and Mulvaney 1982), NH_4^+-N and NO_3^--N (Bremner 1965), water-soluble, citrate-soluble and total P_2O_5 (Jackson 1967) and for counts of P-solubilizing fungus (Subba Rao 1982).

Data were recorded on composition of phospho-compost after 3½ months of decomposition in respect of organic C, total N, C : N ratio, NH_4^+-N, NO_3^--N, water soluble P, citrate soluble P, total P_2O_5 and phosphate solubilizing fungus (*Aspergillus awamori*).

Evaluation of phospho-compost

A field experiment was conducted during the rainy season of 1998 and 1999 at Research Farm of College of Agriculture, Indore, Madhya Pradesh, to assess the P-supplying value of phospho-compost in comparison with single superphosphate (SSP) on equal P_2O_5 basis for symbiotic traits, yield and P uptake of soybean. The climate of Malwa Plateau (western part of Madhya Pradesh) is a subtropical climate with mean annual precipitation of 942 mm, most of which was received from mid-June to the last week of August. The soil of the experimental site belongs to Sarol series of Vertisol order and classified as a member of fine smectitic hyperthermic family of a Typic Haplustert with initial characteristics as : texture-clay, *p*H 7.8; EC 0.21 dS/m; organic carbon, 0.30%; available N, 180 kg/ha; available P_2O_5 27.6 kg/ha and available K_2O, 460 kg/ha. The treatments were: T_1, control (without P); T_2, 60 kg P_2O_5/ha as phospho-compost of 12.5% JRP applied @ 2.5 tonnes/ha (PC_1); T_3, 50 kg P_2O_5/ha as phospho-compost of 25.0% JRP, applied @ 1.5 tonnes/ha (PC_2); T_4, 60 kg P_2O_5/ha as SSP; and T_5, 60 kg P_2O_5/ha as SSP + 5 tonnes farmyard manure/ha. The experiment was laid out in randomized block design with 4 replications. A basal dose of 20 kg N and 20 kg K_2O/ha was applied at the time of sowing through urea and muriate of potash respectively. Soybean var 'JS 335' was sown in 5 m × 3.2 m plots, keeping row-to-row distance of 40 cm.

The data were recorded on symbiotic traits including nodule number, nodule dry weight, shoot dry weight of soybean at 50-day stage of the crop during rainy season of 1998 and 1999.

Composition of phospho-compost

Organic carbon and total nitrogen: Organic C content in the composted material reduced to 24.18% in the organic waste (C_1) and 23.80% in the amended organic waste (C_2) compared with 46.12% in the original raw substrate (Table 1). Incorporation of Jhabua rockphosphate (JRP) @ 12.5% (C_3) and 25.0% (C_4) further reduced the organic C to 21.35 and 19.76% respectively. The highest significant reduction was, however, noticed when the phospho-compost was charged with JRP @ 25.0%. In contrast to organic C, the total N content in the finished phospho-compost increased significantly due to charging of organic waste either at 12.5% or 25.0% level (1.09% or 1.17% respectively) compared with organic waste with or without amendment.

C : N ratio : The decline in C : N ratio was recorded in all the 4 treatments due to composting, the values ranging from 27.79 in C_1 to 16.89 in C_4. The maximum decline was noted in C_4, where organic waste was charged with JRP @ 25.0%, the C : N ratio of the original, raw organic waste being 67.82. The decline in C : N ratio was due to optimum proportion of the organic substrates (8 : 1 : 0.5 : 0.5), as it provides a congenial atmosphere for decomposition. Mishra and Bangar (1986) also found this ratio as optimum for decomposition of organic wastes.

NH_4^+-N and NO_3^--N : A significant increase in NH_4^+-N as well as NO_3^--N was recorded in both the treatments where JRP was incorporated with the organic waste either at 12.5% or 25.0% level over the organic waste material alone or with amendment, the values of NH_4^+-N, being 216 and 256 mg/kg and those of NO_3^--N being 300 and 355 mg/kg respectively.

Table 1 Chemical composition of phospho-compost after 3½ months of decomposition

Compost	Organic C (%)	Total N (%)	C : N ratio	NH_4^+-N (mg/kg)	NO_3^--N (mg/kg)	Water-soluble P (mg/kg)	Citrate-soluble P (g/kg)	Total P_2O_5 (%)	P-solubilizing fungus (10^5 CFU/g)
C_1	24.18	0.87	27.79	162	232	160	1.26	0.32	4.3
C_2	23.80	0.88	27.05	170	240	172	1.28	0.35	5.0
C_3	21.35	1.09	19.59	216	300	370	3.41	4.04	11.7
C_4	19.76	1.17	16.89	256	355	520	5.10	6.22	15.0
CD (P = 0.05)	1.26	0.07		34	41	74	0.28	0.15	3.9
Initial	46.12	0.68	67.82						

Details of composts are given under Materials and Methods

Water soluble P, citrate soluble P and total P_2O_5 : Addition of JRP at both the levels (12.5% and 25.0%) in treatments C_3 and C_4 resulted in significantly higher water-soluble, citrate-soluble and total P_2O_5 compared with C_1 and C_2 without JRP, the values being 370 and 520 mg/kg, 3.41 and 5.10 g/kg and 4.04 and 6.22% respectively. However, C_4 exhibited its superiority to C_3.

Phosphate-solubilizing fungus: A significantly higher population of phosphate-solubilizing fungus (PSF) was recorded due to addition of JRP @ 12.5 and 25.0%, respectively, compared to the organic waste material without JRP (C_1 and C_2), the values of PSF being 11.7 and 15.0 × 10^5 CFU/g (count fungal unit) of the phospho-compost.

Bhanavase *et al.* (1994) and Manna *et al.* (1997) also reported a significant increase in NH_4^+-N, NO_3^+-N, water-soluble P, citrate-soluble P and total P and decrease in C : N ratio.

Influence of phospho-compost on soybean

Symbiotic traits: The application of phospho-compost prepared from 12.5 and 25.0% JRP (T_2 and T_3) produced a significantly more number of nodules/plant, nodule dry weight and shoot dry weight compared to their respective controls (Table 2). It was noted that these phospho-composts, when applied to soil @ 2.5 and 1.5 tonnes/ha, respectively, to supply 60 kg P_2O_5/ha to a soybean crop, behaved identically with single superphosphate (SSP) applied @ 60 kg P_2O_5/ha for producing nodules/plant, nodule dry weight and shoot dry weight. The application of 60 kg P_2O_5/ha through SSP + 5 tonnes farmyard manure/ha (T_5) helped in bringing about more nodules/plant, nodule dry weight and shoot dry weight compared to the application of single superphosphate alone @ 60 P_2O_5/ha.

Table 2 Effect of phospho-compost on symbiotic traits (50 days after sowing) and uptake of phosphorus by soybean at harvest (mean data of 2 years)

Treatment	Nodules/ plant	Nodule dry weight (mg/plant)	Shoot dry weight (g/plant)	Total P uptake (kg/ha)
T_1	22	140	4.68	5.23
T_2	37	189	7.30	10.90
T_3	35	190	7.09	10.67
T_4	33	182	6.88	10.55
T_5	40	196	8.17	11.00
CD (P = 0.05)	6	11.1	1.20	0.55

Details of treatments are given under Materials and Methods

Phosphorus-uptake: The mean P uptake of soybean during 1998 and 1999 in different treatments ranged from 5.23 to 11.00 kg/ha (Table 2). It was noted that both the phospho-composts (PC_1 and PC_2) behaved identically for total P-uptake by grain and straw and were at par with SSP, the values ranging from 10.55 to 10.90 kg/ha. Singh (2000), Rasal *et al.* (1996) also reported results of the similar kind while studying the effect of phospho-compost on nodulation, dry-matter yield and grain yield of soybean.

Seed and straw yield: The treatments (T_2, T_3, T_4 and T_5) (PC_1, PC_2 SSP and SSP + 5 tonnes FYM/ha) significantly increased the yield of soybean over no application of P, and were statistically identical (Table 3). The mean seed yield given by T_2 and T_3 was 1.679 and 1.653 tonnes/ha, whereas the straw yield was 2.959 and 2.864 tonnes/ha respectively. Both the phospho-composts were found as effective as the application of 60 kg P_2O_5/ha through SSP, which registered the mean seed and straw yield of 1.636 and 2.786 tonnes/ha respectively. The treatment without P application recorded the mean seed yield of 1.192 tonnes/ha and straw yield of 2.001 tonnes/ha. Although treatment T_5 (60 kg P_2O_5/ha through SSP + 5 tonnes FYM/ha) increased the symbiotic traits significantly, it could bring about only numerical rise in seed as well as straw yields compared with 60 kg P_2O_5/ha applied through T_2, T_3 and T_4.

Net return: The highest net return (Rs 9 904/ha) was obtained in T_2, followed by T_4. All the levels were significantly higher than control (T_1) in respect of net return. Treatment T_2 gave 43% higher net return over the control (T_1). Net return/Re invested followed the same trend as that of net return (Rs/ha). No significant difference was obtained in treatments T_1 and T_5 in net return/Re invested. This was due to the higher

Table 3 Seed and straw yields of soybean and net return as influenced by phospho-compost application in soybean (mean data of 2 years)

Treatment	Seed yield (tonnes/ha)	Straw yield (tonnes/ha)	Cost of grain (Rs/ha)	Cost of straw (Rs/ha)	Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	Net return/ Re invested
T_1	1.192	2.001	10 728	600	11 328	5 682	5 646	1.00
T_2	1.679	2.959	15 111	888	15999	6 095	9 904	1.63
T_3	1.653	2.864	14 877	859	15 736	6 180	8 556	1.38
T_4	1.636	2.786	14 724	836	15 560	6 747	8 813	1.30
T_5	1.776	3.109	15 984	933	16 917	8 347	8 570	1.03
CD (5%)	0.269	0.430			2 800	409	1 354	0.21

Details of treatments are given under Materials and Methods

Cost of cultivation excluding fertilizer P_2O_5: Rs 5 682; price of seed Rs 9 000/tonne; Price of straw Rs 300/tonne; Price of single superphosphate Rs 2 840/tonne; farmyard manure Rs 320/tonne; price of Jhabua rockphosphate Rs 1 310/tonne; T_2 @ 2.5 tonne/ha PC) - 125 kg rockphosphate required for preparation of 1 tonne of PC; T_3 @ 1.5 tonnes/ha PC)-250 kg rock phosphate required for preparation of 1 tonne of PC

cost of farmyard manure used in T_5.

The results of 1998 and 1999 with respect to nodulation, shoot dry weight, yield and P uptake of soybean indicate that enrichment of compost with indigenously available Jhabua rockphosphate of low grade (containing 20% P_2O_5 and costing Rs 131/100 kg) has the potential of producing a good quality manure rich in available P which could influence the symbiotic parameters and finally the yield of soybean. The production technology of phospho-compost not only provides the benefits of transforming insoluble phosphorus existing in Jhabua rockphosphate into the plant available form, but also makes available the organic matter was well as other essential plant nutrients required for sustainable crop production.

It was concluded that the application of 1.5 to 2.5 tonnes/ha of phospho-compost prepared by co-composting of bio-degradable farm wastes and rockphosphate can fulfil the entire P-requirement of soybean crop (60 kg P_2O_5/ha) and can act as a substitute of single superphosphate, when applied to soil, prior to sowing, on equal P_2O_5-basis.

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Effect of planting date, irrigation and weed-control method on yield and water-use efficiency of cumin (*Cuminum cyminum*)

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ABSTRACT

A study was conducted during the winter season of 1996–97 and 1997–98 at the Agricultural Research Station, Mandor, Rajasthan to determine the effect of planting date, irrigation and weed-control measure on yield and water-use efficiency in cumin (*Cuminum cyminum* L.). Cumin planted on 15 November gave significantly higher seed yield (834 kg/ha) than 30 November planting. Irrigation schedule of 4 irrigations resulted in significantly higher seed yield (889 kg/ha) of cumin over 3 irrigations under 15 November planting. However, under late-sown condition of 30 November, 3 irrigations gave seed yield statistically at par (748 kg/ha) with the schedule of 4 irrigations in cumin. Fluchloralin at 1.0 kg/ha as pre-plant incorporation resulted significantly higher seed yield (814 kg/ha) of cumin over weedy check and hand-weeding. However, the maximum seed yield (865 kg/ha) of cumin was obtained under weed-free treatment. Maximum water-use efficiency (5.83 kg/ha-mm) was recorded in 15 November planting and weed-free treatments (7.86 kg/ha-mm), followed by fluchloralin at 1.0 kg/ha. Marginally higher water-use efficiency was obtained under 3 irrigations over schedule of 4 irrigations during both years.

Keywords: Aromatic crop, Cumin production, *Cuminum cyminum*, Fluchloralin, Consumptive use, Weed, Sowing date

Cumin (*Cuminum cyminum* L.) is one of the most important seed spice crops of arid regions of Rajasthan and Gujarat. Common planting time of cumin in the arid region is around 15–30 November, depending on the cropping system adopted. Patel *et al.* (1992) and Jangir and Singh (1996) reported the irrigation schedule of cumin for arid and semi-arid regions, but information on irrigation scheduling in relation to planting time is meagre. Further, cumin is a short-stature crop with slow initial growth and, therefore, gets heavily infested with several weeds which cause severe competition with the crop, resulting in yield reduction of 80–90% and associated losses in profitability (Choudhary and Gupta 1992, Parihar and Singh 1994). Fluchloralin is a commonly used herbicide to control weeds in cumin (Mehta and Bhadoriya 1982). The emergence and growth of weeds in relation to planting time and irrigation may influence the competition of weeds and efficiency of herbicides (Malik and Singh 1993). Hence an experiment was conducted to determine the effect of weed control, planting date and irrigation on yield and water-use efficiency of cumin.

MATERIALS AND METHODS

The field experiment was conducted at the Agricultural Research Station, Mandor (Jodhpur), during the winter season of 1996–97 and 1997–98. The sandy loam soil was alkaline (*p*H 8.3), low in organic carbon (0.25%) content, medium in available P (12.4 kg/ha) and high in available K (259 kg/ha). The moisture contents at field capacity and 15 bar tension were 7.93% and 2.84% water respectively. The bulk density of 25 cm surface soil was 1.54 g/cm^3. The preceding crop in both the years was pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz].

The treatments comprised 2 planting date (D_1, 15 November and D_2, 30 November) and 2 irrigation levels [I_1, at 10, 40 and 70 days after sowing (DAS); I_2, 10, 35, 60 and 85 DAS] in main plots and 4 weed-control treatments [hand-weeding, fluchloralin at 1.0 kg/ha as pre-plant incorporation; weed-free and a weedy check] in subplots, were tested in split-plot design with 3 replications. The weed-free treatment was achieved by applying pendimethalin at 1.0 kg/ha as pre-emergence and then weeds were removed by hand-weeding as and when emerged.

The cumin variety, 'RZ 19' was sown as per the planting treatments at a row spacing of 30 cm. The 15 kg N and 8.6 kg P/ha were uniformly applied at sowing and remaining 15 kg N top-dressed at the time of the second irrigation. Irrigation depth was kept 50 mm in all irrigation levels. Soil water content to a depth of 60 cm was determined using the gravimetric method. Soil-moisture measurements were taken in the experimental field before sowing, before each irrigation and 24 hr after the irrigation throughout the growing season.

Crop water use and water-use efficiency for each treatment

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was calculated as described by Dastane (1972) and Viets (1962) respectively. Herbicides were sprayed with a hand-operated knapsack sprayer. The samples for weed dry matter were collected randomly from each plot using a 50 cm × 50 cm quadrat.

RESULTS AND DISCUSSION

Weeds

The major weed species of the experimental field were lamb's quarters (*Chenopodium album* L.); *bathu* (*C. murale* L.) and *jungli palak* (*Rumex dentatus* L.) during both the years. The other weeds were wild onion (*Asphodels tenuifolius* Cav.), *dhub grass* [*Cynodon dactylon* (L.) Pers.] and annual yellow sweet clover (*Melilotus indica* (L.) All. The planting date significantly affected the dry weight of weeds in cumin. Crop planted 30 November significantly reduced the dry weight of weeds compared with that planted on 15 November during both the years (Table 1). This may be due to the reduction in the mean temperature. Malik and Singh (1993) also reported reduction in growth of *Chenopodium* spp under delayed planting of wheat.

Irrigation scheduling of 3 or 4 irrigations did not affect the dry weight of weeds during both the years (Table 1). It may be attributed to the deeper tap root-system of weeds, particularly of dominant *Chenopodium* spp (Shahi 1978).

All the weed-control treatments minimized the dry weight of weeds significantly compared with the weedy check (Table 1). Application of fluchloralin at 1.0 kg/ha as pre-plant incorporation (ppi) significantly reduced the dry weight of weeds in cumin compared to hand-weeding treatment during both the years. Parihar and Singh (1994) also reported similar results.

Crop

Significantly higher seed yield of cumin was obtained under 15 November planting than 30 November planting, because of higher number of branches and umbles/plant and 1 000-seed weight in early planting date (Table 1). Irrigation scheduling of 4 irrigations significantly increased the seed yield of cumin compared with 3 irrigations during both the years. The findings of the study confirm those of Jangir and Singh (1996) who advocated schedule of 4 irrigations for normal sowing cumin.

Significant interaction between planting dates and irrigation scheduling showed that the planting of cumin on 15 November with 4 irrigations resulted in the maximum seed yield of cumin compared with application of 3 irrigations; however, the seed yield of cumin was not significantly affected due to 4 irrigations under delayed sowing of 30 November (Table 2).

All the weed-control treatments significantly increased branches/plant, umbles/plant, 1 000-weight and consequently seed yield of cumin compared with the weedy check (Table 2). Maximum and significantly higher seed yield of cumin was obtained in weed-free treatment, followed by fluchloralin @ 1.0 kg/ha as pre-plant incorporation compared to hand-weeding during both the years. The results confirm the findings of Mehta and Bhadoriya (1982) and Parihar and Singh (1994).

Table 1 Effect of planting date, irrigation scheduling and weed control on weed dry weight, yield attributes and seed yield of cumin

Treatment	Weed dry weight (g/m²)		Branches/plant		Umbles/plant		1 000-seed weight (g)		Seed yield (kg/ha)		
	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98	Mean
Planting date											
15 November	21.76** (473)	23.11 (534)	4.0	5.6	20.4	25.4	5.26	5.41	805	862	834
30 November	18.49 (342)	16.67 (278)	4.8	4.9	15.8	17.2	4.87	5.12	701	810	755
CD (P = 0.05)	0.95	1.84	0.4	0.3	3.6	4.2	0.18	0.24	50	49	25
*Irrigation Schedule**											
3 irrigations	20.43 (417)	19.96 (398)	4.1	5.0	16.2	17.8	5.04	5.31	718	809	763
4 irrigations	19.82 (393)	19.52 (393)	4.7	5.5	20.0	24.8	5.09	5.21	789	863	826
CD (P = 0.05)	NS	NS	0.4	0.3	3.6	4.2	NS	NS	50	49	25
Weed control											
Hand-weeding at 30 DAS	20.43 (417)	16.36 (268)	4.7	5.2	14.2	22.4	5.12	5.40	651	760	705
Fluchloralin at 1.0 kg/ha ppi	7.82 (61)	10.36 (107)	5.7	7.1	25.6	28.6	5.36	5.71	794	835	814
Weed-free	0.7 (0)	0.7 (0)	6.2	7.8	30.6	32.4	5.42	5.74	815	916	865
Weedy check	49.85 (2,485)	52.88 (2,796)	1.0	1.0	2.0	2.0	4.36	4.21	2	4	3
CD (P = 0.05)	1.25	3.12	0.6	0.8	4.4	4.8	0.26	0.28	41	39	22

* 3 irrigaions at 10, 40 and 70 days after sowing (DAS); 4 irrigations at 10, 35, 60 and 85 DAS; ** Data transformed to $\sqrt{X + 0.5}$

Original data are given in parentheses

Table 2 Effect of planting date and irrigation scheduling on seed yield of cumin (mean data of 2 years)

Irrigation scheduling	Planting date		
	15 November	30 November	Mean
3 irrigations	779	748	763
4 irrigations	889	763	826
Mean	834	755	
CD (P = 0.05)	35		

Table 3 Effect of planting date, irrigation scheduling and weed control on consumptive use and water-use efficiency of cumin

Treatment	Consumptive use of water (mm)			Water-use efficiency (kg/ha-mm)		
	1996–97	1997–98	Mean	1996–97	1997–98	Mean
Planting date						
15 November	141	146	143	5.71	5.90	5.83
30 November	134	132	133	5.23	6.13	5.73
Irrigation scheduling						
3 irrigations	130	134	132	5.52	6.04	5.78
4 Irrigations	145	144	144	5.44	5.99	5.71
Weed control						
Hand-weeding at 30 DAS	158	154	156	4.12	4.93	5.52
Fluchloralin at 1.0 kg/ha ppi	122	131	126	6.51	6.37	6.44
Weed free	109	111	110	7.48	8.25	7.86
Weedy check	161	160	160	0.01	0.02	0.01

*3 irrigations at 10, 40 and 70 days after sowing (DAS); 4 irrigations at 0, 35, 60 and 85 DAS ; ** Data transformed to $\sqrt{X + 0.5}$ Original data are given in parentheses

Water use

Consumptive use and water-use efficiency were higher under 15 November planting than those under 30 November planting (Table 3). Singh *et al.* (1997) also reported similar results in sunflower (*Helianthus annuus* L). Increase in irrigation frequency increased the seasonal consumptive use of water by cumin. The mean increase in consumptive use was 12 mm in 4 irrigations over 3 irrigations schedule (Table 3). The water-use efficiency was marginally increased under the schedule of 3 irrigations over that of 4 irrigations in both the years. Kumar *et al.* (1986) and Patel *et al.* (1992) reported that water-use efficiency may be decreased with increase frequency of irrigations.

Maximum seasonal consumptive use was recorded in the weedy check, followed by hand-weeding and minimum in weed-free treatment during both the years. (Table 3). This might be due to the more number of weeds in these treatments that transpire m[illegible] f water (Grupce and Grupce 1987). Maximum water-use efficiency was obtained in weed-free plots and minimum under weedy check. Fluchloralin at 1.0 kg/ha resulted in higher water-use efficiency than hand-weeding during both the years. Riffle *et al.* (1990) and Yadav (1998) also reported that early control of weeds increased the water-use efficiency of the crop.

It may be concluded that an application of 4 irrigations at 10, 35, 60 and 85 days after sowing was found to be the appropriate schedule for normal (15 November)-sown cumin, but under late sown conditions (30 November), 3 irrigations at 10, 40 and 70 days after sowing were sufficient for cumin cultivation. Application of fluchloralin at 1.0 kg/ha as pre-plant incorporation significantly reduced the dry weight of weeds and resulted in higher seed yield of cumin.

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Influence of graded levels of nitrogen, phosphorus and potassium on yield and quality of polyhouse grown tomato (*Lycopersicon esculentum*) hybrids

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ABSTRACT

An experiment comprising 3 levels of N : P : K (200:100:150; 350:200:250 and 500:300:350 kg/ha) and 4 indeterminate tomato (*Lycopersicon esculentum* Miller nom. cons.) hybrids ('Rakshita', 'Karnataka', 'Naveen' and 'Sun 7611') was conducted under multi-span polyhouse during 2000–2001 and 2001–2002 at New Delhi. The hybrid 'Karnataka' showed the maximum fruit diameter (6.97 and 6.98 cm), average fruit weight (83.28 and 83.88 g), fruit yield (2.85 and 3.07 kg/plant), calculated yield (8.55 and 9.21 kg/m²), juice content (58.84 and 62.43%), gross income (Rs 94.05 and 101.31/m²), net income (Rs 17.38 and 24.64/m²), benefit : cost ratio (1.23 : 1.00 and 1.32 : 1.00) and minimum cost of cultivation (Rs 76.67/m² in each year). The hybrid 'Rakshita' exhibited the maximum pulp content (77.46 and 78.73%), total soluble solids (6.07 and 6.27%), and shelf-life (6.40 and 6.50 days) compared to other hybrids. Among the fertility levels, N : P : K @ 350 : 200 : 250 kg/ha was found superior in influencing fruit diameter, average fruit weight and yield. The gross income and benefit : cost ratio were higher at this fertility level. The fruits/plant were the maximum at higher dose of NPK. The quality parameters were not significantly influenced by the NPK levels in both the years.

Keywords: Fruit yield, Fertility levels, Tomato hybrids, *Lycopersicon esculentum*, Polyhouse cultivation

Prevailing low temperature and frost injury during winter are limiting factors for growing high-value vegetables like tomato (*Lycopersicon esculentum* Miller nom. cons.) capsicum (*Capsicum annuum* L.), cucumber (*Cucumis sativus*), etc. under north Indian conditions. To make their cultivation successful in winter and spring–summer seasons in low- to medium-cost polyhouse is a viable solution (Chandra *et al.* 2000). Cultivation of indeterminate tomato hybrids is highly promising for the periurban farmers of the country.

Nutrients play major role in achieving maximum yield of any crop. The indeterminate tomato hybrid plants remove considerable amount of nutrients from the soil when grown under polyhouse to yield for quite longer time than the open field-grown tomato (Singh *et al.* 2000, Chaurasia *et al.* 2001). Considering these facts, this experiment was conducted to find out optimum dose of NPK and suitable hybrid for maximum yield of tomato fruits in a multi-span, fan-pad system polyhouse under north Indian plain.

MATERIALS AND METHODS

The experiment was conducted during early winter season of 2000–2001 and 2001–2002 at the Plasticulture Development Centre, Division of Agricultural Engineering, IARI, New Delhi. The soil was sandy loam and having *p*H 8.0. Four indeterminate tomato hybrids, viz 'Rakshita', 'Karnataka', 'Naveen' and 'Sun 7611', were grown in a 23 m × 22 m × 3.5 m size, automatic thermostat-control, fan-pad-polyhouse covered with 200 micron thick UV stabilized polythene film. The experiment was laid out in randomized block design with 4 hybrids of tomato and 3 combinations of N : P : K (200:100:150; 350:200:250; 500:300:350 kg/ha) with 3 replications.

Farmyard manure was applied basal @ 2 kg/m² to all treatment plots 15 days before planting. One-fourth amount of N and whole amount of P and K were applied basal before transplanting and remaining N was applied in 3 splits, each at 20 days interval after transplanting of tomato seedling, The N, P and K were applied in the form of urea, single superphosphate and muriate of potash respectively. Tomato seedlings were sown in small polythene bags of 10 cm × 5 cm size which were filled with sieved mixture of soil, sand and farmyard manure in the ratio of 1:1:1 and treated with Bavistin @ 2 g/litre water. Seedlings of 25 days age were transplanted at 60 cm × 60 cm spacing under the polyhouse after treating with a fungicide (copper oxychloride @ 0.5 g/litre water). The plants were tied vertically up with the help of plastic strings 25–30 days after planting. All the primary branches were removed at weekly intervals and the fruits were allowed to set

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only on the main stem flower clusters. The temperature was maintained by complete covering with polyethylene film at night and, if required, during day time also in December and January. This cover was generally folded back during daytime between 10 AM and 12 noon or 4 PM from February till May. Data were recorded from randomly selected 5 tagged plant of each plot on fruits/plant, fruit diameter (cm), average fruit weight (g), yield (kg/plant). The cost of cultivation/m^2 was cultivated item-wise and presented in Table 3. The yield (kg/m^2), gross income/m^2, net income/m^2 and benefit : cost ratio were calculated and presented in Table 1. The qualitative parameters like juice (%), pulp (%), total soluble solids (%), shelf-life (days) and weight loss (%) when starts shrinkage, were measured.

RESULTS AND DISCUSSION

Performance of hybrids

All the 4 hybrids significantly differed for fruits/plant, fruit diameter, average fruit weight and yield (Table 1). The hybrid 'Karnataka' recorded the highest fruit diameter, average fruit weight and yield (Table 1). The minimum cost of cultivation and highest gross income were noticed by growing hybrid 'Karnataka' under polyhouse. It showed the maximum benefit : cost ratio of 1.23 and 1.32 during 2000–2001 and 2001–2002, respectively, followed by the hybrid 'Naveen' (1.12 and 1.26). Chandra *et al.* (2000) also recorded the highest yield of the hybrid 'Naveen' under polyhouse. Hence the polyhouse cultivation of these 2 hybrids is most rewarding in north Indian plains. The better performance of the hybrid 'Naveen' was also reported by Pandey *et al.* (1996) under open field condition.

Significant difference in qualitative parameters was noted among the hybrids (Table 2). The highest juice content (58.84 and 62.43%), shortest shelf-life (4.75 and 4.25 days) and maximum weight loss (14.42 and 13.36%) were recorded in hybrid 'Karnataka'. The hybrid 'Rakshita' had the maximum pulp content (77.46 and 78.73%), TSS (6.07 and 6.27%) and shelf-life (6.40 and 6.50 days), followed by 'Naveen'. Hence 'Rakshita' hybrid can be used for processing purposes. It is well evident from the studies that the hybrids containing more pulp and less juice has the longer shelf-life. In the present study, it was also observed that the hybrid 'Rakshita' gave lowest yield (2.43 and 2.48 kg/plant) but recorded the highest TSS (6.07 and 6.27%). Stevens and Rudich (1978) also observed similar results earlier and found negative relationship between solids content and yield.

Effect of NPK

Significant effects of NPK levels were observed on yield and yield attributes (Table 1). The number of fruits/plant increased with the increase in fertility levels, being maximum (50.16 and 53.93) at NPK @ 500:300:350 kg/ha. Brar *et al.* (1971), Singh *et al.* (2000) and Chaurasia *et al.* (2001) also reported increase in fruit number with fertility levels. The maximum fruit diameter (6.18 and 6.17 cm), average fruit weight (63.88 and 62.05 g), yield (3.02 and 3.48 kg/plant) were recorded at medium NPK level (350:200:250 kg/ha). The increase in yield may be correlated with increase in fruit size and average fruit weight. Khan and Mishra (1976), Gupta *et al.* (1978) and Chaurasia *et al.* (2001) were of the opinion that higher yield of tomato in open field obtained at optimum fertility level which corroborates with the present findings. The fertility levels

Table 1 Influence of graded levels of NPK on yield and yield attributes of tomato hybrids under polyhouse

Treatment	Fruits/plant		Fruit diameter (cm)		Average fruit weight (g)		Yield (kg/plant)		Calculated yield (kg/m^2)		Cost of cultivation (Rs/m^2)		Gross income (Rs/m^2)		Net income (Rs/m^2)		Benefit : cost ratio	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Tomato hybrid																		
'Rakshita'	48.88	52.81	5.30	5.42	49.66	52.66	2.43	2.48	7.29	7.44	77.83	77.83	80.2	81.8	2.4	4.0	1.03	1.05
'Karnataka'	34.22	36.68	6.97	6.98	83.28	83.88	2.85	3.07	8.55	9.21	76.67	76.67	94.0	101.3	17.4	19.9	1.23	1.32
'Naveen'	50.66	55.56	5.19	5.28	51.55	52.88	2.61	2.94	7.83	8.82	76.74	76.74	86.1	97.0	9.4	22.6	1.12	1.26
'Sun 7611'	52.41	51.78	4.56	4.53	48.68	48.50	2.55	2.51	7.65	7.53	76.84	76.84	84.2	82.8	7.3	7.5	1.09	1.08
SEm±	0.515	1.356	0.105	0.119	0.308	0.686	0.047	0.047	0.145	0.140								
CD (P = 0.05)	1.511	3.986	0.309	0.585	0.902	2.017	0.138	0.138	0.426	0.353								
NPL (kg/ha)																		
200:150:150	42.10	46.58	5.02	5.09	53.29	54.83	2.24	2.22	6.72	7.65	76.57	76.57	73.9	84.2	—2.7	7.6	0.96	1.10
350:200:250	47.37	47.11	6.18	6.17	63.88	62.05	3.02	3.48	9.06	10.05	76.88	76.88	99.7	110.6	22.9	33.7	1.30	1.43
500:300:350	50.16	53.93	5.31	5.38	57.71	61.55	2.89	2.83	8.67	8.67	77.88	77.88	95.4	95.4	17.5	17.5	1.22	1.22
SEm±	0.446	1.175	0.01	0.102	0.266	0.594	0.040	0.040	0.126	0.121								
CD (P = 0.05)	1.308	3.454	0.267	0.299	0.782	1.746	0.117	0.118	0.370	0.301								

Y_1, 2000–2001; Y_2, 2001–2002
Average selling price of tomato in both years, Rs 11/kg
Number of plants accommodated/m^2, 3

Table 2 Influence of graded levels of NPK on quality of tomato hybrids under polyhouse

Treatment	Juice (%)		Pulp (%)		TSS (%)		Shelf-life (days)		Weight loss (%) when shrinkage starts	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Tomato hybrid										
'Rakshita'	19.52	19.26	77.46	78.73	6.07	6.27	6.40	6.50	11.50	9.46
'Karnataka'	58.84	62.43	37.20	35.56	5.56	5.62	4.75	4.25	14.42	13.36
'Naveen'	30.62	29.11	66.48	66.87	5.57	5.83	6.00	6.00	12.90	11.31
'Sun 7611'	42.78	42.54	54.21	53.46	65.46	5.71	4.50	4.75	11.18	10.25
SEm±	2.031	0.179	0.163	0.181	0.136	0.152	0.055	0.161	0.258	0.054
CD (P = 0.05)	5.971	0.526	0.479	0.532	0.399	0.447	0.162	0.473	0.758	0.159
NPK (kg/ha)										
200+100+150	39.47	38.44	57.38	58.55	5.71	5.83	5.25	5.00	12.17	11.04
350+200+250	38.69	38.39	55.80	57.61	5.73	5.90	5.00	5.25	12.50	11.14
500+300+350	35.66	38.18	56.35	58.81	5.55	5.85	5.00	5.00	12.50	11.10
SEm±										
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Y_1, *2000–2001*; Y_2, *2001–2002*

Table 3 Cost of cultivation of polyhouse grown tomato

Name and quantity of item	Rs/m²/season
10 polybags	1.0
Compost + sand	0.40
Farmyard manure	0.50
Polyhouse structure with DG set	25.0
Polyethylene cover	8.30
Drip irrigation system	8.0
Electric charge	18.75
Irrigation charge	18.75
Fungicide and insecticide	1.50
Total labour charge	4.65
Miscellaneous charge	3.0
Total	72.60
Cost of 10 seeds of tomato hybrid	
'Rakshita'	1.82
'Karnataka'	0.66
'Naveen'	0.73
'Sun 7611'	0.83
NPK dose	
200+100+150	2.96
350+200+250	3.40
500+300+350	3.86

used for the present study did not influence the quality of the fruits during both years. The cost of cultivation increased with increase in fertilizer levels and the highest benefit : cost ratio (1.30 and 1.43) was recorded in N:P:K levels of 350:200:250 kg/ha.

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Influence of integrated use of nitrogen, phosphorus, potassium and farmyard manure on yield-attributing traits and marketable yield of carrot (*Daucus carota*) under high hills dry temperate conditions of north–western Himalayas

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ABSTRACT

A field experiment was conducted during the summer season of 2000 and 2001 in Lahaul valley under high-hill dry-temperate zone of Himachal Pradesh, to study the effect of integrated use of farmyard manure and N, P and K fertilizers on yield-attributing characters and root yield of carrot (*Daucus carota* L.). Three levels of N, P and K [50, 100 and 150% of recommended dose (50, 40 and 35 kg N, P_2O_5 and K_2O/ha)] and 3 levels of farmyard manure (0, 10 and 20 tonnes/ha) were evaluated in split-plot design with 3 replications. An application of 10 tonnes farmyard manure/ha resulted in significant increase in root yield and other characters over the control in both the years. An application of 100% NPK significantly outyielded the other 2 fertilizer combinations of 50 and 150% for root yield. The response of increasing levels of fertilizers was at par for other characters, but significantly better than 50% level. The interaction effect of farmyard manure and NPK fertilizers was also found significant. The maximum net returs (Rs 155 000/ha) were obtained with the application of 10 tonnes farmyard manure/ha + 100% NPK with benefit : cost ratio of 4.37. Application of 10 tonnes farmyard manure/ha resulted in the saving of N, P_2O_5 and K_2O to the tune of 25, 20 and 15 kg/ha respectively.

Keywords: Vegetable production, Carrot, *Daucus carota*, Integrated nutrient management, Farmyard manure, Fertilizers, Interaction effects

Carrot (*Daucus carota* L.) is an important off-season vegetable crop, grown in the high hill dry temperate conditions of Himachal Pradesh. The carrot roots available in summer months find ready market in the plains bringing lucrative returns to the growers. With the emergence of the urban middle class market having specific kitchen needs and healthy security, there is a growing demand for quality vegetables. Keeping in view the increasing demand of off-season vegetables, there is an urgent need to increase their productivity. One of the practical ways to boost the yeild is to encourage the use of organics in combination with chemical fertilizer vegetable production. Since organics alone cannot meet the nutrient requirement of these exhaustive crops, integrated nutrient supply and management holds great promise in crop production not only for securing high productivity but also against emergence of multiple nutrient deficiences and deterioration of soil environment (Paikaray *et al.* 2002). However, no systematic research work has been done so far to evaluate the effect of integrated nutrient management on productivity of carrot under high-hill dry-temperate conditions. Hence a field experiment was conducted to investigate the effects of farmyard manure and inorganic fertilizers on root yield and yield-attributing traits in carrot.

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MATERIALS AND METHODS

A field experiment was conducted during the summer season of 2000 and 2001 at the Experimental Farm of High Land Agricultural Research and Extension Centre, Kukumseri in Lahaul and Spiti district of Himachal Pradesh. The centre is situated at 32° 44'15"N and 76°41'23" E at an elevation of 2 672 m above mean sea-level in a dry temperate high hill zone in the north-western Himalayas. Lahaur valley is characterized by the sloppy mountains with short snowless growing season of 6 months during April to September. The soil of experimental field was sandy loam, having *p*H 6.8, organic carbon 6.8 g/kg soil and available N, P and K 370, 30 and 298 kg/ha respectively.

The experiment was laid out in split-plot design with 3 levels of farmyard manure (0, 10 and 20 tonnes/ha) in main plots and 3 levels of fertilizers (50, 100 and 150% of the recommended dose) in the subplots, with 3 replications. The recommended dose is 50, 40 and 35 kg N, P_2O_5 and K_2O/ha.

'Nantes' carrot was sown in a plot size of 2.7 m × 2.0 m at 30 cm × 7.5 cm spacing on ridges in the last week of May each year. Full dose of farmyard manure, P_2O_5, K_2O and one-half of N were applied at the time of sowing and remaining N was applied 1 month after sowing. The deata were recorded on 5 random plants for average root weight (g), root length (cm), root girth (cm), root diameter (cm), root : top ratio and total plant weight (g). The root yield was recorded on plot basis and was converted to tonnnes/ha. The data for each individual year and pooled over years were statistically analysed as per the standard procedure. Economics was calculated on the basis of prevalent market prices of inputs and outputs.

RESULTS AND DISCUSSION

Effect of farmyard manure

An application of farmyard manure @ 10 tonnes/ha significantly increased the root weight, root length, root girth, root diameter, root : top ratio, total plant weight and root yield compared with the control (Table 1). However, further increase in the level of farmyard manure, ie 20 tonnes/ha could not differ significantly from 10 tonnes/ha in respect of yield-attributing characters as well as root yield. The application of farmyard manure increased the root yield significantly by 22.4 and 16.0%, 64.4 and 63.7% and 41.6 and 37.8% at 10 and 20 tonnes/ha over the control in 2000, 2001 and pooled data respectively. The results were observed by Saprov (1992), Silalahi and Parlindungan 91994), Zdravkovic *et al.* (1997) and Rumpal *et al.* (1998). This beneficial effect of organic manure on yield and its atttributes might be because of additional supply of plant nutrients as well as improvement in physical and biological properties of the soil (Majumdar *et al.* 2002). It could also be attributed to the fact that after proper decomposition and mineralization, the manures supplied available nutrients directly to the plant and also had solubilizing effect on fixed form of nutrients in soil (Sinha *et al.* 1981). The additional improvement in root yield because of farmyard manure application might be owing to cumulative effect of improvement in vegetative growth and yield attributes.

The application of farmyard manure @ 10 tonnes/ha resulted in significantly higher net returns (Rs 115 000/ha) as well as benefit : cost ratio (3.49) over the control. Though these were at par with the application of 20 tonnes farmyard manure/ha.

Effect of fertilizers

An application of 100% NPK significantly increased average root weight, root length, root girth, root diameter, root : top ratio, total plant weight and root yield over 50% NPK (Table 1). The application of 150% NPK could not improve the yield further over 100% recommended dose. The average root weight, root length, root girth, root diameter and total plant weight were at par with 100 and 150% NPK, but significantly improved over 50% recommended dose in both

Table 1 Response of carrot to farmyard manure and fertilizer application for its yield and yield-attributing characters

Treat-ment	Average root weight			Root length (g)			Root girth (cm)			Root diameter (cm)			Root : top ratio		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
M_0	93.17	94.2	93.7	11.94	11.38	11.66	9.75	9.87	9.81	3.12	3.15	3.14	2.96	3.01	2.99
M_{10}	101.74	102.9	102.26	14.63	14.17	14.40	10.68	10.47	10.58	3.42	3.35	3.38	3.64	3.68	3.66
M_{20}	96.88	107.0	102.0	14.50	13.83	14.16	10.61	10.57	10.59	3.39	3.39	3.39	3.55	3.55	3.55
CD ($P = 0.05$)	NS	3.7	3.8	1.07	0.71	0.53	NS	NS	NS	NS	NS	0.20	0.46	0.46	0.27
NPK (50%)	90.22	92.8	91.50	12.49	11.13	11.81	9.25	9.52	9.39	2.97	3.05	3.01	3.15	3.19	3.17
NPK (100%)	106.25	106.2	106.22	14.68	14.35	14.52	11.03	10.97	11.00	3.52	3.51	3.51	3.72	3.76	3.74
NPK (150%)	95.31	105.0	100.2	13.90	13.90	13.90	10.75	10.41	10.58	3.44	3.33	3.39	3.28	3.29	3.28
CD ($P = 0.05$)	8.60	5.5	4.8	1.06	1.44	0.85	0.84	0.56	0.48	0.27	0.19	0.15	0.38	0.23	0.21

Treat-ment	Total plant weight (g)			Root yield (tonnes/ha)			Net returns (Rs million/ha)			Benefit : cost : ratio		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
M_0	125.7	125.3	24.6	20.7	22.7	0.08	0.06	0.07	10.0	2.84	2.39	2.62
M_{10}	128.9	131.6	130.2	30.7	34.1	32.1	0.10	0.12	0.11	3.28	3.69	3.49
M_{20}	124.8	136.6	130.76	28.6	33.9	31.4	0.09	0.121	0.10	2.96	3.51	3.23
CD ($P = 0.05$)	NS	NS	NS	NS	4.98	3.30	NS	0.026	0.01	NS	0.53	0.36
NPK (50%)	119.1	121.5	120.3	23.2	22.7	22.9	0.07	0.06	0.70	2.56	2.50	2.53
NPK (100%)	132.1	121.5	120.3	23.2	22.7	22.9	0.01	0.08	0.08	2.56	2.50	2.53
NPK (150%)	127.6	136.8	132.2	28.4	31.63	30.1	0.09	0.11	0.10	3.09	3.38	3.23
CD ($P = 0.05$)	NS	7.3	6.42	3.5	2.5	2.02	0.017	0.013	0.010	0.39	0.26	0.22

Y_1, 2000; Y_2, 2001; M_0, M_{10}, M_{20}: o, 10 and 20 tonnes farmyard manure/ha respectively the years. However, the root : top ratio was higher at 100% NPK, but decreased significantly with lower or higher dose of NPK. The recommended dose of NPK alone increased root yield by 36.4, 50.6 and 43.4% over 50% NPK in 2000, 2001 and pooled data. These results substantiated the findings of Hassan *et al.* (1992) and Lyngdoh (2001). The increase in yield owing to the application of NPK may be attributed to the fact that these nutrients being important constituents of nucleotides, proteins, chlorophyll and enzymes, involve in various metabolic processes which have direct impact on vegetative and reproductive phases of plants (Mengel and Kirkby 1996). The maximum net returns and benefit : cost ratio (Table 1) were obtained with the application of recommended dose of fertilizers (Rs 119 000/ha), followed by 150% NPK (Rs 104 000/ha).

Interaction effects

The integrated use of farmyard manure along with NPK fertilizers increased root yield (Table 3) in both the years over their sole use. The higher root yield (38.55 tonnes/ha) was recorded under 100% recommended dose of fertilizers along with 10 tonnes farmyard manure/ha, which may be attributed to significantly increased average root weight, root girth, root diameter and root : top ratio (Tables 2, 3). The application of 20 tonnes farmyard manure + 100% NPK/ha also resulted in significantly higher yield in 2001 and over years. These findings are in line with those of Kropisz (1992), Kadi *et al.* (1994) and Neilsen *et al.* (1998). The improvement in yield owing to the integrated use of farmyard manure and fertilizers might be brought about by the beneficial effect of these on nutrient uptake, physiological growth and yield-attributing

Table 2 Interaction effect of farmyard manure and fertilizer levels on yield-attributing traits in carrot (pooled data)

Treatment	Average root weight (g)			Root girth (cm)			Root diameter (cm)			Root : top ratio			Total plant weight (g)		
	M_0	M_{10}	M_{20}	M_0	M_{10}	M_{20}	M_0	M_{10}	M_{20}	M_0	M_{10}	M_{20}	M_0	M_{10}	M_{20}
NPK (50%)	82.84	89.17	102.50	8.72	8.85	10.60	2.81	2.84	3.40	2.70	3.20	3.63	112.56	117.20	131.15
NPK (100%)	99.39	113.17	106.11	9.60	12.35	11.06	3.06	3.96	3.54	3.15	4.22	3.85	125.75	140.89	134.34
NPK (150%)	98.75	104.45	97.28	11.12	10.54	10.10	3.56	3.36	3.24	3.11	3.58	3.17	137.44	132.56	126.63
CD ($P = 0.05$)															
At same level			8.39			0.83			0.27			0.36			11.11
At same or or different level			8.53			1.05			0.30			0.39			11.32

M_0, M_{10}, M_{20}, 0, 10 and 20 tonnes farmyard manure/ha respectively

Table 3 Interaction effect of farmyard manure and fertilizer levels on carrot root yield and their economics

Treatment	Root yield (tonnes/ha)			Net returns (Rs million/ha)			Benefit : cost ratio		
	M_0	M_{10}	M_{20}	M_0	M_{10}	M_{20}	M_0	M_{10}	M_{20}
NPK (50%)	19.98	23.93	25.76	0.057	0.075	0.081	2.33	2.66	2.68
NPK (100%)	25.34	38.55	31.13	0.083	0.147	0.198	2.88	4.20	3.24
NPK (150%)	28.61	28.03	28.84	0.100	0.093	0.095	3.33	2.99	2.95
CD ($P = 0.05$)									
At same level			6.01			0.030			0.67
At same or different level			7.67			0.039			0.85
		2001			*2001*			*2001*	
NPK (50%)	17.54	24.89	25.80	0.045	0.079	0.081	2.04	2.46	2.67
NPK (100%)	21.14	41.82	39.78	0.065	0.163	0.151	2.76	4.54	3.77
NPK (150%)	23.45	35.44	36.11	0.073	0.131	0.132	2.69	4.14	3.69
CD ($P = 0.05$)									
At same level			4.29			0.022			0.45
At same or different level			6.04			0.031			0.63
		Pooled			*Pooled*			*Pooled*	
NPK (50%)	18.76	24.41	25.78	0.051	0.077	0.081	2.14	2.56	2.68
NPK (100%)	23.24	40.19	35.46	0.074	0.155	0.130	2.82	4.37	3.51
NPK (150%)	26.03	31.74	32.48	0.087	0.112	0.114	3.01	3.57	3.32
CD ($P = 0.05$)									
At same level			3.50			0.018			0.38
At same or different level			4.36			0.022			0.52

M_0, M_{10}, M_{20}, 0, 10 and 20 tonnes farmyard manure/ha respectively parameters (Singh *et al.* 2002) and improved physio-chemical and microbial environment of the rhizosphere leading to better expression of response to applied chemical fertilizers (Sharma *et al.* 1988). The yield obtained under 10 tonnes farmyard manure + 100% NPK/ha was statistically superior to that at 150% NPK alone, thereby indicating the saving of fertilizers N, P_2O_5 and K_2O to the tune of 25, 20 and 15 kg/ha with the use of 10 tonnes of farmyard manure/ha. The result corroborates the finding of Ramlingaswamy *et al.* (1999) that organic manure helps in economizing the use of chemical fertilizers.

Economics

The maximum net returns of Rs 147 000, 163 000 and 155 000/ha were recorded with the application of 10 tonnes farmyard manure + 100% NPK, with benefit : cost ratio of 4.20, 4.54 and 4.37 in 2000, 2001 and over years, respectively, followed by 20 tonnes farmyard manure + 100% NPK/ha. The application of 10 tonnes farmyard manure + 100% NPK/ha gained an additional Rs 68 000/ha over 150% NPK alone and Rs 25 000 over 20 tonnes farmyard manure + 100% NPK/ha.

Thus it could be inferred that to harness full yield potential of carrot in higher hill dry temperate conditions, it is essential to go for integrated nutrient management strategy involving 10 tonnes farmyard manure + 100% NPK/ha.

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Evaluation of mango (*Mangifera indica*) cultivars for quality attributes*

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Mango (*Mangifera indica* L.) has several varieties grown in various parts of the country (Singh and Chadha 1981, Ghosh *et al.* 1985, Sharma and Josan 1995, Kumar 1997 and Mitra *et al.* 2001). Emphasis has been paid to mango improvement through intervarietal hybridization (Chadha 1989). Although, a large number of mango cultivars are being grown in Bihar, most of them do not satisfy the requirements of an ideal commercial cultivar. To regulate market for consumer acceptability to get greater remuneration, it becomes imperative to study the performance of different leading cultivars of the country under Bihar conditions. Keeping above facts in view, a study was carried out to have the information regarding fruit quality attributes of different cultivars.

Twenty mango cultivars ('Dashehari', 'Langra', 'Fajri', 'S B Chausa', 'Mallika', 'Alphonso', 'Kesar', 'Mankurad', 'Fernandin', 'Vanraj', 'Baneshan', 'Bangalora', 'Mulgoa', 'Neelum', 'Swarnarekha', 'Zardalu', 'Bombai', 'Bombay Green', 'Himsagar' and 'Krishnabhog') were planted in experimental orchard of Department of Horticulture under All-India Co-ordinated Research Project on Sub-tropical Fruits (ICAR), Bihar Agricultural College, Sabour, during 1980 in randomized block design with 4 replications. Planting was done at a distance of 10 m and uniform cultural practices were provided. Performance of each cultivar was evaluated in terms of fruit quality parameters during 1997–99. The total soluble solids and titratable acidity were determined by standard

*Short note

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Table 1 Fruit weight, pulp and peel of different cultivars of mango

Cultivar	Fruit weight (g)			Pulp (%)			Peel (%)		
	1997	1998	1999	1997	1998	1999	1997	1998	1999
'Dashehari'	171.00	175.33	165.38	64.00	66.54	64.99	18.10	18.19	18.00
'Langra'	237.98	240.57	246.63	65.00	64.33	64.00	17.13	17.57	17.67
'Fajri'	450.98	458.37	457.88	53.00	54.20	54.00	20.00	20.79	20.17
'S.B.Chaousa'	163.73	165.34	158.55	62.00	63.50	63.00	17.20	17.50	17.37
'Mallika'	416.78	420.00	482.20	68.00	69.10	67.75	18.95	19.90	18.00
'Alphonso'	117.08	119.00	113.00	61.50	62.50	60.00	18.20	18.50	18.10
'Kesar'	178.48	175.50	162.65	62.32	63.30	61.10	18.10	19.00	18.30
'Mankurad'	147.45	148.30	148.90	58.21	60.00	59.00	20.00	18.40	20.11
'Fernandin'	107.58	110.40	110.20	57.25	58.50	59.50	21.00	18.19	21.14
'Vanraj'	148.05	150.00	159.20	58.00	59.00	57.13	21.50	20.50	21.00
'Baneshan'	299.13	305.00	253.20	61.00	62.20	58.91	21.10	21.40	21.13
'Bangalora'	172.25	175.10	178.40	56.00	57.10	62.00	21.39	22.00	21.00
'Mulgoa'	198.78	199.40	182.25	54.00	55.40	57.00	22.00	21.90	22.45
'Neelum'	68.80	70.00	77.23	55.28	56.50	53.19	22.10	22.00	22.30
'Swarnarekha'	262.90	270.00	266.48	57.69	58.40	54.20	21.90	22.40	21.80
'Zardalu'	193.15	196.30	158.25	62.00	63.30	57.19	18.20	22.12	18.60
'Bombai'	204.73	208.00	201.63	60.00	61.20	63.11	18.26	21.80	18.19
'Bombay Green'	200.43	205.17	213.65	60.59	62.34	61.90	18.17	18.40	18.20
'Himsagar'	207.03	210.30	234.68	59.11	60.00	62.00	19.00	18.51	19.50
'Krishna Bhog'	199.63	205.17	209.75	58.29	57.00	60.00	19.13	19.34	19.00
CD ($P = 0.05$)	3.55	3.44	11.91	3.10	2.11	2.90	2.09	02.01	2.03

Table 2 Total soluble solids, acidity and ascorbic acids in fruits of different cultivars of mango

Cultivar	TSS (%)			Acidity (%)			Ascorbic acid (mg/100 g)		
	1997	1998	1999	1997	1998	1999	1997	1998	1999
'Dashehari'	21.90	21.09	21.00	0.20	0.20	0.22	69.00	71.0	68.00
'Langra'	18.53	18.53	18.69	0.27	0.27	0.26	60.00	62.0	61.15
'Fajri'	17.29	17.29	17.00	0.26	0.26	0.25	43.12	44.11	44.11
'S.B.Chaousa'	20.95	20.95	20.78	0.18	0.18	0.19	49.21	50.12	48.00
'Mallika'	20.98	20.98	20.80	0.33	0.33	0.31	52.00	54.0	50.00
'Alphonso'	20.30	20.32	20.10	0.17	0.17	0.21	42.15	43.12	43.00
'Kesar'	19.61	19.61	19.51	0.30	0.30	0.30	44.26	45.21	46.00
'Mankurad'	19.73	19.73	19.65	0.18	0.18	0.18	40.20	41.23	41.00
'Fernandin'	17.74	17.74	17.70	0.30	0.19	0.19	41.00	42.13	43.00
'Vanraj'	17.77	17.57	17.71	0.18	0.20	0.19	42.00	43.00	45.13
'Baneshan'	17.36	17.36	17.40	0.19	0.20	0.20	40.00	42.09	42.11
'Bangalora'	15.58	15.58	15.59	0.20	0.17	0.18	44.00	49.13	46.31
'Mulgoa'	17.72	17.72	17.80	0.20	0.29	0.21	43.21	43.50	45.00
'Neelum'	18.84	18.84	18.80	0.17	0.20	0.27	45.00	46.00	46.33
'Swarnarekha'	19.09	19.02	19.11	0.20	0.27	0.28	46.21	47.11	47.00
'Zardalu'	19.84	19.84	19.89	0.21	0.20	0.23	49.00	51.00	41.00
'Bombai'	18.57	18.56	18.50	0.17	0.26	0.28	52.31	54.17	55.00
'Bombay Green'	19.46	19.46	19.40	0.20	0.28	0.26	49.24	52.00	48.00
'Himsagar'	21.00	21.00	21.10	0.26	0.29	0.29	62.10	63.17	63.00
'Krishna Bhog'	17.09	17.09	17.17	0.28	0.28	0.27	48.31	49.00	49.00
CD ($P = 0.05$)	0.66	0.86	0.61	0.02	0.02	0.01	3.11	2.89	3.46

Table 3 Total sugar, reducing sugar and total carotenoid in fruits of different cultivars of mango

Cultivar	Total sugar (%)			Reducing sugar (%)			Total carotenoid (mg/100 g)		
	1997	1998	1999	1997	1998	1999	1997	1998	1999
'Dashehari'	16.08	16.11	16.11	3.90	3.92	3.91	3.45	3.55	3.79
'Langra'	14.90	14.99	14.91	3.20	3.21	3.19	4.00	4.11	4.11
'Fajri'	13.10	13.15	13.23	2.62	3.654	2.61	3.39	3.46	3.20
'S.B. Chaousa'	15.93	16.00	15.90	3.19	3.20	3.20	3.12	3.19	3.10
'Mallika'	15.97	16.11	15.91	3.14	3.19	2.32	4.95	4.99	4.90
'Alphonso'	14.67	14.71	14.57	2.98	2.99	2.90	2.33	2.49	2.30
'Kesar'	14.39	14.45	14.40	2.94	2.93	2.91	3.90	3.98	3.71
'Mankurad'	14.00	14.11	14.11	2.90	2.91	2.94	2.66	2.71	2.70
'Fernandin'	13.78	13.90	13.79	2.88	2.90	2.81	2.97	2.99	2.90
'Vanraj'	13.68	13.91	13.75	2.70	2.73	2.73	2.86	2.89	2.80
'Baneshan'	13.60	13.70	13.70	2.79	2.83	2.71	3.00	3.19	3.11
'Bangalora'	13.10	13.20	13.54	2.67	2.71	2.61	3.11	3.30	3.10
'Mulgoa'	13.69	13.70	13.11	2.70	2.74	2.60	3.00	3.11	3.09
'Neelum'	13.99	14.10	13.70	2.73	2.79	2.72	2.98	3.03	2.90
'Swarnarekha'	14.00	14.15	13.90	3.00	3.11	2.74	3.13	3.15	3.12
'Zardalu'	14.11	14.10	14.11	3.11	3.14	3.19	4.67	4.80	4.70
'Bombai'	13.90	14.98	14.20	2.90	2.94	2.80	3.67	3.79	3.59
'Bombay Green'	14.00	14.15	13.91	3.10	3.19	3.11	3.60	3.69	3.44
'Himsagar'	16.00	16.13	16.11	3.00	3.11	3.10	4.00	4.19	4.12
'Krishna Bhog'	13.78	13.81	13.14	2.19	2.27	2.16	3.69	3.74	3.62
CD ($P = 0.05$)	1.02	1.10	1.19	0.22	0.21	0.31	0.20	0.23	0.32

methods. Ascorbic acid and sugars were determined as per AOAC, Washington (1980). Analysis of total carotenoids was done as per the method suggested by Roy (1973).

'Fajri' fruits were maximum in weight (450.98 g), followed by 'Mallika' (416.78 g) and 'Baneshan' (299.13 g), while minimum fruit weight was recorded in 'Neelum' (Table 1). 'Bombai' and 'Zardalu' cultivars had marginal differences in fruit weight. These findings are in accordance with the findings of Sharma and Josan (1995), Kumar (1997) and Chaudhary and Desai (1996) in mango. 'Mallika' recorded the maximum pulp content (68.00%), followed by 'Dashehari' and 'Langra', while minimum was found in 'Mulgoa'. Total soluble solids, total sugar, reducing sugar and ascorbic acid content were found maximum in 'Dashehari', followed by 'Mallika', 'Langra', 'S B Chausa' and 'Himsagar' (Tables 1, 2, 3). In terms of total carotenoid content, 'Mallika' was on the top (4.95 mg/100 g), followed by 'Himsagar' and 'Langra'. There was marginal difference in total soluble solids, sugars and total carotenoid content among different commercial cultivars ('Langra', 'Zardalu', 'Himsagar' and 'Bombai') of Bihar. In general, South and West zone cultivars were inferior to East and North zone cultivars in terms of fruit-quality characters. Similar pattern was also followed in another 2 successive years (1998 and 1999) of experimentation. Kumar (1997) and Mitra *et al.* (2001) also reported the varietal differences in fruit quality attributes in mango. 'Mallika' fruits were available for marketing from the last week of June to first week of July when leading cultivars of this region ('Bombai', 'Langra', 'Zardalu' and Himsagar) were almost over. In view of the overall performance, 'Mallika' had much potential for cultivation under Bihar conditions in addition to leading cultivars. Hence it may be recommended for this region.

SUMMARY

Twenty mango (*Mangifera indica* L.) cultivars ('Dashehari', 'Langra', 'Fajri', 'S.B. Chausa', 'Mallika', 'Alphonso', 'Kesar', 'Mankurad', 'Fernandin', 'Vanraj', 'Baneshan', 'Bangalora', 'Mulgoa', 'Neelum', 'Swarnarekha', 'Zardalu', 'Bombai', 'Bombay Green', 'Himsagar' and 'Krishnabhog') were evaluated during 1997–99 for their fruit-quality attributes under Bihar conditions. 'Mallika' fruits were maximum (68.00) in pulp percentage, and total carotenoid content (4.95 mg/100 g) and proved to be medium late cultivar, while 'Dashehari' had maximum percentage of total soluble solids (21.90), and total sugar content (16.08). 'Fajri' fruits were maximum in weight (450.98 g), followed by 'Mallika' and 'Baneshan'. 'Mallika' was available for marketing during the first fortnight of July when leading cultivars ('Bombai', 'Zardalu', 'Langra', and 'Himsagar') of this region were almost over. In view of the excellent quality characters, it may be recommended for higher returns in addition to 'Langra' and 'Bombai' under Bihar conditions.

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Effect of nitrogen nutrition on leaf-nutrient status of 'Bagugosha' pear (*Pyrus communis*)*

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'Bagugosha' is an important low-chill cultivar of pear (*Pyrus communis* L.). Though it bears good-quality fruits, its productivity is very poor. Leaf-nutrient status has been the major contributing factor influencing productivity in pear. Nitrogen nutrition is the major practice adopted by the farmers with a limited success. Use of appropriate doses of nitrogen may enhance growth and productivity. Keeping this in view, present investigation with graded doses of N was carried out in Mollisols of Pantnagar, during 1998 and 1999, to determine the adequate dose of N for optimum leaf-nutrient status which gives better yield and quality of 'Bagugosha' pear.

Ten-year-old 24 'Bagugosha' pear trees planted at 5 m × 5 m spacing in a square system, trained in a modified leader system and maintained under uniform cultural schedule were selected for the present study. The orchard soil was clay loam, having *p*H 8.0, high organic carbon (0.85%), available phosphorus (37.51 kg/ha) and potassium (315.46 kg/ha) but moderate available nitrogen (319.87 kg/ha). Eight levels of N, viz 20, 40, 50, 60, 70, 80, 90 and 100 g/tree/year age applied in 2 splits, two-third prior to balloon bud stage on 27 January and remaining on 12 May during active growth stage as urea in tree plots during 1998–99. The treatments were laid out in randomized block design with 3 replications. A uniform dose of 40 g each of P_2O_5 and K_2O/tree/year age in the form of single superphosphate and muriate of potash along with the N doses were applied basal. Fifty leaves per tree were collected in paper-bags from the middle position of shoots distributed all around the tree. Sampling was done in the second week of June, according to the guidelines of Chapman (1964). Leaf samples were washed free of dust and dirt in running tap-water followed by rinsing in acidified distilled water and finally with plain distill water. After drying at 60°C in a hot-air oven for 48 hr, these samples were grinded in stainless steel Wiley Mill to a fineness of 40 mesh and stored in sample tubes. Analytical procedure used for the estimation of total N, P, K, Ca, Mg, Zn, Cu and B in the leaf tissue are given in Table 1.

Application of N significantly affected the leaf N levels (Table 2). Leaf N increased with every increase in the dose of the applied N. Leaf N levels were significantly higher than the control in all the N doses except 40 g N/tree/year age. The maximum leaf N level was observed in the highest N dose (100 N/tree/year age). The maximum efficiency was observed in 60 g N/tree/year age, showing 19.44% (32.01%) increase in leaf N over the next lower treatment of 50 g N/tree/year age (Table 2).

Applied N marginally affected the phosphorus content in the leaf. The differences among the treatments were non-significant. Leaf P decreased by > 16% in the highest dose of applied N (100 g N/tree/year age). Leaf potassium decreased marginally with increase in the applied N. Leaf K decreased by nearly 6% in the highest dose of applied N. Though not significantly, the applied N affected leaf Ca negatively (Table 2). Leaf Ca decreased from 1.51% in the control to 1.38% in the highest dose of applied N. A decrease of >8% was observed under this treatment.

Leaf magnesium, was significantly affected by applied nitrogen. As the applied N level increased, the magnesium level in leaf also increased. An increase of about 56% was observed. The leaf Zn marginally increased with the increase in the dose of N. The maximum leaf Zn (39.49 ppm) was observed in 90 g N/tree/year age treatment which was more than 14% higher than the control. Leaf Cu content also

Table 1 Analytical procedure adopted for estimation of total N, P, K, Ca, Mg, Zn, Cu and B in leaf tissue

Mineral nutrient	Method
Nitrogen	Modified micro-Kjeldahl's method
Phosphorus	After wet digestion P in the extract was estimated by vanado-molybdophosphoric yellow colour methods using blue filter
Potassium	The extract from the wet digestion was used for determination of potassium using flame emission photometry
Calcium	EDTA titration method
Magnesium	EDTA titration method
Zinc	Atomic absorption spectrophotometry
Copper	Atomic absorption spectrophotometry
Boron	Curcumin method

*Short note

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Table 2 Effect of nitrogen levels on leaf mineral nutrient status of 'Bagugosha' pear

Dose	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)	B (ppm)
20 g N/tree/year age (control)	2.28, — (8.67)	0.24, — (2.83)	1.68, — (7.74)	1.51, — (7.06)	0.34, — (3.35)	34.62, — (36.03)	15.05, — (22.80)	71.90, — (58.05)
40 g N/tree/year age	2.39, +4.82 (8.89)	0.24, — (2.82)	1.69, +0.59 (7.47)	1.50, —0.66 (7.03)	0.37, +8.82 (3.51)	34.63, +0.02 (36.03)	14.49, —3.72 (22.36)	69.16, —3.93 (56.28)
50 g N/tree/year age	2.52, +10.52 (9.03)	0.23, —4.16 (2.77)	1.67, —0.59 (7.42)	1.49, —1.32 (7.02)	0.40, +17.64 (3.64)	35.31, +1.99 (36.45)	16.46, +9.36 (23.90)	71.26, —1.01 (57.59)
60 g N/tree/year age	3.01, +32.01 (9.89)	0.22, —8.33 (2.73)	1.34, —2.38 (7.37)	1.46, —3.31 (6.94)	0.45, +32.35 (3.86)	36.03, +4.07 (37.48)	16.39, +8.90 (23.83)	60.57, —15.86 (50.03)
70 g N/tree/year age	2.92, +28.07 (9.84)	0.23, —4.16 (2.71)	1.64, —2.38 (7.37)	1.47, —2.64 (6.96)	0.48, +41.17 (3.97)	37.06, +7.04 (36.88)	15.77, +4.78 (23.32)	58.72, —18.43 (51.12)
80 g N/tree/year age	3.28, +43.85 (10.43)	0.22, —8.33 (2.69)	1.62, —3.57 (7.31)	1.43, —5.29 (6.86)	0.51, +50.00 (4.10)	38.32, +10.68 (38.23)	16.74, 11.22 (24.11)	52.51, —27.05 (46.44)
90 g N/tree/year age	3.46, +51.75 (10.72)	0.21, —12.50 (2.64)	1.59, —5.35 (7.25)	1.39, —7.94 (6.77)	0.53, +55.88 (4.19)	39.39, +14.06 (38.92)	17.16, +14.01 (24.38)	48.63, —32.44 (44.21)
100 g N/tree/year age	3.53, +54.82 (10.83)	0.20, —16.66 (2.60)	1.58, —5.95 (7.23)	1.38, —8.60 (6.76)	0.53, +55.88 (4.18)	39.42, +13.86 (38.88)	17.39, +15.54 (24.61)	41.21, —42.75 (39.92)
CD ($P = 0.05$)	0.39	NS	NS	NS	0.34	NS	NS	3.64

First value shows leaf-nutrient status; second value shows % increase (+) or decrease (—) in leaf-nutrient status over the control; values in parentheses are transformed

responded to increase in N application in almost the same manner as in leaf Zn. Applied N significantly affected the leaf B content. Leaf B decreased with every increase in the dose of applied N. Significant decrease in leaf B was observed in the trees applied with a N dose of 60 g/tree/year age and above with a maximum decrease being in the highest level nearly by 43% over the control.

Rupp and Hubner (1995) also reported increased level of leaf N with increasing level of applied N. Effect of applied N on lowering leaf Ca and enhancing leaf Mg (Table 2), matched with the findings of Darfeld and Lenz (1985) in 'Alexander Lucas' pear. The positive effect of N on Zn and Cu and negative effect on B (Table 2) are in line with those of Singh *et al.* (1995).

On the basis of results nitrogen @ 50–60 g/tree/year age was found best which maintained a balance leaf nutrient status in 'Bagugosha' pear.

SUMMARY

An experiment was carried out on 10-year-old 'Bagugosha' pear (*Pyrus communis* L.) trees at Pantnagar, with 8 levels of N (20, 40, 50, 60, 70, 80, 90 and 100 g N/tree/year age) along with fixed doses of P_2O_5 and K_2O (each @ 40 g N/tree/year age) during 1998–1999. An increase in applied N increased the level of leaf N, Mg, Zn and Cu and decreased P, K, Ca, B. Lower doses of applied N caused the decrease in the status of leaf Mg, Zn and Cu and increased in P, K, Ca and B. Nitrogen @ 50–60 g/tree/year age maintained an adequate leaf-nutrient status of 2.52–3.01% N, 0.22–0.23% P, 1.34–1.67% K, 1.46–1.49% Ca, 0.40–0.45% Mg, 35.31–36.03 ppm Zn, 16.39–16.46 ppm Cu and 60.57–71.26 ppm B.

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Surface seeding of wheat (*Triticum aestivum*) as affected by seed rate and nitrogen level*

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In parts of north eastern India, soil remains wet long after harvesting of rice crop which makes it impossible for undertaking early tillage operation for the establishment of succeeding wheat (*Triticum aestivum* L. emend. Fiori & Paol.). In such areas soaked wheat seed can be broadcast in the untilled field immediately after harvest of rice (*Oryza sativa* L.) crop under wet saturated conditions. This system of growing wheat is called surface seeding which is an extreme form of zero tillage. This method advances wheat sowing by 10–20 days, depending on the soil-moisture content and other environmental factors. Since sowing time is very critical for ultimate growth and yield of wheat, surface seeding seems to be a possible answer to this limitation of late sown wheat. hence the present study was undertaken to assess the effect of N levels and seed rates on the performance of surface seeded wheat.

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A field trial was conducted at the Agricultural Research Farm, BHU, Varanasi, during the winter season of 1999–2000 and 2000–2001 to evaluate the effect of 3 nitrogen levels (60, 90 and 120 kg/ha) and 3 seed rates (125, 150 and 175 kg/ha) on the performance of surface seeded wheat. Variety 'HUW 234' was sown on 18 December 1999 and 22 December 2000, respectively, with pre-soaked seed in cowdung slurry to avoid any bird damage. The trial consisting of 9 treatment combinations was laid out in split-plot design with 3 replications by keeping N level in the main plot and seed rate in subplot. Sowing was done between stubbles on harvested rice crop in well-moist soil. A common dose of 26.40 kg P and 33.20 kg K/ha were applied basal, while N was applied as per treatment in 3 splits at 2 : 1 : 1 ratio at the time of sowing, crown-rot-initiation and panicle-initiation stages respectively. For weed control isoproturon @ 1.0 kg ai/ha + 2,4-D @ 0.5 kg ai/ha were applied 32 days after sowing to manage small canopy grass (*Phalaris minor* Retz.) and other broad-leaf weeds. The soil of the site was sandy clay loam in texture with 7.4 *p*H, 0.46% organic carbon and 204.8, 26.6., 245.5 kg of

Table 1 Effect of nitrogen and seed rate on the growth of surface-seeded wheat

Treatment	Leaf-area index (60 DAS)		Dry weight (60 DAS) (g/m)		Chlorophyll content (60 DAS) (Spad.)		Root length (cm)		Root volume (cm³)		Root weight (g)	
	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001
Nitrogen												
N_{60}	5.98	5.57	256.73	232.16	34.11	34.57	25.30	31.20	5.08	8.22	1.32	1.40
N_{90}	6.12	6.08	296.29	286.71	36.99	37.38	24.70	29.70	5.10	9.31	1.52	1.63
N_{120}	7.05	7.86	333.47	339.12	38.15	38.63	24.00	22.70	6.14	11.78	1.65	1.76
SEm	0.43	0.54	19.53	22.82	0.95	1.07	3.48	1.82	1.23	0.89	0.29	0.02
CD (P = 0.05)	1.18	1.49	54.21	62.98	2.14	2.97	NS	5.05	NS	NS	NS	0.06
Seed rate												
S_{125}	5.62	5.87	277.33	282.46	33.15	35.53	24.30	25.40	4.10	9.01	1.04	1.50
S_{150}	7.12	7.35	307.76	296.56	36.16	38.69	24.50	27.60	5.66	9.06	1.53	1.62
S_{175}	6.94	6.30	301.40	295.05	34.15	36.35	25.20	30.60	6.57	11.23	1.93	1.67
SEm	0.29	0.36	48.30	41.10	0.82	1.14	2.50	1.16	0.77	0.82	0.31	0.06
CD (P = 0.05)	0.62	0.78	NS	NS	1.77	2.48	NS	2.53	1.67	1.80	0.67	0.13

N_{60}, N_{90} and N_{120}, 60, 90 and 120 kg N/ha; S_{125}, S_{150} and S_{175}, 125, 150 and 175 kg seed/ha respectively

Table 2 Effect of nitrogen and seed rate on the reproductive characters of surface-seeded wheat

Treatment	Productive tillers/m		1 000-seed weight (g)		Grain yield (tonnes/ha)		Straw yield (tonnes/ha)	
	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001
Nitrogen								
N_{60}	54.17	43.40	40.50	37.50	2.310	1.724	2.780	2.303
N_{90}	82.72	66.50	41.50	38.30	3.080	2.330	3.740	2.951
N_{120}	90.61	72.90	41.00	38.00	3.440	2.361	3.870	3.080
SEm	6.76	6.25	0.72	0.58	0.159	0.066	0.086	0.048
CD (P = 0.05)	18.77	17.35	NS	NS	0.440	0.185	0.237	0.133
Seed rate								
S_{125}	64.56	45.80	40.90	36.50	2.640	1.983	3.100	2.496
S_{150}	80.72	67.10	41.50	38.10	2.890	2.198	3.550	2.848
S_{175}	82.22	70.90	40.50	37.90	3.010	2.283	3.730	2.989
SEm	5.40	3.70	0.64	0.58	0.076	0.050	0.095	0.066
CD (P = 0.05)	11.77	8.07	NS	NS	0.165	0.111	0.206	0.145

available N, P and K respectively. Root study was made at the time of flowering of the crop. The root cores were collected up to 25 cm depth by root sampler of 7 cm internal diameter. After washng off the soil root length was measured by line interception method. The whole root-system was then immersed in water filled measuring cylinder and the displacement of volume of water in the measuring cylinder was measured on the root volume. The roots obtained after measuring length and volume were oven-dried at 60°C for constant weight and then the dry weight was taken (Singh *et al.* 2000).

Leaf-area index, chlorophyll content and dry matter of plant increased with the increasing dose of N and the highest was observed at 120 kg N/ha during both the years. It was as expected since vegetative growth resulting from higher photosynthetic activities is well known to be influenced by nitrogen (Reddy 2000). In the root study, root length and weight were significantly affected by N in the second year only, although the trend was same during both the years. While the root length decreased with the increasing N dose, root weight and its volume increased with the increasing N levels. Availability of sufficient nutrient and moisture at the surface layer of soil from high N level most probably restricted the development of root length. Instead it developed laterally and expanded in volume, resulting in higher root dry weight. Production of ears is the function of total tiller produced and their survival potentiality. Accordingly 120 kg N/ha resulted in the highest number of tillers, although it remained statistically at par with 90 kg N/ha in the second year. In case of test weight although a slight increase was observed, it was not significant in any of the years. The cumulative effect of all these parameters was reflected in grain and straw yields which increased with an increasing N level. However, during both the years N_{90} and N_{120} remained at par with each other. Overall 90 kg N/ha registered 33.33% and 35.15% more grain yield than 60 kg N/ha during the first and second year respectively. These results confirm the findings of Dhiman *et al.* (2001).

Leaf-area index and chlorophyll content were significantly affected by seed rate, while dry-matter yield was not affected significantly. Seed rate 150 kg/ha registered the highest leaf-area index and chlorophyll content and remained significantly higher than 125 kg/ha. Lower leaf-area index and chlorophyll content at 175 kg seed/ha were most probably due to corwding effect of over-population which inhibited the growth of leaf size. In the root study also, all the root characters were significantly affected by seed rate. An increase in seed rate increased the root length, volume and weight. Less competition, easy availability of nutrients at lower plant population might have confined the overall proliferation of root to the upper surface area only and thereby limiting its length and volume. Productive tillers/running m were also significantly affected by seed rate. Seed rate of 150 kg/ha while remaining statistically at par with 175 kg seed/ha produced significantly more number of ears than 125 kg seed/ha. Test weight being mostly a genetic character, no significant difference was observed due to different seed rates in any of the years. However, grain and straw yields were affected significantly by seed rate. Sowing at 150 kg seed/ha resulted in significantly higher yield than 125 kg/ha but remained at par with 175 kg/ha. Srivastava *et al.* (1996) also observed a similar trend while experimenting with wheat at different seed rate, spacing and fertilizer levels. Selection of appropriate plant density for higher productivity depends mainly on leaf-area index, tillering and lodging. An ideal fertilizer dose and planting density increase the leaf-area index for efficient use of solar radiation. However, higher levels of nutrients and high density beyond optimum leads to mutual shading of leaves due to which it fails to exploit the inputs fully (Reddy 2000). In this case also 150 kg depicted the highest leaf-area index and higher productive tillers. Moreover a little lodging at 175 kg seed rate also restricted the ultimate productivity to some extent. It can therefore be concluded that in the present study 150 kg seed rate with 90 kg N/ha is optimum for more economic yield in surface-seeded late-sown wheat.

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SUMMARY

A field experiment was condeucted during the winter season of 1999–2000 and 2000–2001 at Varanasi, to investigate the effect of nitrogen levels (60, 90 and 120 kg/ha) and seed rates (125, 150 and 175 kg/ha) on performance of surface-seeded 'HUW 234' wheat (*Triticum aestivum* L. emend. Fiori & Paol.). The higher levels of nitrogen (120 kg/ha) although registered more tillers/m, leaf-area index, dry-matter accumulation, chlorophyll content, 1 000-seed weight, grain yield (3.440 and 2.361 tonnes/ha) and straw yield (3.870 and 2.890 tonnes/ha), remained at par with 90 kg N/ha during both the years (except leaf-area index in second year). Nitrogen 90 kg/ha recorded 33.33 and 35.15% more grain yield than 60 kg N/ha during first and second year respectively. Similarly, in all these parameters 150 kg seed/ha exhibited best results which remained at par with 175 kg/ha. Root length reduced with the increase in dose of nitrogen, while root volume and dry weight were enhanced. The seed rate of 175 kg/ha showed significantly better root length and volume during both the years.

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Influence of single superphosphate incubation with farmyard manure on enhancing phosphorus-use efficiency in rainfed upland rice (*Oryza sativa*) farming*

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Rainfed uplands having low productivity and low soil fertility are affected by frequent droughts during the crop-growing season and are therefore, risk-prone. Farmers generally apply most of the available resources (organic manures and inorganic fertilizers) in low risk-prone lowlands (Singh *et al.* 1992). The upland farmers in eastern India follow a 4 years crop rotation of growing pulses in the first year, upland rice (*Oryza sativa* L.) in the second year, minor millets in the third year and keep the fields fallow in the fourth year (Singh *et al.* 1994). Phosphorus is generally a limiting factor in rainfed upland soil, and incubation of P with organic manure increased the P availability (Singh *et al.* 1991, O'Halloran and Sigrist 1993, Gupta *et al.* 1995). Since every farm family in eastern India has very small amount of farmyard manure, the present study was undertaken to improve the P-use efficiency for developing effective P-management technique using a small portion of farmyard manure available with farmers.

This study was undertaken in the farmers' fields with their participation in an upland rice farming village in Chatra district, Jharkhand. The soil of farmers' field was acidic (*p*H 5.2 to 5.6), low in organic carbon (0.30%) and double acid-extractable P (3.7 ppm) and sandy loam in texture. The water-holding capacity ranged from 28.6 to 32.3% and soil expansion values from 9.3% to 13.5%. The fertilizers were applied as: T_1, farmers' method (20 kg N + 7 kg P/ha); T_2, 40 kg N + 7 kg P (without incubation) + 10 kg K/ha; T_3, 40 kg N +7 kg P (incubated with farmyard manure, 1: 2 ratio) + 10 kg K/ha; and T_4, 40 kg N +7 kg P (incubated with farmyard manure, 1:4 ratio) + 10 kg K/ha. The farmyard manure used in experimentation contained carbon 6.8%, nitrogen 0.59%, phosphorus 0.12%, potassium 0.82% on dry-weight basis and moisture 49.7%. Nitrogen, phosphorus and potash were applied through urea, single superphosphate and muriate of potash respectively, in all the treatments. Phosphorus from single superphosphate was mixed with moist farmyard manure at 1:2 and 1:4 ratios (oven-dry-weight basis) and the mixture was incubated for 72 hr in plastic bags under shade. The mixture of single superphosphate + farmyard manure with potash and rice seeds was applied in the furrows opened by a bullock-drawn indigenous wooden plough. Single superphosphate in treatment T_2 was applied in same furrow before rice seeding. Care was taken for the uniform placement of rice seeds and fertilizers. Nitrogen was applied in 2 equal splits: at 25 and 45 days after germination. The farmers method included broadcasting and mixing of rice seeds in the soil with bullock-drawn wooden plough, followed by *tiwai* operation (ploughing the rice seeded field 3 days after seeding) after applying 5 kg N + 7 kg P/ha. Nitrogen 15 kg/ha was broadcast 25 days after germination. An improved upland rice variety 'Vandana' was grown using seed rate of 100 kg/ha in treatments T_2, T_3 and T_4. In the farmer methods (T_1), 150 kg seeds/ha of same variety were seeded. The trials were conducted on 100 m^2 plot/treatment during wet seasons in 1997 and 1998 and replicated 5 times in farmers' fields. Treatments effects were evaluated by measuring the rice-growth parameters and grain and straw yields. For growth parameters, 2 samples of 0.25 m^2 size from each treatment and each farmer were harvested and all the plants from 0.25 m^2 were measured for plant height, panicle length, plant and panicle weight. Daily rainfall was recorded by installing rain gauge at the experimental sites during the crop-growth period. The P in soil was estimated using double acid extractant (0.05 N HCl + 0.025 N H_2SO_4) and plant P using vanadomolybdo-phosphoric yellow colour method (Jackson 1973). The total rainfall was 886 mm (1997) and 840 mm (1998) and number of rainy days was 42 and 48 in 1997 and 1998 respectively. The experiment was laid out in randomized block design and the data were analysed following IRRI stat 1994.

A significant response to phosphorus for biomass production and rice grain and straw yields was observed in both the years (Table 1). Without using the farmyard manure for P incubation, both the grain and straw yields and biomass were generally lower than the incubated P application at 1:2 single superphosphate to farmyard manure ratio. These yields were further lower when P was applied at *tiwai* as farmers'

*Short note

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Table 1 Grain, straw, biomass yield and grain P-use efficiency of rice grown in farmers' field under different fertilizer treatments in rainfed upland soils, Chatra, Jharkhand

Treatment	Grain yield (tonnes/ha)		Straw yield (tonnes/ha)		Biomass yield (tonnes/ha)		Grain P-use efficiency (kg/kg)	
	1997	1998	1997	1998	1997	1998	1997	1998
N_{20}+P_7 kg/ha (farmers' method)	1.28	0.60	2.17	1.38	3.45	2.04	282	444
N_{40}+P_7 (without incubation) + K_{10} kg/ha	1.66	0.85	3.10	1.70	4.75	2.55	286	244
N_{40}+ P_7 (SSP incubated with FYM, 1:2 ratio) + K_{10} kg/ha	2.16	1.29	3.40	2.24	5.61	3.52	268	347
N_{40}+ P_7 (SSP incubated with FYM, 1:4 ratio) + K_{10} kg/ha	1.70	0.91	2.69	1.48	4.39	2.38	298	374
LSD (P = 0.05)	0.22	0.22	0.53	0.35	0.64	0.53	NS	38.97
CV	9.5	17.2	13.5	14.9	10.1	14.7		8.03
SE	0.72	0.71	0.17	0.11	0.21	0.17	17.33	12.64

SSP, Single superphosphate; FYM, farmyard manure

Table 2 Yield-attributing characters of rice grown in farmers' field under different fertilizer treatments in rainfed upland soil, Chatra, Jharkhand

Treatment	Plant height (cm)		Single plant weight (g)		Panicle length (cm)		Single panicle weight (g)	
	1997	1998	1997	1998	1997	1998	1997	1998
N_{20}+P_7 kg/ha (farmers' method)	88.9	81.5	2.58	1.65	17.7	14.9	2.31	1.80
N_{40}+P_7 (without incubation) + K_{10} kg/ha	101.1	88.4	2.69	2.06	20.4	17.0	3.02	1.96
N_{40}+ P_7 (SSP incubated with FYM, 1:2 ratio) + K_{10} kg/ha	110.7	92.8	2.85	1.92	21.3	17.6	3.34	1.94
N_{40}+ P_7 (SSP incubated with FYM, 1:4 ratio) + K_{10} kg/ha	91.9	73.4	2.62	1.63	19.0	15.0	2.57	1.61
LSD (P = 0.05)	8.88	14.09	NS	0.32	1.04	1.46	0.44	0.30
CV	6.6	12.2		12.7	3.9	6.6	11.5	12.0
SE	2.88	4.57	0.18	0.10	0.34	0.47	0.14	0.98

practice. The grain, straw and total biomass yields in P-incubated treatment at 1:4 single superphosphate to farmyard manure ratio were comparable with that of non-incubated P treatment but higher than the farmer's practice. The higher effectiveness of incubated P, particularly at 1:2 ratio may be due to the increased availability of inorganic soil P in the root zone of rice during the growth period (6.97 and 7.09 ppm P after harvest in 1997 and 1998 respectively). The increased C: P ratio decreased the availability of P to plant (4.85 and 5.18 ppm P in soil after harvest in 1997 and 1998, respectively, in T_4 treated plots) because of decreased P solubility and high level of P immobilization (Donald *et al.* 1993). Sharif *et al.* (1974) incubated single superphosphate with farmyard manure at 5 ratios (1:2, 1:4, 1:8, 1:16 and 1:32) and found that the 1:2 ratio to be the best for P availability. They reported a consistent decrease in P uptake with increased single superphosphate : farmyard manure ratio. The positive effect of incubating single superphosphate with farmyard manure on the rice grain yield was consistent even in drought year 1998, when the crop suffered from long dry spells at different growth stages in its growing period. Gupta *et al.* (1995) also reported the effect of drought on rice yield.

The P uptake by grain and straw was influenced with the treatment and total P (grain + straw) uptake in 1997 was maximum in the treatment containing incubated P fertilizer with farmyard manure in 1:2 ratio. In 1998, the P uptake trend was similar to 1997, but the total P uptake of all treatments was drastically reduced due to frequent drought. The P-build up in soil due to P application was also estimated after each harvest. The double acid-extractable soil P due to application of incubated P fertilizer with farmyard manure in 1:2 ratio increased from initial 3.70 ppm to 6.97 and 7.09 ppm P in 1997 and 1998 respectively. The P-build up during 1998 was greater than 1997 due to poor rice-crop growth. These observations supported by grain P use efficiency (grain yield/total P uptake kg/kg).

Maximum plant height, plant weight, panicle length and panicle weight were recorded with the application of incubated P at 1:2 single superphosphate to farmyard manure ratio (Table 2). It can be concluded that the growth and yield of rainfed upland rice can be substantially improved by the application of incubated P with locally available farmyard manure at a ratio of 1: 2 even in drought year.

SUMMARY

An experiment was conducted to study P-fertilization in rainfed upland rice (*Oryza sativa* L.) cultivation during 1997 and 1998 in a typical drought-prone area with shallow and acidic soils in Chatra district, Jharkhand. The P was applied with and without incubation along with farmyard manure and compared with the farmer's practice of P fertilization. The effect of the treatments was measured on growth and yield parameters of the crop. The P applied after incubation with farmyard manure in 1:2 ratio resulted in better yield attributes with concomitant higher grain (1.73 tonnes/ha) and straw (2.82 tonnes/ha) yields as well as total biomass production (4.57 tonnes/ha) through the enhanced solubility (7.03 ppm) of P, even in a drought year. Application of single superphosphate : farmyard manure ratio (1: 4) depressed the growth and yield of rice crop. Results indicate that the growth and yield of rainfed upland rice can be substantially improved by the application of incubated P with locally available small quantity of farmyard manure.

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Hybrid cotton (*Gossypium hirsutum*) seed production technology for northern India*

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The seed is a most important input among various agricultural inputs like seed, fertilizer and pesticides etc. because the efficacy of other inputs depends on these. The availability of adequate quantities of high-quality seed at the right place, price and time to the farmers is essential to obtain the desired impact of cultivars and other inputs. During the last 4–5 years 10–15% area has been covered under hybrid cotton (*Gossypium hirsutum* L.) cultivation in northern India and due to this the demand for hybrid seed of cotton (*Gossypium hirsutum* L.) also increased significantly. Because of the heavy demand of hybrid seed, the hybrids which are not released and also not suitable for environmental condition of northern India are being supplied by private seed traders from other states. Most of them are not suitable for this zone because either they are of longer maturity period or highly susceptibility to pest and disease. By growing these hybrids the farmers of this area have incurred heavy losses in cotton production. The cost of seed is also very high in market. To avoid this situation, it is important to start hybrid seed production of released hybrids under this zone itself by the seed producers. Therefore the standardization of cotton hybrid seed production technology for this zone is essential, since the climatic conditions greatly influence the behaviour of flowering, boll setting and quality of hybrid seed (Storman 1949). As the meagre information is available on this aspect (Singh and Singh 1987, Meena *et al.* 2002) the present study was undertaken to find out suitable sowing time to get flowers for longer duration for crossing, optimum plant-to-plant spacing among female plants for successful crossing programme and also to identify the suitable crossing period for higher boll setting with superior quality seed of the released hybrid 'Om Shankar' and 'LHH 144' for northern India.

Female parents 'SH 2379' of hybrid 'Om Shankar' and 'PIL 43' of 'LHH 144' were sown on 2 different dates of sowing, ie 12 May and 24 May with 2 spacings ie 67.5 cm × 90 cm and 67.5 cm × 120 cm, in an area of 0.16 ha and male parents 'K 34007' and 'PIL 8' of hybrid 'Om Shankar' and 'LHH 144', respectively, on 0.04 ha by adopting all the recommended agronomic and plant-protection measures. Crosses were made on 20 selected plants of female parents of each hybrid daily from commencement of flowering to completion, ie from 16 August to 26 October. Data on flowers produced on each plant/day during crossing period, cross boll setting (%) and ovules/ovary were recorded. The whole crossing period was divided into 7 intervals of 10 days each. The average data of 10 days period of each interval are presented in Table 1. At maturity seeds/boll were counted and seed setting (%) and seedling vigour index in the laboratory as per ISTA (1985) recommendation.

Initially the flowers/plant were less on female parent in both the hybrids but increased gradually with progress in season and were the maximum (average 10–15) during the first week of September–first week of October. After this period, gradual reduction in flowers/plant started in both the hybrids (Table 1). Narkhede *et al.* (2000) and Sharma *et al.* (2001) also observed reduction in flower numbers at late phase of crop in cotton. The time of sowing did not exhibit any effect on flowers/plant at early crop phase, but during the last phase of crop (after second week of October) flowers/day were higher in late-sown crop (Table 1). Plant spacing also influenced flowers/plant. The mean flowers/plant were 13.1 and 10.9 in wider spacing and 11.2 and 9.1 in case of narrow spacing in hybrids 'Om Shankar' and 'LHH 144' respectively. Sharma *et al.* (2001) and Bishnoi *et al.* (2001) also observed reduction in yield when cotton cultivars sown on narrow spacing. The highest cross boll setting of 33.65% was observed in hybrid 'Om Shankar' and 42.37% in hybrid 'LHH 144'. The cross boll setting (%) was higher (above 30) during initial flowering stage but at peak flowering stage (first week of September to first week of October), the setting percentage declined up to average around 15. The reduction in setting percentage of boll may be due to competition in developing flower and bolls for nutrient. After the first week of October the cross boll setting (%) gradually declined with advancement in season. In end of October no boll setting in early-sown crop of both the hybrid was noticed, whereas in late-sown crop of female parent of 'Om Shankar' and 'LHH 144' less than 5% and 10% cross boll setting was observed respectively.

The date of sowing did not exhibit any significant effect

*Short note

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Table 1 Effect of sowing time, plant-to-plant spacing and crossing period on parameters governing seed yield of cotton hybrids

Hybrid	Date of sowing	Spacing (cm × cm)	Parameter	Crossing week							
				I	II	III	IV	V	VI	VII	CD ($P = 0.05$)
'Om Shankar'	12 May	67.5 × 90	Flowers/plant/day	6	7	12	14	15	12	9	3.2
			Boll setting (%)	31.4	33.6	17.4	16.0	12.8	0	0	12.3
			Seed setting (%)	86	90	89	91	80	66	59	11.7
			Seed index	7.9	8.2	8.2	8.1	8.0	7.8	7.6	0.2
			Germination (%)	76	79	80	80	76	72	69	3.9
			Vigour index	1 098	1 102	1 179	1 209	1 201	1 160	1 059	53.2
		67.5 × 120	Flowers/plant/day	7	9	14	15	17	13	11	3.2
			Boll setting (%)	34.1	33.6	21.3	18.4	11.9	1.2	0	12.7
			Seed setting (%)	87	93	90	91	81	69	61	11.3
			Seed index	8.0	8.2	8.4	8.3	8.2	7.9	7.7	0.2
			Germination (%)	75	80	82	80	78	74	68	4.4
			Vigour index	1 104	1 159	1 206	1 250	1 210	1 161	1 071	57.7
	24 May	67.5 × 90	Flowers/plant/day	5	8	12	15	18	14	10	4.1
			Boll setting (%)	25.9	29.5	17.3	12.7	8.04	4.52	5	9.2
			Seed setting (%)	89	91	92	94	81	76	69	8.7
			Seed index	7.7	7.8	8.0	7.7	7.6	7.5	7.5	0.1
			Germination	73	76	78	76	73	68	65	4.3
			Vigour index	1 069	1 092	1 117	1 170	1 153	1 073	1 018	48.2
		67.5 × 120	Flowers/plant/day	8	1	14	16	20	15	13	8.5
			Boll setting (%)	25.4	29.5	22.8	17.3	10.0	0	1.7	10.7
			Seed setting (%)	90	94	95	97	83	71	64	11.8
			Seed index	7.8	8.0	8.2	8.0	7.8	7.6	7.5	0.2
			Germination (%)	74	78	80	90	76	70	66	4.9
			Vigour index	1 071	1 104	1 136	1 182	1 162	1 051	1 030	52.9
'LHH 144'	12 May	67.5 × 90	Flowers/plant/day	5	7	10	12	12	9	6	2.6
			Boll setting (%)	29.6	35.4	25.5	18.2	10.5	1.94	0	12.6
			Seed setting (%)	77	83	84	86	80	65	57	10.0
			Seed index	9.5	9.8	9.9	9.8	9.7	9.4	9.0	0.3
			Germination (%)	74	78	80	84	80	74	68	4.9
			Vigour index	1 091	1 116	1 191	1 203	1 189	1 116	1 079	47.9
		67.5 × 120	Flowers/plant/day	6	8	10	14	15	9	7	3.2
			Boll setting (%)	24.0	42.4	27.9	16.0	7.2	0	0	14.5
			Seed setting (%)	85	90	91	93	82	68	60	11.6
			Seed index	9.5	9.8	10.0	9.9	9.8	9.5	9.1	0.3
			Germination (%)	76	80	82	84	82	78	70	4.4
			Vigour index	1 106	1 137	1 213	1 259	1 203	1 138	1 103	55.0
	24 May	67.5 × 90	Flowers/plant/day	4	7	11	13	14	10	8	3.2
			Boll setting (%)	25.2	23.4	21.0	17.4	16.2	11.0	7.6	5.9
			Seed setting (%)	76	86	89	90	81	69	58	10.8
			Seed index	9.2	9.2	9.5	9.6	9.5	9.3	8.9	0.2
			Germination (%)	70	74	78	78	72	68	65	4.5
			Vigour index	1 071	1 094	1 169	1 197	1 173	1 161	1 073	48.6
		67.5 × 120	Flowers/plant/day	6	10	12	16	17	13	10	3.5
			Boll setting (%)	55.7	22.7	24.0	18.1	12.3	8.3	6.7	15.4
			Seed setting (%)	81	90	92	94	83	76	68	8.6
			Seed index	9.1	9.3	9.6	9.8	9.7	9.2	9.1	0.3
			Germination (%)	72	74	80	78	73	69	65	4.7
			Vigour index	1 081	1 093	1 172	1 202	1 189	1 070	1 078	53.7

I, 16 August to 26 August; II, 27 August to 4 September; III, 5 September to 15 September; IV, 16 September to 26 September; V, 27 September to 4 October, VI, 5 October to 15 October; VII, 16 October to 26 October on setting percentage during the crossing period. The seed setting was more than 85% up to 30 September and after that it gradually declined and in the second week of October it was around 60%.

The seed index was more than 8.0 g in hybrid 'Om Shankar' and 9.7 g in hybrid 'LHH 144' up to the first week of October, thereafter it declined gradually (Table 1). No significant difference in seed index was observed between narrow and wider spacing in both the hybrids. The germination was more than 76% in hybrid 'Om Shankar' and 72% in hybrid 'LHH 144' for the seeds obtained up to the first week of October. After that a gradual reduction in germination level started in both the hybrids. The germination was higher in crop sown on wider spacing more, particularly in case of hybrid 'LHH 144' (Table 1). Similar trend was also recorded for vigour index.

SUMMARY

In an experiment conducted from 1999–2000 to 2001–2002 hybrids 'Om Shankar' and 'LHH 144' released for North Zone, showed the maximum flowers/plant during the first week of September–first week of October. The results also indicated that the cross boll setting (%) was higher in early-sown crop as well as when sown on wider spacing, ie 67.5 cm × 120 cm in both the hybrids. The most suitable crossing period was during 10 August–4 October as the cross boll setting was found to be higher during this period. The cross boll setting (%), germination (%), seedling vigour and seed index gradually declined after this period. The cross boll set after 4 October failed to open as the temperature goes down at the time of their maturity.

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Bioefficacy and persistence of beta-cyfluthrin in or on tomato (*Lycopersicon esculentum*)*

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Tomato (*Lycopersicon esculentum* Miller nom. cons.) is the main off-season cash crop in mid-hills of Himachal Pradesh. Of the several constraints in successful cultivation of tomato, insect-pests are posing several problems of which the fruit-borer [*Helicoverpa armigera* (Hübner)] is an important pest causing as high as 70% loss in yield (Kakar *et al.* 1990). To sustain the productivity of the crop, it is being sprayed by a number of insecticides. The sole dependence on some insecticides has further increased the resistance of this pest to insecticides and resurgence of sucking pests as a result of indiscriminate injudicious use of insecticides (Dhawan 1998, Dhawan *et al.* 2000, Kapoor *et al.* 2000). The dependence on insecticides which are in use for years together can be minimized by introducing new molecules. In the present study, ß-cyfluthrin (Bulldock 025 sc) (SR)-α-cyano-4-fluoro-3-phenoxybenzyl (IRS, 3RS; IRS, =3 SR)-3 (2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate was evaluated simultaneously both for its efficacy and persistence on tomato fruits against the fruit-borer, so that information gathered could be utilized in reducing the number of sprays thus resulting in low health risk to consumers.

Tomato (V 'Naveen 2000+') seedlings were raised in the farm area of the Department of Entomology and transplanted during the summer season (May–July) in the plot size of 2 m × 2 m with spacing of 90 cm × 45 cm between rows and plants respectively. All the agronomic practices except the use of

*Short note

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Table 1 Efficacy of different insecticides against the tomato fruitborer on tomato at fruit development

Treatment (g ai/ha)	Pre-count	Mean larval infestation/10 fruits (days after treatment) 1	2	5	10	15	20	Mean
ß-cyfluthrin 025SC								
12.50	4.33	0.00 (1.00)	0.33 (1.33)	0.00 (1.00)	1.67 (2.24)	2.00 (2.41)	3.00 (2.73)	1.17 (1.78)ab
18.75	3.33	0.00 (1.00)	0.00 (1.00)	0.33 (1.33)	1.67 (2.28)	2.33 (2.52)	2.67 (2.63)	1.17 (1.79)ab
25.00	2.33	0.00 (1.00)	0.33 (1.33)	0.00 (1.00)	1.00 (2.00)	1.67 (2.28)	2.00 (2.41)	0.83 (1.67)a
Endosulfan 35 EC								
500	4.33	0.00 (1.00)	0.00 (1.00)	0.33 (1.33)	1.33 (1.94)	2.00 (2.41)	2.33 (2.63)	0.9 (1.72)ab
Cypermethrin 10 EC								
30	4.33	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	2.33 (2.76)	2.67 (2.63)	3.33 (2.82)	1.39 (1.87)b
Control	5.00	5.00 (3.24)	5.00 (3.24)	5.67 (3.38)	6.00 (3.45)	6.33 (3.51)	6.67 (3.58)	5.78 (3.40)c
Mean	3.94	0.83 (1.37)a	0.94 (1.48)a	1.05 (1.51)a	2.33 (2.44)b	2.83 (2.63)c	3.33 (2.80)cd	
CD ($P = 0.05$)								
Treatment (T)		0.18						
Interval (I)		0.18						
Treatment × interval (T × I)		0.46						

Figures in parentheses are square-root transformed values; figures followed by same letters do not differ significantly insecticides recommended by the University were followed. ß-cyfluthrin (Bulldock 025SC) was sprayed @ 12.50, 18.75 and 25.00 g ai/ha at fruit-development stage of the crop. Three doses of ß-cyfluthrin were compared with cypermethrin (Challenger 10 EC) @ 30 g and endosulfan (Thiodan 35 EC) @ 500 g ai/ha as standards along with an untreated control. The first spray of 3 doses of the ß-cyfluthrin was made at flowering stage (40 days after transplanting), followed by second and third sprays, respectively, at 20-day interval. The observations of larval infestation were recorded as pre-treatment and post-treatment counting (1, 2, 5, 10, 15 and 20 days) after the application of insecticides from randomly selected 10 fruits/plot. At harvest, plot-wise yield was also recorded to compare and analyse the yield on hectare basis. Efficacy of ß-cyfluthrin was based on the mortality (%) of *H. armigera*/10 fruits and fruit yield.

Persistence of ß-cyfluthrin was studied continuously into successive cropping seasons, ie 1999 and 2000. The residues of ß-cyfluthrin at 12.50, 18.75 and 25.00 g ai/ha were estimated in the fruits taken from the bio-efficacy trial when the crop was in full bloom during August. A recovery trial study was carried out to standardize the procedure of extraction of ß-cyfluthrin from the treated tomato fruits and to determine the efficiency of the analytical procedures undertaken. The samples of tomato fruits (1 kg) were collected from each treatment at 0 (2 hr after spray), 1, 3, 5, 7 and 10 days intervals after the application. ß-cyfluthrin residues were extracted from a homogenized representative sample of tomato (50 g) with 200 ml acetone containing 10–15 g celite. After washing (twice) cake with 50 ml acetone-water (66 : 34((v/v), the extracts were filtered and the filtrate was pre-purified by partitioning subsequently with 50 ml dichloromethane:n-hexane (60:40) (v/v). Finally the residues were taken in 5 ml ethyl acetate and analysed by gas-liquid chromatography (Hewlett Packard 5890 A) fitted with NPD, column packed with 3% OV-17. The operating temperatures were: column 260°C, injection 270°C and detector 300°C. The gases used were: N_2, O_2 and hydrogen. The injection volume was 1 µl and the retention time under these conditions was 3.63 min. Spray application of ß-cyfluthrin at 12.50, 18.75 and 25.00 g ai/ha proved effective in comparison with the standard check, ie cypermethrin and endosulfan, against the tomato fruit-borer and significantly reduced *H. armigera* population that varied from 0.33 to 3.00 10/fruits compared with 0.33–3.33 in standards and 5.00–6.67 in control (Table 1). The mean larval infestation did not differ significantly in the doses of ß-cyfluthrin (12.50 and 18.85 g ai/ha) and in endosulfan (500 g ai/ha). However, the incidence in ß-cyfluthrin @ 25.00 g ai/ha-treated plots was significantly less than in cypermethrin, lower doses of ß-cyfluthrin and endosulfan. The results confirm the findings of Sulistyowati *et al.* (1995) and Dhawan and Simwat (2001) compared to other pyrethroids like cyfluthirn, deltamethrin, cyhalothrin, fenvalerate and alphamethrin.

The fruit damage was less (15.93–17.91%) at 3 doses of ß-cyfluthrin against 18.41–19.25% in standards and 35.49% in the control. All crops with the 3 doses of ß-cyfluthrin resulted in higher yield than standards and the control (Table 2). The yield with the 3 doses of ß-cyfluthrin (in their ascending orders)

Table 2 Field evaluation of beta-cyfluthirin against *H. armigera* on tomato

Treatment (g ai/ha)	Average fruit damage (%)	Yield (kg/ha)	Increase (%)
ß-cyfluthrin 0.025 SC			
12.50	17.91	582	21.76
18.75	15.94	639	33.68
25.00	15.93	652	36.40
Endosulfan 35 EC			
500.00	18.41	515	7.74
Cypermethrin 10 EC			
30.00	19.25	538	12.55
Control	35.49	478	

Table 3 Persistence of ß-cyfluthrin on tomato during 1999 and 2000

Sampling interval (days)	Residues (mg/kg)* 12.50 g ai/ha 1999	12.50 g ai/ha 2000	18.75 g ai/ha 1999	18.75 g ai/ha 2000	25.00 g ai/ha 1999	25.00 g ai/ha 2000
0	0.091	0.068	0.114	0.074	0.124	0.107
1	0.051 (43.85)	0.038 (44.12)	0.057 (49.91)	0.049 (33.78)	0.063 (49.07)	0.058 (45.79)
3	0.025 (72.31)	0.017 (75.00)	0.027 (76.14)	0.023 (68.92)	0.031 (75.02)	0.028 (73.83)
5	0.011 (87.58)	0.008 (88.24)	0.013 (88.77)	0.012 (83.78)	0.015 (87.59)	0.015 (85.98)
7	0.006 (93.41)	0.004 (94.12)	0.008 (92.98)	0.004 (94.59)	0.008 (93.55)	0.006 (94.39)
10	ND	ND	ND	ND	ND	0.001 (99.07)
15						
RL_{50} (days)	1.81	1.74	1.86	1.72	1.83	1.56
WP)days)	5.77	4.53	6.53	5.03	6.65	5.37

RL_{50}, Residue half-life; WP, waiting period; *mean of 3 replications
Figures in parentheses are % dissipation

was 582, 639 and 652 kg/ha, respectively, indicating an increase of 21.76, 33.68 and 36.40% respectively, over the control. However, in standard treatments (endosulfan and cypermethrin) the yields were 515 and 538 kg/ha, respectively, showing 7.74 and 12.55% increase over the control.

The recovery of ß-cyfluthrin from the spiked fruits extracted with acetone water (66:34), followed by clean-up using liquid-liquid chromatography and silica gel were found to be 89.17, 92.80 and 96.43% at 0.01, 0.05 and 1.00 mg/kg respectively.

The residues (mg/kg) of ß-cyfluthrin (Bulldock 025sc) in tomato fruits at different days after application (12.50, 18.75 and 25.00 g ai/ha) and corresponding half-life (RL_{50}) values and waiting periods in days are presented in Table 3 which revealed that the initial deposits of ß-cyfluthrin (0 day) were found to be 0.068–0.124 mg/kg, irrespective of doses and seasons. The residues dissipated about 69–76% after third day of application in both seasons for all treatments. On seventh day of application of ß-cyfluthrin, the maximum residues (92–94%) was dissipated in all seasons for 3 doses and no residue were detected on day 10 (except in during 2000 at 25.00 g ai/ha where the amount (0.001 mg/kg) was very less of last application, irrespective of doses and seasons. The half-life values calculated were 1.56 days to 1.86 days at 3 doses in both the seasons. The waiting periods were found to be within 5–7 days irrespective of doses and seasons. The dissipation rate of ß-cyfluthrin followed the first-order kinetic reaction in all seasons. These findings however varied with those reported by Battu *et al.* (1999) who detected ß-cyfluthrin 0.30–0.40 mg/kg in cotton lint even on tenth day of pesticide application. The low level of residues of ß-cyfluthrin may be attributed mainly due to texture and crop canopy as reported by Edling (1963).

The present study indicates that ß-cyfluthrin @ 25.00 g ai/ha is effective for the control of *H. armigera* thus increasing the yield of tomato. Regarding persistence of ß-cyfluthrin in or on tomato fruits about 93–94% of the initial deposits were observed to be dissipated 7 days after application which is not very much alarming from the view point of human consumption. The tolerable maximum residue limit varies from 4.53 to 6.65 days at maximum residue limit of 0.01 g/kg for tomato. It is therefore recommended that tomato fruits may be harvested 7 days after the last application of ß-cyfluthrin (Bulldock 025 sc) at 12.5 g ai/ha dose for consumption without any harmful effect.

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SUMMARY

ß-cyfluthrin, a synthetic pyrethroid, was evaluated during 1999 and 2000 crop seasons for its efficacy against the tomato fruitborer [*Helicoverpa armigera* (Hübner)] and its persistence on tomato (*Lycopersicon esculentum* Miller nom. cons). ß-cyfluthrin @ 12.50, 18.75 and 25.00 g ai/ha was compared with cypermethrin and endosulfan. It was more effective @ 25.00 g ai/ha, giving significantly higher yield of tomato. However, the lower dose (12.50 g ai/ha) was also effective and resulted in more yield than those with cypermethrin or endosulfan. The residue levels reached half of the initial deposits after 1.56–1.86 days with waiting period of 5–7 days, irrespective of doses and seasons.

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Residual toxicity of insecticides applied against fruit-borer (*Helicoverpa armigera*) and fruitfly (*Bactrocera cucurbitae*) and their dissipation on tomato (*Lycopersicon esculentum*)

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Of the important insect-pests of tomato in Himachal Pradesh, fruit-borer (*Helicoverpa armigera* Hübner), fruitfly (*Bactrocera cucurbitae* Coqillett), are the key pests which pose a threat to the successful cultivation of tomato (*Lycopersicon esculentum* Miller nom. cons.) crop in mid-hill zone of the state. Acephate (0.05%), deltamethrin (0.0028%), endosulfan (0.05%) and malathion (0.05%) insecticides are in vogue for the control of these pests on tomato crop but no attempt has been made to study their toxicity and persistence in these areas. Since tomato fruits are harvested at short intervals for table purpose, a study was undertaken to know the persistence and toxicity of these insecticides keeping in view the present-day awareness in the vegetarian society.

The experiment was laid out during the rainy season of 1998 and 1999 at Palampur. During the last week of April 1-month-old seedlings of tomato 'Roma' were planted in plots following recommended agronomic practices. The insecticides, viz acephate, deltamethrin, endosulfan and malathion, were sprayed at 0.05, 0.0028, 0.05 and 0.05 % concentrations with high-volume sprayer respectively. First spray was given at 50% flowering stage and the second 20 days after the first application. Each treatment was replicated 3 times. Residual toxicity of foliar insecticides and their dissipation was studied after the second spray.

For evaluating residual toxicity, laboratory-reared 10 neonate larvae (1 day old) of *H. armigera* were released on treated leaves 0, 1, 3, 7 and 15 days after application. The neonate larvae of *B. cucurbitae* reared in laboratory were released on treated fruits (slices) at different intervals of spray. Mortality data were recorded 24 hr after release and the moribund larvae were taken as dead.

Similarly, to study the dissipation of insecticides samples of leaves and fruits were drawn randomly 0,1,3,7 and 15 days after the second application. A representative sample of 25 g for leaves and 50 g for fruits was taken for residue analysis. Residues of acephate and malathion were extracted as per the procedure of Steinwandter (1989). The procedure of Sanyal (1995) was used for deltamethrin and that given by Dikshit *et al.* (1980) for endosulfan. The extracts obtained were cleaned up by using a mixture of activated charcoal, celite and magnesium oxide (2:2:1) except that of deltamethrin where a mixture of activated silica gel, charcoal and sodium sulphate (3:1:1) was used. The final volume was adjusted to 30 ml with double-distilled hexane for quantization. The residues were estimated by bioassay using *Drosophila melanogaster* Meig. as test insect and by gas liquid chromatography equipped with electron-capture detector (for deltamethrin and

*Short note

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Table 1 Residual toxicity of insecticides to neonate larvae on tomato

Treatment (%)	Corrected mortality (%) at different intervals (days) 0	1	3	7	15
Helicoverpa armigera (on leaves)					
Acephate	100.00	92.10	78.73	40.00	10.00
(0.05)	(88.19)	(77.38)	(62.68)	(39.18)	(18.43)
Deltamethrin	100.00	84.60	56.58	12.50	
(0.0028)	(88.19)	(66.99)	(48.84)	(15.00)	
Endosulpan	100.00	94.74	75.30	52.50	10.00
(0.05)	(88.19)	(79.64)	(60.54)	(46.44)	(18.43)
Malathion	100.00	88.90	63.82	20.00	
(0.05)	(88.19)	(70.60)	(53.30)	(26.36)	
CD (P = 0.05)		(4.42)	(6.69)	(5.13)	
Bactrocera cucurbitae (on fruits)					
Acephate	100.00	66.66	62.50	28.33	
(0.05)	(88.19)	(54.78)	(52.32)	(33.17)	
Deltamethrin	100.00	83.33	41.66	12.50	
(0.0028)	(88.19)	(66.22)	(40.67)	(14.97)	
Endosulfan	100.00	76.66	46.66	22.50	
0.05	(88.19)	(61.22)	(43.08)	(28.00)	
Malathion	100.00	66.66	27.50		
(0.05)	(88.19)	(54.90)	(31.42)		
CD (P = 0.05)	(6.23)	(7.19)	(8.19)		

Average of 2 years data based on 3 replications each
Figures in parentheses are angular transformed values

endosulfan) and nitrogen–phosphorus detector (for acephate and malathion). The half-life values and safety intervals were calculated as per Hoskins (1961). The average recovery of insecticides from leaves ranged from 85.3 to 92.9% and from fruits, it varied from 82.2 to 87.8 %. During sampling period mean maximum and minimum temperature was 26.3–27.6°C and 19.5–19.9°C respectively. The mean relative humidity was 80–82% and rainfall 101.00 mm in 1998 and 217.80 mm in 1999.

All the insecticides resulted in 100 % mortality of neonate larvae of *H. armigera* and *B. cucurbitae* on the day of application (Table 1). A day after application, the order of toxicity against *H. armigera* was endosulfan > acephate > malathion > deltamethrin and against *B. cucurbitae*, it was deltamethrin > endosulfan > acephate and malathion. Acephate and endosulfan were at par with each other in their effectiveness against these pests 3 days after application.

Residual toxicity had positive correlation with the residues of insecticides on respective days after spray. On the basis of persistent toxicity values, the order of effectiveness was endosulfan > acephate > malathion > deltamethrin for *H. armigera* and the order for *B. cucurbitae* was acephate > endosulfan > deltamethrin > malathion. Deltamethrin was found least effective. The present findings are in line with the results of Walgenbach *et al.* (1991). Acephate was most effective and caused higher mortality of neonate larvae of fruitfly at different intervals, confirming the findings of Mann *et al.* (1976).

Table 2 Insecticide residues on tomato leaves and fruits (mean data of 2 years)

Days after spray	Insecticide residues (ppm) Acephate	Deltamethrin	Endosulfan	Malathion
Leaves				
0	5.63	0.78	6.41	4.86
1	4.30 (23.62)	0.30 (61.42)	4.47 (30.31)	2.75 (43.44)
3	2.78 (50.71)	0.11 (86.45)	1.36 (78.85)	1.56 (67.89)
7	1.57 (72.08)	0.02 (97.68)	0.84 (86.91)	0.72 (85.17)
15	0.17 (97.02)	BDL	0.01 (99.91)	BDL
Half-life (days)	3.03	1.13	1.46	2.48
Fruits				
0	2.13	0.11	2.10	2.10
1	1.10 (48.12)	0.05 (56.25)	0.87 (58.34)	1.03 (50.55)
3	0.70 (67.29)	0.02 (83.04)	0.35 (83.17)	0.52 (75.13)
7	0.37 (82.61)	0.01 (92.86)	0.13 (93.95)	BDL
15	BDL	BDL	BDL	BDL
Half-life (days)	3.01	1.57	1.55	1.27
Waiting period (days)	6.03	0.00	3.20	0.00
Tolerance limit (ppm)	0.5	0.2	0.5	3.0

Figures in parentheses are per cent reduction of residues; BDL, below detectable limits

The initial deposits of acephate on leaves obtained in the present study were similar to Dikshit *et al.* (1986). Similarly, endosulfan residues persisted for more than 15 days on leaves while those of deltamethrin and malathion for 7 days (Table 2). The present findings on deltamethrin are in line with those of Singh *et al.* (1992). Antonious (1995) reported 2.13 ppm of initial deposits of acephate which corroborate the initial deposits on fruits in the present findings. The residues of acephate could not be detected on 15th day on fruits, whereas deltamethrin persisted only for 7 days on fruits in small quantities. Similar findings were reported by Paolo *et al.* (1985). The half life of 1.57 days for deltamethrin in the present study is very close to that observed by Awasthi (1986). The present findings on endosulfan deposits are similar to those of Verma (1979), but differed from those of Gangwar and Kumar (1988). No residues of malathion were detectable on 7th day. A waiting period of 6 days for acephate and 3 days for endosulfan was observed on tomato fruits which corroborated the findings of Patil *et al.* (1987) and Dikshit *et al.* (1980).

On the basis of present investigation, acephate and endosulfan may be used for effective control of the insect-pests on tomato crop but a safe-waiting period of 6 and 3 days, respectively, be observed between spray and harvest of tomato fruits; however, deltamethrin and malathion required no waiting period.

SUMMARY

An experiment was conducted during the rainy season of 1998 and 1999 to study the effect of residual toxicity of insecticides on tomato fruit-borer (*Helicoverpa armigera* Hübner) and fruitfly (*Bactrocera cucurbitae* Coquillett) and their dissipation on leaves and fruits of tomato (*Lycopersicon esculentum* Miller nom. cons.). The toxicity of insecticides 1 day after application was in order of endosulfan > acephate > malathion > deltamethrin for tomato fruit-borer, whereas it was deltamethrin > endosulfan > acephate and malathion for fruitfly. Acephate and endosulfan residues on leaves could kill 10% of neonate larvae of tomato fruit-borer on day 15, whereas on fruits, no mortality was recorded in fruitfly larvae. The initial deposits of acephate, endosulfan, deltamethrin and malathion were 5.63, 6.41, 0.78 and 4.86 ppm on leaves and 2.13, 2.10, 0.11 and 2.10 ppm on fruits respectively. The residues of acephate and endosulfan reached below the maximum residue limits after 6 and 3 days on fruits, respectively, and the deposits of deltamethrin and malathion were below the prescribed limits.

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