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Productivity and returns of castor (*Ricinus communis*)-based intercropping systems with pulses and vegetables under rainfed conditions

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ABSTRACT

A field experiment was conducted at Hyderabad during 2001–2002 and 2002–2003 in Alfisols under rainfed conditions, to maximize productivity of castor (*Ricinus communis* L.) in normal rainfall years and minimize risk during drought years. Different pulses and vegetables either in 1 row or 2 rows were evaluated as intercrops between wide-spaced castor rows. In a year of scanty rainfall (2001–2002), the dry matter and yield of intercropped castor (128 g/plant; 1 523 kg/ha) was comparable with sole castor (107 g/plant; 1821 kg/ha). The castor-equivalent yields increased when castor was intercropped with 2 rows of clusterbean [*Cyamopsis tetragonoloba* (L.) Taubert] (2 187 kg/ha), cucumber (*Cucumis sativus* L.) (2 356 kg/ha) and lablab (*Dolichos lablab* L.) (2 255 kg/ha). The net returns were increased when castor was intercropped with 2 rows of clusterbean (Rs/ha 11 217), lablab (Rs/ha 12 729) and cucumber (Rs/ha 13 644). In a drought year (2002–2003), the seed yield of castor (471 kg/ha) was adversely affected due to intercropping when compared to sole crop of castor (748 kg/ha). The castor-equivalent yield was greater when castor was intercropped with clusterbean (1 259; 2 026 kg/ha) and cucumber (*Cucumis sativus*) (1 536; 2 050 kg/ha) either in 1 or 2 rows. The net returns were greater when castor was intercropped with clusterbean (Rs/ha 6 548; 12 611) and cucumber (Rs/ha 8 791; 11 186) either in 1 or 2 rows. Seed or vegetable yields of intercrops were greater in their pure stands followed by when these sown in 2 rows and 1 row as intercrops with castor.

Keywords: Intercropping, System productivity, Castor, *Ricinus communis*, Vegetables

Castor (*Ricinus communis* L.) is one of the important non-edible oilseed crops that has great industrial and commercial value. India is principal producer of castor having an estimated acreage of 0.72 million ha with 0.72 million tonnes production (DES, New Delhi 2001–2002). A sizable area is under rainfed conditions where it is cultivated in marginal and submarginal shallow soils with low inputs by the resource-poor farmers in Andhra Pradesh, Tamil Nadu, Karnataka and Orissa. Wide fluctuations in total amount of rainfall and its distribution received through South–west monsoon results in wide variation in productivity (Rao and Chakrabarthy 1997). Castor is grown both as a sole crop and often as a mixed or intercrop. It is ideally suited for intercropping systems owing to wider inter- and intra-row spacing. The risk during drought periods in rainfed areas can be minimized by adopting appropriate cropping systems which utilize the resources in an efficient way (Chetty 1983). The present study was undertaken with an objective of maximizing productivity in variable rainfall situations in castor. Different pulses and vegetables were evaluated as intercrops between wide-spaced castor rows.

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MATERIALS AND METHODS

A field experiment was conducted during the rainy season of 2001–2002 and 2002–2003 on Alfisol at Narkhoda farm of the Directorate of Oilseeds Research, Hyderabad. The treatments (12 +1) consisting of 2 pulses, viz greengram or mungbean (*Phaseolus radiatus* L.) and soybean [*Glycine max*) (L.) Merr.]; 4 vegetables, clusterbean [*Cyamopsis tetragonoloba* (L.) Taubert], Frenchbean (*Phaseolus vulgaris* L.), lablab (*Dolichos lablab* L.) and cucumber (*Cucumis sativus* L.) sown either in 1 row or 2 rows between the castor ('DCS' 9) rows spaced at 90 cm × 60 cm. Sole crop of castor was also sown with 90 cm × 60 cm spacing. The trial was conducted in randomized block design (RBD) with 13 treatments, replicated thrice. The crops were sown on 20 June 2001 and 10 June 2002. All intercrops were also maintained in pure stands for comparison. They were grown as per recommended cultivation practices under rainfed conditions. Cucumber was sown 1 month after sowing of castor. Sole and intercropping system of castor were received recommended dose of fertilizer (N, P_2O_5, K_2O) @ 60, 40, 30 kg/ha. No additional dose of fertilizer was applied to intercrops. Complete dose of P_2O_5 and K_2O and half of N were applied at the time of sowing, while the remaining half N was top-dressed 35 days after sowing. The dry-matter yields of castor were recorded by harvesting 5 plants from second row on either side of the plots. At maturity, the plot-wise seed or vegetable yields (fresh weights) were recorded separately. The yields of intercrops were converted into monetary terms and expressed as castor-equivalent yields for comparison. Dry-matter production and seed yield of castor were analysed statistically to quantify the effect of intercrops on castor. Castor-equivalent yields were analysed statistically for system productivity comparison. Pooled analysis was done for seed yield of castor and castor seed equivalent yield.

RESULTS AND DISCUSSION

As the years of experimentation were found to be significantly different, year-wise data were presented. The 2 contrast years in respect of amount of rainfall distribution provided an opportunity to test pulses and vegetables as intercrops with castor. The amount of rainfall received during the crop season of 2001–2002 and 2002–2003 was 590 and 390 mm respectively (Fig 1). Nearly 1 month dry spell occurred from the last week of June to July in 2001–2002 (scanty rainfall year). After 1 month dry spell satisfactory distribution of rainfall was received. During 2002–2003 (drought year), 2 dry spells occurred during the second week of June–July and again in September. The moisture stress experienced during crop-growth period in 2002–2003 apart from limited soil depth, adversely affected the vegetative and reproductive stages of crop growth resulting in low yields of all crops. Castor-seed-equivalent yield was positively correlated with amount of rainfall received ($r = 0.97$).

Scanty rainfall year (2001–2002)

The total dry matter of castor under intercropping with pulses and vegetables did not differ significantly with sole castor. The castor seed yield also was not significantly differed under intercropping compared with its sole crop. Rao *et al.* (1989) also reported that when seasonal rainfall (426–606 mm) was satisfactory, castor seed yield was not affected due to intercropping. Intercrops and castor used resources without competition, resulting in enhanced system productivity. It indicates that in a year of subnormal rainfall too castor can be intercropped with pulses and vegetables without much adverse effect on total dry-matter and seed yields of base crop of castor.

The castor-equivalent yield was significantly greater in castor + cucumber, castor + clusterbean and castor + lablab intercropping systems either as 1 row or 2 rows of intercrops than sole crop of castor. The castor-equivalent yields of other intercropping systems, viz castor + mungbean, castor + soybean and castor + Frenchbean, were not significantly differed compared to that of sole castor.

Among the castor-based intercropping systems with vegetables, clusterbean, lablab and cucumber either in 1 row or 2 rows increased the gross returns compared to sole crop of castor because of higher yields of vegetable intercrops and castor. Intercropping of castor with clusterbean with 2 rows, lablab either in 1 row or 2 rows and cucumber either in 1 row or 2 rows are superior in terms of net returns. Castor intercropping with clusterbean was found productive and profitable in shallow soils (Katyal *et al.* 1993). Therefore, clusterbean, cucumber and lablab were better compatible intercrops with castor. It indicates that the systems exploited

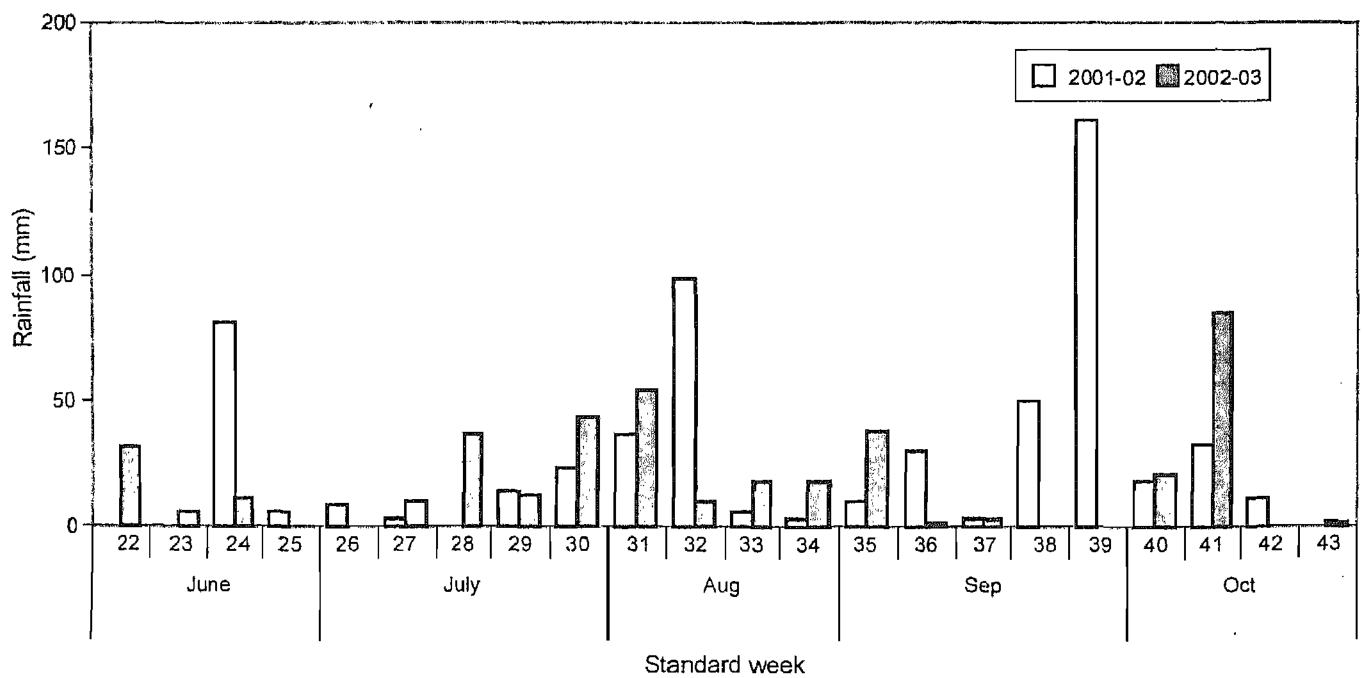

Fig 1 Rainfall distribution during the cropping season

Table 1 Productivity and economics of castor-based intercropping systems involving pulses and vegetables

Intercropping system	No. of intercrop rows	Dry matter of castor (g/plant) 45 DAS	Dry matter of castor (g/plant) 110 DAS	Castor seed yield (kg/ha)	Intercrop yield (kg/ha)	Castor-equivalent yield (kg/ha)	Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	Benefit: cost ratio
2001–2002										
Castor + mungbean	1	55	114	1 529	287	1 960	19 595	8 567	11 028	2.29
	2	45	110	1 390	395	1 983	19 825	8 886	10 939	2.23
Castor + soybean	1	59	131	1 694	216	1 867	18 668	8 600	10 068	2.17
	2	45	90	1 564	346	1 841	18 408	8 800	9 608	2.09
Castor + clusterbean	1	71	141	1 654	1 483	1 951	19 506	8 550	10 956	2.28
	2	52	136	1 568	3 096	2 187	21 872	10 655	11 217	2.05
Castor + Frenchbean	1	48	152	1 405	361	1 549	15 494	9 050	6 444	1.71
	2	55	90	1 583	933	1 956	19 562	10 655	8 907	1.83
Castor + lablab	1	50	151	1 505	1 568	1 975	19 754	8 583	11 171	2.30
	2	57	132	1 528	2 423	2 255	22 549	9 820	12 729	2.30
Castor + cucumber	1	46	166	1 414	2 792	2 172	19 724	8 583	11 141	2.30
	2	68	122	1 436	4 602	2 356	23 564	9 920	13 644	2.38
Sole castor		60	107	1 821		1 821	18 210	7 550	10 660	2.41
SEm±		6.6	19.8	85.2		113				
CD (P = 0.05)		NS	NS	NS		325				
CV (%)		16.3	20.0	9.6		10.0				
2002–2003										
Castor + mungbean	1	26	178	433	202	735	7 360	5 257	2 103	1.40
	2	20	87	262	351	788	7 885	5 876	2 009	1.34
Castor + soybean	1	29	117	583	211	752	7 518	5 590	1 928	1.34
	2	29	106	460	373	758	7 584	6 546	1 098	1.16
Castor + clusterbean	1	25	126	393	4 329	1 259	12 588	6 040	6 548	2.08
	2	27	121	358	8 338	2 026	20 256	7 645	12 611	2.65
Castor + Frenchbean	1	32	112	637	2 421	1 121	11 210	5 940	5 270	1.88
	2	23	92	577	3 117	1 185	11 850	7 445	4 405	1.59
Castor + lablab	1	25	85	314	1 934	894	8 942	5 573	3 369	1.60
	2	21	85	328	2 135	968	9 685	6 810	2 875	1.42
Castor + cucumber	1	25	146	694	4 212	1 536	15 364	6 573	8 791	2.34
	2	23	151	607	6 513	2 050	19 096	7 910	11 186	2.41
Sole castor		26	205	748		748	7 480	5 440	5 440	1.40
SEm±		2.6	11.2	53		101				
CD (P = 0.05)		NS	32.7	155		293				
CV (%)		18.5	15.6	19.0		15.4				

Vegetable or seed yield of intercrops (kg/ha) under sole cropping

Sole crops	Mungbean	Soybean	Clusterbean	Frenchbean	Lablab	Cucumber
2001–2002	1 046	650	5 443	1 309	3 525	9 922
2002–2003	720	437	9 575	4 106	2 341	10 298

Produce price (Rs/kg): Castor, 10.00; mungbean, 15.00; soybean, 8.00; clusterbean, 2.00; Frenchbean, 4.00; lablab, 3.00; cucumber, 2.00

resources in a better way and intercrops created less competition to castor. Lowest gross returns were obtained from sole castor compared to its intercropping. The net returns were lowest from intercropping of castor with Frenchbean either in 1 row or 2 rows. Net returns of intercropping of castor with mungbean, soybean and clusterbean (1 row system) were not varied much with that of sole castor. Sole crop of castor and other intercropping systems obtained greater benefit : cost ratio (> 2.00) except castor + Frenchbean. It indicated that intercropping of castor with pulses and vegetables is profitable even under subnormal rainfall situations.

The grain or vegetable yields were greater when they were sown in 2 rows compared to that of 1 row due to greater population in 2 rows compared to that of single row. Intercrops under sole cropping recorded higher yields. Dry-matter and yield of intercrops were greater in pure stands than that of intercropping situations. Similar observation was also reported by Subramanian and Venkateswarlu (1989).

Drought year (2002–2003)

In early stages (45 days after sowing), dry-matter production of castor was not significantly influenced due to intercropping, indicating minimal competition for resources. At maturity stage (110 days after sowing), the dry-matter production of castor significantly declined due to intercropping. Dry-matter production of castor intercropped with 1 row of intercrop did not differ significantly from the dry-matter production of castor intercropped with 2 rows of intercrop.

The castor seed yield significantly decreased in intercropping systems compared to its sole crop. Reddy and Venkateswarlu (1989) and Jadhav *et al.* (1992) also reported reduction in seed yield of castor when intercropped with clusterbean. Double row of intercrops decreased the castor seed yield compared to 1 row of intercrops. Among the different intercropping systems, castor seed yield was least affected when intercropped with Frenchbean and cucumber. Significantly lower castor seed yield was obtained when castor was intercropped with lablab, clusterbean, mungbean and soybean perhaps these crops could have exhausted limited soil moisture. The reduction in castor seed yield with intercropping could be attributed to the vigorous growth of intercrops, which competed for the limited supply of soil moisture in shallow soils.

The castor-equivalent yield significantly increased under intercropping with clusterbean and cucumber either in 1 row or 2 rows. Castor-equivalent yields of sole castor, castor + mungbean and castor + soybean were at par indicating that under drought situations sole cropping of castor is better than its intercropping with mungbean and soybean. However, an intercropping of castor with vegetables like clusterbean and cucumber was better than sole cropping in terms of castor-equivalent yields.

Intercropping of castor + clusterbean and castor + cucumber offered higher gross returns and net returns than sole castor and all other intercropping systems owing to better yield of base crop of castor and intercrops. Intercropping of castor with Frenchbean and lablab recorded greater gross returns and net returns than sole castor, castor + mungbean and castor + soybean. This indicates that intercropping of castor with clusterbean and cucumber systems exploited resources in a better way and increased the system productivity. Intercropping of castor with clusterbean and cucumber either in 1 row or 2 rows obtained greater benefit: cost ratio (> 2.00) compared to all other intercropping systems and sole castor. Katyal *et al.* (1993) also reported that castor intercropping with clusterbean was productive and profitable in shallow soils.

Grain or vegetable yields were greater in their pure stands and followed by when they sown in 2 rows and 1 row probably owing to greater population. The results confirm the findings of Subramanian and Venkateswarlu (1989).

Thus, castor may be intercropped with 2 rows of clusterbean and cucumber between the wide-spaced castor rows (90 cm × 60 cm) for maximizing the productivity and profitability in subnormal rainfall years and to minimize risk during drought years.

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Effect of lime and phosphorus on yield and phosphorus uptake by radish (*Raphanus sativus*) in mountain acidic soil of North–West Himalayas, India

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ABSTRACT

An experiment was conducted to study the effect of lime and phosphorus on yield and P uptake by radish (*Raphanus sativus* L.) during 1999 and 2000 on a Typic hapludalf mountain acidic land in western Himalayan region. The treatment comprised 3 levels of lime application (0, 1.54 and 3.08 tonnes/ha) and 4 levels of phosphorus (0, 0.011, 0.022 and 0.033 tonne P/ha). Lime application with full lime requirement (3.08 tonnes/ha), significantly upgraded the productivity and the uptake of P in radish crop, ie 32 and 41%, respectively. Likewise, the application of phosphorus up to highest level, ie 0.033 tonne/ha, also improved the yield and P uptake to a significant level. The increase in productivity of radish being 25%, whereas in uptake being 40 % was observed when P was applied @ 0.033 tonne/ha over no P. There was also a significant effect of lime and phosphorus on the build up of phosphorus in the soil at the harvest of the crop. The benefit : cost ratio, response yardstick and value : cost ratio realized were 5.9, 34.5 kg radish/kg P and 6.9 due to phosphorus; and 1.2, 3.2 kg radish/kg lime and 2.2 due to residual effect of lime respectively.

Keywords: Radish, *Raphanus sativus,* Lime, Phosphorus, Yield, P-uptake, P-build up, North-West Himalayas

Among the soil fertility constraints responsible for low productivity of the crops in mountain acidic soils of North–West Himalayas, poor availability of P is the dominant one, because P is rendered immobile and unavailable to plants due to low *p*H and dominance of active forms of Al and Fe that not only fix the applied P, but also make it inert (Dixit and Sharma 1993). Besides, such lands also become problematic in relation to the availability of other nutrients such as Ca, Mg, S, Mo and B by creating nutrient imbalances. Therefore to overcome this barrier, liming could be a good management practice, which eventually can be responsible for elimination or reduction in soil acidity due to repression of active forms of Al and Fe. Besides, the mountain acidic lands of western Himalayas have poor physical features such as marginality, inaccessibility and sloppiness that impart them a kind of unsustainability so far as their quality for vegetable production is concerned. Such lands have low productivity of radish (*Raphanus sativus* L.), because of severe phosphorus hunger, higher acidity and presence of phosphorus-fixation sites that entrap phosphorus, thereby resulting in P deficiency. However, there are tremendous possibilities of upgrading the productivity of crops (2–3 times) by soil amelioration management skills such as application of lime and phosphorus. However, there is a wide information gap in the studies involving the effect of lime and P on radish crop. Keeping this in view, a study was undertaken to study the effect of lime and phosphorus on radish in a maize (*Zea mays* L.)–radish–onion (*Allium sativum* L.) cropping sequence.

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MATERIALS AND METHODS

A field experiment was conducted during 1999 and 2000 with 'Japanese White' radish. The soil was silty clay loam in texture with low available N (203 kg N/ha), medium in available P (11.5 kg/ha) and K (148 kg K/ha). The cation-exchange capacity of the soil was 12.1 Cmol (P^+)/ kg. Twelve treatments comprised 4 levels of P (0, 0.011, 0.022 and 0.033 tonne/ha) and 3 levels of lime [no lime, 50% of lime requirement (1.54 tonnes/ha) and 100% (3.08 tonnes/ha) of the lime requirement] were tried. There were 3 replications. Phosphorus was applied directly to the crop during both the years, whereas lime at the beginning of the first crop, ie before sowing of first crop that was maize in maize–radish–onion cropping sequence such that the effect of lime was residual in case of radish during both the years. Row–to–row spacing was 30 cm. The crop was sown in the first week of October and harvested during the second fortnight of December (2000 and 2001).

RESULTS AND DISCUSSION

Productivity of radish

Application of lime up to full lime requirement (3.08 tonnes/ha) significantly enhanced average marketable yield of radish (Table 1), being 32 % over the control. It could be owing to its effect in reducing acidity, improving base saturation, enhancing nutrients availability, upgrading microbial activity emanating from improved *p*H, less toxicity of elements like Al, Fe and Mn. Since soil was acidic, such results are understandable. Besides, lime plays positive role in upgrading the granulation and microbial growth which are responsible for decomposition of organic matter and mineralization of nutrients from the original source (Sumner and Farina 1986).

An application of phosphorus @ 0.033 tonne P/ha significantly increased radish to 25 % (Table 1) and the probable reason for improvement was, as P is an essential nutrient being involved in strengthening the roots, cell division, elongation, production of ATP and various metabolic reactions and thereby improving the productivity of radish. The results confirm the findings of Singh *et al.* (1995), who reported that P application significantly increased the leaf size, length, productivity and uptake of P and K by radish in mountain acidic lands of Nagaland. Likewise, Wang *et al.* (1995) also reported the response of radish to P on such lands.

Table 1 Effect of lime and phosphorus application on radish productivity, P uptake and build up of phosphorus in mountain acid soil (average data of 1999 and 2000)

Treatment	Productivity		P uptake		Available P at
Lime (tonnes/ha)	tonnes/ha	% increase	kg/ha	% increase	radish harvest* (kg/ ha)
0	10.19		1.86		15.28
1.54	12.22	19.9	2.29	23.1	18.30
3.08	13.45	32.0	2.62	40.9	20.02
CD (*P*=0.05)	0.39		0.07		1.39
Phosphorus (tonne P/ha)					
0	10.42		1.84		12.76
0.011	11.86	13.8	2.18	18.5	16.27
0.022	12.54	20.3	2.41	31.0	19.83
0.033	13.01	24.8	2.58	40.2	22.60
CD (*P*=0.05)	0.45		0.09		1.60

* 2000

Phosphorus uptake

Significant effect of phosphorus and lime was observed on P uptake by radish crop. Radish responded significantly to lime application with each increment up to highest level (Table 1). The increase over the control was 41% in plots, where lime was applied up to the extent of 3.08 tonnes/ha.

The increase in P uptake due to liming may be due to fact, that it breaks the Fe and Al phosphates in soil, thereby, making P available to plant (Rattan *et al.* 2001). Besides, available P status increase may be due to increase in mineralization of organic P as affected by lime (Haynes 1992).

With each increment of phosphorus, its uptake by radish increased significantly up to 0.033 tonne P/ha and the increase was 40.2% over the control which can be explained on the grounds that the P application might have increased the availability of P and productivity of the crops (Singh *et al.* 1995).

Available P status

A significant build up of available P status in 1.54 tonnes /ha over no lime and 3.08 tonnes/ha over 1.54 tonnes/ha level, which indicates that lime application up to full lime requirement responded significantly in improving the available P status of the soil. The per cent increase due to lime @ 3.08 tonnes/ha over no lime in the build up of soil-available P was 31.0. Such an increase ascribed to the action of lime which was due to its effect in breaking the complex Fe and Al phosphates and making phosphate available in the form of mono-calcium phosphate (Gupta and Sharma 1985, Rattan *et al.* 2001).

There was a significant build of available P status following P application to radish crop in mountain acidic land (Table 1). Phosphorus @ 0.033 tonne/ha increased its status by 77.1% over no phosphorus. Such an increase in available P status due to P application has also been reported by Sanyal and Datta (1991), and could be easily attributed to the build up of available P in soil.

Economic returns

Phosphorus application @ 0.033 tonne/ha increased the radish yield by 25% over no P application and lime application @ 3.08 tonnes/ha by 32% over no lime treatment. Benefit : cost ratio, value : cost ratio and response yardsticks (kg produce/ kg P applied) were 5.9, 6.9 and 34.5 in radish due to phosphorus application @ 0.033 tonne/ha, whereas the corresponding values following lime application @ 3.08 tonnes/ha were 1.2, 2.2 and 3.2 respectively.

Thus, it is feasible to upgrade the productivity of radish in mountain acidic land of western Himalayas by ameliorating such lands with lime and phosphorus, at the same time, realizing higher economic returns.

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Effect of planting and fertigation on growth and yield of green chilli (*Capsicum annuum*)

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ABSTRACT

An experiment was conducted during the summer season of 2001 and 2002 to study the effect of different planting techniques (paired row, triangular and normal planting) and fertigation intervals (2 days, 4 days, 6 days and 8 days interval) on growth and yield of green chilli (*Capsicum annuum* L.). Use of triangular planting technique (30–90 cm × 45 cm) recorded significantly higher yield of green chilli (8.55 and 9.40 tonnes/ha) in both the years compared to paired row (45–75cm × 45cm) and normal planting (60 cm × 45 cm). Fertigation of recommended dose of fertilizer (100:50:50 kg NPK/ha) at every irrigation (2-day intervals) up to 105 days resulted significantly higher yield of green chilli of 9.30 and 9.06 tonnes/ha during first and second year respectively. However, it was on a par with fertigation at every alternate irrigation (4-day intervals) up to 105 days (8.62 and 8.00 tonnes/ha). Significantly low yield was observed in surface irrigation with recommended dose of fertilizer through straight fertilizers. Significantly higher uptake of nitrogen (104.69 and 96.94 kg/ha), phosphorus (12.58 and 11.81 kg/ha) and potassium (99.10 and 86.34 kg/ha) was recorded in fertigation of recommended dose of fertilizer at every irrigation (2-day intervals) up to 105 days.

Chilli (*Capsicum annuum* L.) is extensively grown for its pungent fruits which are used both green and ripe to impart pungency to the food. It forms indispensable adjunct in every house of the tropical part of the world as a spice. It is also used in medicine and used for preparation of chutenies and pickles. Application of water-soluble fertilizers through micro-irrigation system like drip (fertigation) is gaining importance in present-day agriculture to boost the production and productivity of various crops. However, initial cost for installation of drip system is very high but change in planting geometry is cost-free input which helps reduce cost of laterals and emitters to the extent of 20–30 % (Pawade and Satpute 1987). Hence a study was carried out to increase the yield potential of green chilli by changing the planting techniques and using fertigation techniques.

MATERIALS AND METHODS

The field experiment was conducted during the summer season of 2001 and 2002 at Rahuri, Maharashtra. The soil was sandy clay loam, medium in available nitrogen (146.85 kg/ha) and phosphorus (7.74 kg/ha) and high in potassium (243.85 kg/ha) with slightly alkaline in reaction (*p*H 8.00).The experiment was laid out in randomized block design (factorial) replicated twice. The treatments consisted of 3 planting techniques, viz P_1, paired row planting (45–75 cm × 45 cm); P_2, triangular planting (30–90 cm × 45 cm) and P_3, normal planting (60 cm × 45 cm), and 5 fertigation intervals, viz F_1, fertigation of recommended dose (100:50:50 kg NPK/ha) at every irrigation up to 105 days (2-day intervals); F_2, fertigation of recommended dose at every alternate irrigation up to 105 days (4-day intervals); F_3, fertigation of recommended dose at every third irrigation up to 105 days (6-day intervals); F_4, fertigation of recommended dose at every fourth irrigation up to 105 days (8-day intervals); and F_5, recommended dose of fertilizer through straight fertilizer + surface irrigation (control). The crop was transplanted on 13 February 2001 and 5 March 2002 during the first and second year respectively. The transplanting was done as per the treatments of planting technique. In drip, irrigation was applied at every alternate day by using pan evaporation data. The quantity of irrigation water was calculated by using the standard method (Vermerian and Jobling 1980). In surface irrigation method, scheduling was done at 75 mm CPE with 6.0 cm depth at each turn. The consumptive use was calculated as suggested by Dastane (1972). In fertigation water-soluble fertilizer (20:10:10 % NPK grade) was used. The water-soluble fertilizer was applied through fertilizer injector pump. Number of splits of recommended dose of fertilizer in fertigation treatments, viz F_1, F_2, F_3 and F_4, were 52, 26, 18 and 13 respectively.

RESULTS AND DISCUSSION

Planting technique

The growth attributes, viz plant height (cm), branches/

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plant and dry-matter accumulation (g)/plant, were significantly higher under triangular planting technique. However, it was on a par with paired row planting technique during both the years (Table 1). Significantly lowest values of these parameters were observed under normal planting technique. The results confirm those of Jayraj *et al.* (1999).

The number of fruits and weight of fruits/plant were found maximum under triangular planting technique and it was significantly higher than normal planting but at par with paired row planting technique (Table 2). Maximum and significantly higher green chilli yield was found under triangular planting technique. This might be owing to plant receiving sufficient light energy and aeration for promotion of photosynthesis and plant metabolism for assimilation of nutrients and food resources for higher yield. During both the years significantly lowest yield was noticed in normal planting technique compared to paired row and triangular planting technique (Table 2). These results confirm the findings of Pundir and Porwal (1999).

During both the years the triangular planting technique resulted in the maximum uptake of nitrogen, phosphorus and potassium, however, it was at par with paired row planting technique and significantly superior to normal planting technique (Table 3).

Fertigation intervals

All the growth attributes of the chilli, viz plant height (cm), branches/plant and dry-matter accumulation (g)/plant, were significantly higher owing to fertigation of recommended dose of fertilizer at every irrigation (2-day intervals) up to 105 days compared to rest of the fertigation intervals except fertigation at every alternate irrigation (4-day intervals) up to 105 days during both the years (Table 1). These results are in agreement with those reported by Alcantar *et al.* (1999).

All the fertigation treatments showed the great impact on yield attributes and yield of green chilli compared to surface irrigation and straight fertilizers. The yield attributes,

Table 1 Growth attributes of green chilli as influenced by planting and fertigation

Treatment	Plant height (cm)			Branches/plant			Dry-matter accumulation/ plant(g)		
	2001	2002	Pooled mean	2001	2002	Pooled mean	2001	2002	Pooled mean
Planting technique									
P_1, Paired row planting (45–75 cm × 45 cm)	74.16	76.54	75.64	18.57	16.32	17.64	167.16	169.48	168.30
P_2,Triangular planting (30–90 cm × 45 cm)	76.71	79.41	77.36	20.94	17.70	19.32	172.02	171.00	171.51
P_3, Normal planting (60 cm × 45 cm)	69.84	72.24	70.24	16.35	13.62	14.38	161.77	163.62	162.69
SE(±)	1.10	1.30	1.84	0.79	0.75	1.14	1.60	0.62	1.27
CD (P = 0.05)	3.34	3.95	5.32	2.41	2.28	3.23	4.88	1.87	3.68
Fertigation interval									
F_1, Fertigation at every irrigation (2 days) up to 105 days	78.76	80.05	79.40	22.81	19.46	21.13	191.29	180.08	185.66
F_2, Fertigation at every alternate irrigation (4 days) up to 105 days	76.83	79.90	78.36	20.88	17.56	19.22	187.00	178.41	181.95
F_3, Fertigation at every third irrigation (6 days) up to 105 days	73.89	75.11	74.50	18.28	15.46	16.87	185.49	166.85	176.92
F_4, Fertigation at every fourth irrigation (8 days) up to 105 days	72.15	74.70	73.42	16.51	14.90	15.50	170 22	165.31	167.76
F_5, Surface irrigation + 100 % RDF (straight fertilizer)	66.22	70.55	67.05	13.28	12.00	12.14	100.85	149.50	125.17
SE (+)	1.42	1.68	1.79	1.02	0.97	1.15	1.90	0.80	1.61
CD (P = 0.05)	4.31	5.10	5.14	3.11	2.95	3.32	5.75	2.42	3.73
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2 Yield attributes and yield of green chilli as influenced by planting and fertigation techniques

Treatment	Fruits/plant			Weight of fruits/plant (kg)			Yield (tonnes/ha)		
	2001	2002	Pooled mean	2001	2002	Pooled mean	2001	2002	Pooled mean
Planting technique									
P_1, Paired row planting (45–75 cm × 45 cm)	653	629	643	1.90	2.10	2.01	7.96	6.87	7.41
P_2, Triangular planting (30–90cm × 45 cm)	656	637	644	2.00	2.12	2.03	8.55	9.40	8.97
P_3, Normal planting (60 cm × 45 cm)	628	604	613	1.73	2.01	1.85	6.76	6.25	6.50
SE(±)	1.25	3.68	1.13	0.04	0.02	0.03	0.25	0.23	0.39
CD (P = 0.05)	3.81	11.18	3.41	0.13	0.07	0.08	0.78	0.72	1.15
Fertigation interval									
F_1, Fertigation at every irrigation (2 days) up to 105 days	776	656	716	2.41	2.35	2.33	9.30	9.06	9.18
F_2, Fertigation at every alternate irrigation (4 days) up to 105 days	772	645	703	2.38	2.27	2.31	8.62	8.14	8.31
F_3, Fertigation at every third irrigation (6 days) up to 105 days	660	630	645	2.06	2.02	2.03	7.95	7.56	7.75
F_4, Fertigation at every fourth irrigation (8 days) up to 105 days	657	620	625	2.04	1.98	1.99	7.88	6.97	7.42
F_5, Surface irrigation + 100 % RDF (straight fertilizer)	404	565	484	1.13	1.77	1.43	4.38	5.95	5.16
SE(±)	1.62	4.76	5.05	0.08	0.03	0.02	0.33	0.30	0.41
CD (P = 0.05)	4.92	14.43	14.92	0.26	0.10	0.06	1.01	0.93	1.19
Interaction	NS	NS	NS	NS	Sig	NS	NS	Sig	NS

viz number of fruits and weight of fruits/plant, and yield of green chilli were found significantly higher in fertigation of recommended dose of fertilizer at every irrigation (2-day intervals) up to 105 days and it was at par with fertigation at every alternate irrigation (4-day intervals) up to 105 days during both the years. This might be owing to fertigation that helps continuous supply of required quantity of nutrients in the root zone of the crop which creates favourable conditions for growth and development of crop by way of increasing metabolic activities in the plant system and resulted in maximum yield. During both the years significantly lowest yield was noticed in surface irrigation with straight fertilizer treatment. The results are in the line of Castellanos *et al.* (1999).

Fertigation of recommended dose of fertilizer at every irrigation (2-day intervals) up to 105 days recorded significantly higher uptake of nitrogen (104.69 and 96.94 kg/ha), phosphorus (12.58 and 11.81 kg/ha) and potassium (99.10 and 86.34 kg/ha), respectively, followed by fertigation at every alternate irrigation (4-day intervals) up to 105 days during both the years. These results are in accordance with those reported by Veeranna *et al.* (2000).

Triangular planting technique (30–75 cm × 45 cm) and fertigation of recommended dose (100:50:50 kg NPK/ha) of fertilizer at every irrigation up to 105 days (2-day intervals) found beneficial to increase the green chilli yield.

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Table 3 Uptake of nitrogen phosphorus and potassium (kg/ha) in green chilli as influenced by planting and fertigation techniques

Treatment	Nitrogen (kg/ha)			Phosphorus (kg/ha)			Potassium (kg/ha)		
	2001	2002	Pooled mean	2001	2002	Pooled mean	2001	2002	Pooled mean
Planting technique									
P_1, Paired row planting (45–75 cm × 45 cm)	91.65	88.58	89.11	9.93	9.37	9.64	86.90	82.27	83.33
P_2,Triangular planting (30–90cm × 45 cm)	93.33	89.52	91.42	10.75	11.11	10.80	88.18	83.13	83.58
P_3, Normal planting (60 cm × 45 cm)	83.45	79.02	81.23	9.10	6.27	8.13	84.59	58.79	69.61
SE(±)	0.70	0.45	0.93	0.66	1.36	0.94	0.81	0.81	2.01
CD (P = 0.05)	2.15	1.38	2.70	1.87	4.12	2.72	2.48	2.47	5.98
Fertigation interval									
F_1, Fertigation at every irrigation (2 days) up to 105 days	104.69	96.94	100.96	12.58	11.81	12.19	99.10	86.34	93.71
F_2, Fertigation at every alternate irrigation (4 days) up to 105 days	101.97	95.37	98.67	11.83	11.33	11.39	96.50	85.19	90.84
F_3, Fertigation at every third irrigation (6 days) up to 105 days	95.68	84.07	91.87	11.09	8.29	10.08	95.25	72.74	84.83
F_4, Fertigation at every fourth irrigation (8 days) up to 105 days	89.68	83.09	85.88	9.56	8.02	9.05	84.29	70.68	77.48
F_5, Surface irrigation + 100 % RDF (straight fertilizer)	87.30	69.07	58.90	8.53	5.14	6.77	44.60	58.70	51.65
SE (±)	0.91	0.58	6.83	0.58	1.75	0.67	1.05	1.05	2.38
CD (P = 0.05)	2.77	1.78	26.88	1.75	5.32	1.93	3.20	3.19	7.09
Interaction	NS	NS	NS	NS	NS	NS	NS	Sig	NS

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Seed germination and seedling growth of citrus (*Citrus* species) rootstocks under different salinity regimes*

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Citrus (*Citrus* sp) is grown in many semi-arid climates where rainfall is limited and irrigation is generally required to sustain the plant growth. *Citrus* species are highly sensitive to soil salinity (Maas 1992). However, the capacity of citrus trees to tolerate salinity varies among species and even among the strains within a species (Singh *et al.* 1997). Rootstocks in citrus affect the plant growth, fruit quality and adaptation to different soil and climatic conditions. So, the test of performance of rootstock cultivars is essential for successful cultivation of citrus. In earlier studies, the salt tolerance of a rootstock was generally determined at seedling level, which is very time-consuming, requires large space and is costly too. If the salt tolerance can be tested at seed level, it can be used for screening of large germplasm populations against salinity. Keeping this in view, the present investigation was carried out to assess the performance of commercial citrus rootstocks.

The present investigation was carried out during 1998–2000 at Hisar. Different levels of soil salinity were created by using a group of salts in a sandy soil. The salinity levels used for screening were control, 2, 4, 6 and 8 dS/m of Cl^- -dominated salinity. Saline soil (1.5 kg) was put in an earthen pot of 2 kg capacity, lined with polyethylene bag for seed sowing. Seeds of 3 rootstocks, rough lemon (*Citrus jambhiri* Lush.), Rangpur lime (*C. limonia* Osbeck) and trifoliate orange (*Poncirus trifoliata* Raf.) were sown in different salinity levels with 3 replications and 15 seeds/replication in factorial completely randomized design in the screen-house. The experiment was terminated 3 months after seed sowing. Germination was recorded up to 90 days. All the characters except initiation of seed germination and germination (%) were recorded at the time of termination of the experiment.

*Short note

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Initiation of germination was recorded when the first seedling emerged in a particular treatment. Seed germination (%) was recorded at 4-day intervals after initiation and finally when maximum germination occurred. The data were analysed according to Panse and Sukhatme (1985).

Seed germination was maximum in Rangpur lime, followed by rough lemon, whereas it was minimum in trifoliate orange (Table 1). An increase in salinity resulted in a decrease in seed germination (%), as maximum germination was recorded in the control and minimum in 8 dS/m in all the rootstocks. The reduction in seed germination with an increase in salinity level was minimum in Rangpur lime, followed by rough lemon, whereas in trifoliate orange, germination did not occur after 4 dS/m. The results confirm the findings of Zekri (1994).

An increase in salinity delayed seed germination. For initiation of germination, rough lemon required minimum days, followed by Rangpur lime at control, 2, 4, 6 and 8 dS/m salinity levels. Trifoliate orange required 30 days for initiation of germination at all the levels of salinity, in which seeds germinated. With an increase in salinity, a delay in the initiation and maximum germination was recorded but this delay was rootstock specific. The reduction and delay in seed germination might be due to the osmotic effects of salinity, which can affect the seed imbibition (Zekri 1993). The reduction in maximum germination in trifoliate orange with an increase in salinity may be due to the effects of Cl^-, which is a toxic ion to the plant.

Decrease in plant height, stem diameter, number of leaves/seedling, fresh top and root biomass, dry top and root biomass as well as total fresh and dry biomass was recorded with an increase in salinity level in all the rootstocks, but this decrease was minimum in Rangpur lime, followed by rough lemon and trifoliate orange (Table 1). These results are in agreement with the findings of El-Desouky and Atawia (1998). Rangpur lime exhibited an increase at 2 dS/m over the control for all the characters studied.

Growth reduction is generally related to the total concentration of soluble salts and osmotic potential of the

Table 1 Effect of salinity on seed germination and seedling growth in citrus rootstocks

Rootstock (A)	Salinity level (B) (dS/m)	Seed germination (%)	Per cent increase or decrease in*						
			Plant height	Stem diameter	Number of leaves	Fresh top biomass	Fresh root biomass	Dry top biomass	Dry root
Rough lemon	Control	95.33 (77.54)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	95.33 (77.97)	0.6(2.4)	−21.9 (−27.9)	0.7 (3.9)	−13.1 (−20.9)	−12.9 (−13.9)	−21.0 (−27.1)	0.6 (−1.7)
	4	60.00 (50.78)	−15.0 (−22.6)	−47.2 (−43.3)	4.0 (9.8)	−29.8 (−33.0)	−46.6 (−43.0)	−44.3 (−41.7)	−51.7 (−45.9)
	6	38.00 (38.05)	−35.1 (−36.2)	−70.4 (−57.1)	−12.9 (−13.1)	−68.0 (−55.8)	−70.5 (−57.3)	−65.6 (−54.3)	−57.0 (−49.1)
	8	31.00 (33.81)	−42.7 (−40.8)	−76.2 (−60.9)	−20.5 (−26.8)	−72.9 (−58.8)	−81.5 (−64.6)	−67.3 (−55.2)	−72.8 (−58.8)
	Mean	63.93 (55.63)	−18.5 (−19.4)	−43.1 (−37.6)	−5.7 (−5.3)	−36.8 (−33.7)	−42.3 (−35.8)	−39.7 (−35.7)	−36.2 (−31.1)
Rangpur lime	Control	100.00 (90.00)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	89.00 (70.80)	6.1 ((9.3)	0.5 (2.7)	−10.2 (−18.2)	12.6 (13.9)	6.6 (8.9)	1.2 (1.0)	6.8 (9.1)
	4	71.00 (57.43)	−11.4 (−18.9)	−11.2 (−23.4)	−5.0 (−10.5)	−12.9 (−13.8)	−18.8 (−25.7)	−27.5 (−31.4)	−25.6 (−29.9)
	6	69.00 (56.37)	−21.4 (−26.3)	−16.2 (−16.7)	−11.7 (−16.5)	−29.0 (−32.1)	−29.0 (−30.7)	−39.9 (−39.0)	−16.3 (−23.0)
	8	58.00 (58.00)	−23.6 (−28.7)	−15.3 (−15.8)	6.8 (13.4)	−25.8 (−28.8)	−38.0 (−36.8)	−36.7 (−36.9)	−40.9 (−38.5)
	Mean	77.40 (64.84)	−10.1 (−12.9)	−8.4 (−10.6)	−4.0 (−11.7)	−11.0 (−12.2)	−15.8(−16.9)	−20.6 (−21.3)	−15.2 (−16.5)
Trifoliate orange	Control	53.33 (46.92)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	22.00 (26.96)	−7.9 (−14.9)	−2.1 (−6.5)	−6.7 (−14.9)	3.4 (6.4)	−20.4 (−26.5)	−6.4 (−14.0)	−36.7 (−36.7)
	4	11.00 (19.32)	−12.7 (−21.8)	−45.7 (−42.6)	−2.8 (−3.1)	−42.3 (−40.6)	−61.7 (−53.1)	−57.6 (−49.4)	−69.2 (−56.3)
	6	0.00 (0.0)	−100.0 (−90)	−100.0 (−90)	−100.0 (−90)	−100.0 (−90)	−100.0 (−90)	−100.0 (−90)	−100.0 (−90)
	8	0.00 (0.0)	100.0 (−90)	−100.0 (−90)	−100.0 (−90)	−100.0 (−90)	−100.0 (−90)	−100.0 (−90)	−100.0 (−90)
	Mean	17.27 (18.64)	−44.1 (−43.1)	−49.6 (−45.8)	−41.2 (−39.6)	−47.8 (−42.8)	−56.4 (−51.9)	−52.8 (−48.7)	−61.2 (−54.6)
CD ($P = 0.05$)									
	A	2.03	5.40	8.06	10.11	8.25	10.31	6.43	9.98
	B	2.63	6.97	10.40	13.05	10.65	13.31	8.31	12.89
	A × B	4.55	12.07	18.01	22.60	18.45	NS	14.38	22.33

*Values in parentheses are the angular-transformed values root media and vegetative growth decreases in direct proportion to increasing salt concentration. Minimum reduction in all these characters was recorded in Rangpur lime, followed by rough lemon and trifoliate orange, which indicated the tolerance of Rangpur lime to salinity. Rangpur lime was also reported salinity tolerant by El-Desouky and Atawia (1998). Trifoliate orange proved to be very susceptible to salinity. These results are in agreement with the earlier findings (Storey and Walker 1999). Addition of salts increased the concentration of Na^+ and Cl^- in all the plant parts at higher salt concentration, which might be responsible for poor growth of the seedlings (Syvertsen *et al.* 1988). There is alteration of biological activities of the phytohormones due to salinity, which might be responsible for poor growth of the seedlings (El-Desouky and Atawia 1998). The increase in growth in Rangpur lime at 2 dS/m indicated a certain threshold limit for the character expression.

On the basis of the pattern of germination and reduction in plant growth, Rangpur lime was adjudged as tolerant, rough lemon as moderately tolerant and trifoliate orange as susceptible to salinity. The reduction and delay in seed germination and reduction in seedling growth can be considered as reliable criterion for screening citrus rootstocks for salt tolerance.

SUMMARY

Three citrus rootstocks, viz rough lemon (*Citrus jambhiri* Lush.), Rangpur lime (*Citrus limonia* Osbeck) and trifoliate orange (*Poncirus trifoliata* Raf.) were screened during 1998–2000 for salt tolerance through seed germination at control, 2, 4, 6 and 8dS/m of Cl^--dominated salinity under the screen-house conditions. Increase in salinity reduced and delayed seed germination in all the rootstocks, but the least affected rootstock was Rangpur lime, followed by rough lemon and trifoliate orange. Increase in salinity caused reduction in seedling height, stem girth, fresh and dry aerial and root biomass, but these reductions were less in Rangpur lime than those of the othe rootstocks. Rangpur lime was adjudged as tolerant, rough lemon as moderately tolerant and trifoliate orange as susceptible rootstock to salinity. Rangpur lime exhibited a threshold level for salinity, up to which there was an increase in growth characteristics and beyond that the growth of the seedlings was reduced. The reduction and delay in seed germination may be considered as reliable criteria for screening of citrus rootstocks for salt tolerance.

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Growth, flowering behaviour and vase life of Asiatic hybrid lily as influenced by planting time and varieties*

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Keywords: Asiatic hybrid lily, *Lilium*, Growth, Flowering, Planting time, Varieties, Vase life

Lilium has a great potential as commercial cut-flower crop and ranks seventh among top 10 cut-flowers in the International trade. It is propagated through bulbils, scales and bulblets. Good-quality bulbs are the basic and most important input for cut-flower production, as the initial growth of plants largely depends on bulb and bulblets, other inputs are rendered ineffective if the bulbs are not of good quality. In the absence of scientific information on optimum agro-techniques to be followed for the successful cultivation of *Lilium*, the present experiment was conducted to standardize the time of planting, select best varieties and to examine the vase life of flowers for commercial flower production.

An experiment was carried out during the winter season of 2001–2002. The soil was silty loam having *p*H 7.8. The experiment was laid out in factorial randomized block design with 3 replications. There were 3 planting dates, ie 15 November (P_1), 25 November (P_2), 5 December (P_3), and 3 varieties, viz 'Elite' (V_1) 'Novecento' (V_2) and 'Pollyanna' (V_3). Recommended cultural practices such as irrigation, weeding, hoeing and fertilizer application were followed for *Lilium* cultivation. Observations were recorded on plant growth, flowering and vase life of *Lilium*.

The time of planting had significant influence on growth, flowering and vase life of Asiatic hybrid lily (Table 1). Early planting during the first fortnight of November recorded significantly higher growth and flowering thans later planting.

*Short note

Based on complete information of MSc thesis of the first author, submitted to Narendra Deva University of Agriculture and Technology, Faizabad, Uttar Pradesh, in 2002 (unpublished)

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Table 1 Effect of planting time and varieties on growth, flowering and vase life of Asiatic hybrid lily

Treatment	Sprouting time (days)	Plant height (cm)	Number of leaves	Days to first bud initiation	Days to bud loosening	Number of buds/plant	Days to first bud opening	Days to last bud opening	Duration of flowering	Vase life (days)
P_1	10.00	69.66	109.73	43.34	35.72	7.64	96.04	104.47	29.59	15.00
P_2	11.89	64.77	97.44	31.97	32.24	7.02	91.20	101.80	28.86	12.63
P_3	14.00	62.77	90.88	27.82	29.68	6.24	85.74	100.80	27.03	9.97
CD (P=0.5)	0.28	1.69	4.76	0.54	1.26	0.59	1.17	0.64	0.14	0.06
V_1	11.56	81.38	107.64	33.67	31.41	7.82	93.51	103.01	29.46	13.63
V_2	11.78	54.41	91.87	34.67	32.94	6.03	90.30	100.76	28.29	11.36
V_3	12.56	61.41	98.70	34.73	33.28	7.06	89.18	102.46	27.73	12.61
CD (P=0.5)	0.28	1.69	4.76	0.54	1.26	0.59	1.17	0.64	0.14	0.06
P_1V_1	9.00	88.61	124.20	42.08	34.80	8.83	98.40	107.23	30.53	16.30
P_1V_2	10.00	56.13	96.73	43.87	36.03	6.50	95.27	102.30	30.53	13.40
P_1V_3	11.00	64.23	108.43	44.07	36.33	7.60	94.47	104.80	27.70	15.30
P_2V_1	12.00	80.50	98.80	31.07	32.33	8.03	94.43	101.30	28.70	14.30
P_2V_2	11.33	51.97	94.00	32.40	31.06	6.00	98.80	100.20	28.60	11.33
P_2V_3	12.33	61.83	99.53	32.27	33.33	7.03	89.37	104.00	29.27	12.27
P_3V_1	13.67	75.03	99.93	27.87	27.10	6.60	87.70	100.50	29.13	10.30
P_3V_2	14.00	55.13	84.87	27.73	31.73	5.60	85.83	99.80	25.73	9.33
P_3V_3	14.33	58.17	88.13	27.87	30.20	6.53	83.70	102.10	26.23	10.27
CD (P=0.5)	NS	2.93	0.69	0.94	2.18	NS	NS	1.12	1.98	0.11

P_1, 15 November, P_2, 25 November, P_3, 5 December
V_1, 'Elite'; V_2, 'Novecento', V_3, 'Pollyanna'

The better performance of Asiatic hybrid lily under early planting conditions may be owing to longer growing season and availability of appropriate climatic conditions for growth, as could be seen through better flowering and keeping quality. The results are in agreement with the findings of Beattie and White (1993) in *Lilium* and Kumar and Kaur (1997) in statice. Early planting in the first fortnight of November resulted significantly higher number of leaves, plant height, delayed first bud initiation, bud loosening, first bud opening, last bud opening as well as increased number of buds /plant, duration of flowering and vase life, but resulted significantly lower sprouting time as compared to later planting.

The growth, flowering and vase life were significantly influenced by varieties (Table1). The variety 'Elite' exhibited significantly higher growth, flowering and vase life over other varieties, 'Novecento' and 'Pollyanna'. The better performance of 'Elite' may be because of genetic make-up of bulb for plant growth and flowering, as could be seen through better keeping quality. The findings substantiated the results of Khobragade *et al.* (1997) in tuberose (*Polianthus tuberosa* L.) and Singh *et al.* (2000) in *Lilium*. The variety 'Elite' showed significantly more number of leaves and plant height, delayed first bud opening and last bud opening, increased number of buds/plant, duration of flowering and vase life. However, this variety showed significantly lower sprouting time, earlier bud initiation and bud loosening than varieties 'Novecento' and 'Pollyanna'.

All the 3 varieties were promising when planted early during the first fortnight of November but when the planting was delayed to 25 November the performance of variety 'Elite' was superior to that of variety 'Pollyanna' and 'Novecento'. In general, there was a drastic reduction in growth and keeping quality of all the varieties when planted on 5 December. The results are in confirmation with those of Trivedi and Singh (2000) in tuberose. Therefore, planting of bulb during the first fortnight of November may be recommended variety 'Elite' under eastern Uttar Pradesh Conditions.

SUMMARY

A field experiment conducted during the winter season 2001–2002, showed that planting of Asiatic hybrid lily during the first fortnight of November resulted in significantly higher plant height; number of leaves; delayed first bud initiation, bud loosening, first bud opening, last bud opening; number of buds plant; duration of flowering and vase life than later plantings. Variety 'Elite' performed better in respect of growth and flowering behaviour than 'Novecento' and 'Pollyanna'. In the interaction of planting date and variety, the variety 'Elite' found promising in terms of growth and flowering behaviour when planted in first fortnight of November.

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Effect of maturity at harvest on physico-chemical attributes of sweet pepper (*Capsicum annuum* var *grossum*) varieties*

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Keywords: Post-harvest technology, Harvesting stages, Physiochemical attributes, Sweet pepper, *Capsicum annuum* var *grossum*

Sweet pepper [*Capsicum annuum* L. var *grossum* (L.) Sendt.] is one of the important vegetable crops, requires mild climate for growth and flowering. The fruits are harvested either at the green, mature or colouring stage. The red or yellow fruits on full ripening are used for preparing fast food in the cosmopolitan cities. It is obvious that the maturity at the time of harvest drastically influences the yield and physico-chemical attributes. Precise determination of fruit maturity is difficult in sweet pepper. If fruits are harvested immature, they may not develop acceptable flavour upon ripening (Boonyakiat *et al.* 1987).

Moreover, since fruit growth continues until harvest, size of immature fruit will be smaller than the mature fruit resulting in a loss of harvest yield. Therefore determining the optimum maturity will benefit both consumer and grower. Maturity assessment of capsicum fruits normally based on visual colour, size, hand press to evaluate firmness or days from anthesis (Lin *et al.* 1993, Howard *et al.* 1994, Sanchez *et al.* 1993).

Thus, there is need to develop maturity and quality indices for sweet pepper which are more consistent and reliable than the existing methods. The objective of this research was to determine a reliable harvest maturity index for the fruit.

The experimental materials comprised 6 commercial varieties of sweet pepper, viz 'Pusa Deepti' (F_1), 'Purple Beauty', 'Golden Bell', 'California Wonder', 'Yolo Wonder' and 'Russian Yellow', were grown under low-cost polyhouse at New Delhi from October 2001 to April 2002. The experiment was laid out in randomized block design with 3 replications. Seedlings of 6 cultivars were transplanted in 3 m × 3 m bed at 50 cm × 30 cm spacing in mid-October 2001. Flowers were tagged at anthesis to determine the stage of fruit growth and 10 fruits randomly harvested from 5 plants of each cultivar per replication 30, 40 and 50 days after anthesis (DAA) to determine their growth and maturity. The fruit growth attributes, viz length (cm), diameter (cm), fresh weight (g), volume (ml) and pericarp thickness (cm), were measured. Total soluble solids (° B), moisture (%), ascorbic acid (mg/100 g), acidity (%), carotene (mg/100 g) and total chlorophyll (mg/100 g) were estimated according to the standard procedures of AOAC (1970). The fruit firmness (rupture and compression force) was determined with the help of Universal Testing machine. A 6 mm diameter probe was used to rupture the capsicum at 2 different places of each fruit with a crosshead speed of 50 mm/min, having 100 Newton load cell. The peak rupture force was recorded as Newton (N). Similarly, 3.6 mm diameter probe was used to record the data on compression up to a depth of 4–5 mm.

Fruit growth of sweet pepper followed single sigmoid-type curve, which is a characteristic of many fruits (Rhodes 1980). The statistical significant difference existed among the cultivars for physical attributes of fruits in all 3 stages (Table 1). The maximum fruit girth, volume and fresh fruit weight were recorded in 'California Wonder' 30, 40 and 50 days after anthesis respectively. The cultivars with higher fruit diameter and volume produced higher fresh fruit weight. This shows that fresh weight of sweet pepper can be predicted by measuring the fruit diameter and volume. Tadesse *et al.* (2002) also reported that measurement of fruit diameter and volume can be used successfully to estimate and predict fresh weight of sweet pepper. The fruit dimensions (length, diameter, volume) and fruit weight increased as maturity progressed (Table 1). However, the differences between 40 and 50 days after anthesis in fruit dimension and fruit weight were less compared to the difference between 30 and 40 days after anthesis. This slow growth in fruit dimension and fruit weight indicated that the fruits of all cultivars attained the mature green stage at around 40 days after anthesis At 50 days after anthesis (breaker stage) the maximum diameter, fruit weight and volume were recorded in 'California Wonder'. The moisture content of the fruits of all cultivars

* Short note

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Table 1 Physical attributes of varieties of sweet pepper at 30, 40 and 50 days after anthesis

Variety	30 days after anthesis							40 days after anthesis							50 days after anthesis						
	Length (cm)	Girth (cm)	Pericarp thickness (cm)	Average fruit weight (g)	Volume (ml)	Rupture force (N)	Compression force (N)	Length (cm)	Girth (cm)	Pericarp thickness (cm)	Average fruit weight (g)	Volume (ml)	Rupture force (N)	Compression force (N)	Length (cm)	Girth (cm)	Pericarp thickness (cm)	Average fruit weight (g)	Volume (ml)	Rupture force (N)	Compression force (N)
'Pusa Deepti'	9.3	5.3	0.45	67.67	168	15.2	15.18	9.83	5.37	0.5	110.6	175	25.35	29.72	10.8	6.4	0.5	128	182	22.8	28.61
'Purple Beauty'	5.8	3.7	0.27	30.85	42.5	13.85	10.96	9.53	3.77	0.27	73.89	89	21.79	18.74	10	4.2	0.27	79.3	91	21.18	23.62
'Golden Bell'	7.8	5.6	0.58	92.73	138	17.71	16.25	10.23	6.53	0.67	103.64	145	20.36	21.76	10.5	7.8	0.67	109	210	20.08	24.65
'California Wonder'	6.67	7.43	0.5	106.59	198	18	13.69	9.3	8.5	0.67	127.16	205	27.38	24.32	9.4	9.43	0.7	132	225	24.9	26.77
'Yolo Wonder'	4.5	4.5	0.4	36.8	45	17.16	13.12	7.7	7.6	0.6	120.82	169	29.49	25.85	8.7	9.4	0.67	127	213	22.82	25.13
'Russian Yellow'	5.5	3.9	0.35	28.27	41	14.18	10.21	6.5	4.8	0.37	50.26	78	23.67	21.82	6.8	5.3	0.37	68.3	80	20.38	24.36
CD (P= 0.05)	2.93	1.32	NS	9.52	16.16	5.47	NS														

Table 2 Bio-chemical attributes of varieties of sweet pepper at 30, 40 and 50 days after anthesis

Variety	30 days after anthesis						40 days after anthesis						50 days after anthesis					
	Moisture (%)	TSS (°B)	Ascorbic acid (mg/100 g)	Acidity (%)	Carotene (mg/100 g)	Chlorophyll (total) (mg/100 g)	Moisture (%)	TSS (°B)	Ascorbic acid (mg/100 g)	Acidity (%)	Carotene (mg/100 g)	Chlorophyll (total) (mg/100 g)	Moisture (%)	TSS (°B)	Ascorbic acid (mg/100 g)	Acidity (%)	Carotene (mg/100 g)	Chlorophyll (total) (mg/100 g)
'Pusa Deepti'	93.00	5.00	40.77	0.16	0.133	63.13	91.30	7.50	58.77	0.41	0.625	42.96	90.60	7.50	61.00	0.37	1.127	13.92
'Purple Beauty'	93.40	5.17	45.31	0.16	0.133	46.05	92.10	7.00	60.04	0.53	0.528	56.98	90.80	10.00	61.67	0.22	0.550	44.29
'Golden Bell'	93.90	5.00	27.27	0.18	0.133	108.15	93.40	6.00	69.08	0.36	0.750	63.14	92.00	9.00	88.70	0.37	1.500	33.14
'California Wonder'	93.60	5.67	36.24	0.16	0.266	148.84	92.90	6.50	50.64	0.56	0.550	198.21	90.60	7.00	94.62	0.26	0.700	86.47
'Yolo Wonder'	93.00	5.00	41.36	0.15	0.291	65.79	92.13	5.50	70.82	0.32	0.480	50.50	91.50	6.00	84.46	0.18	0.650	50.63
'Russian Yellow'	93.00	4.83	40.01	0.15	0.263	58.16	91.60	6.00	45.24	0.38	0.717	18.75	91.36	6.50	49.20	0.16	1.217	4.58
CD (P=0.05)	1.67	1.73	12.62	0.08	0.09	14.20												

decreased as the maturity advanced. The harvesting time (days after anthesis) also influenced significantly the chemical and textural attributes of the sweet pepper fruits of different varieties. The fruit firmness particularly rupture force increased with fruit size and reached maximum at 40 days after anthesis but reduced during ripening (Table 1). As consumers prefer mature and reasonably firm fruit, harvesting 40 days after anthesis may provide a reliable index of maturity. The pericarp thickness was the highest at 40 days after anthesis (at green maturity) in almost all varieties. It clearly indicates the positive correlation between pericarp thickness and fruit firmness. This relationship was also confirmed by Tadesse *et al.* (2002). The total soluble solids, ascorbic acid and carotene content increased during fruit maturity and ripening in all cultivars, whereas the acidity increased at maturity (40 days after anthesis) but reduced at ripening (50 days after anthesis). At 40 days after anthesis, the highest total soluble solids, ascorbic acid, acidity and carotene content were observed in 'Pusa Deepti', 'Yolo Wonder', 'California Wonder' and 'Pusa Deepti' respectively. At breaker stage (50 days after anthesis), the maximum total soluble solids, ascorbic acid and carotene content were found in 'Purple Beauty', 'California Wonder' and 'Golden Bell' respectively. The increase in total soluble solids of sweet pepper fruit with maturity is probably a result of hexose sugar accumulation during fruit ripening (Nielsen *et al.* 1991), as there is a close positive correlation between rise in total soluble solids and soluble sugars (Mendlinger *et al.* 1992). The total chlorophyll content (chlorophyll A and B) was reduced as the maturity advanced and minimum during fruit ripening (50 days after anthesis) in almost all cultivars except 'Purple Beauty' and 'California Wonder' where maximum chlorophyll found at 40 days after anthesis (Table 2). The colour change in sweet pepper corresponds to a fall in chlorophyll and an increase in carotenoid synthesis (Pretel *et al.* 1995) may be due to the transformation of chloroplasts to chromoplasts (Leshem *et al.* 1986). The surface colour change and fruit firmness can be used to determine the fruit maturity in all the cultivars under study and 40 days after anthesis is the appropriate stage of harvesting of green capsicum.

SUMMARY

An experiment was conducted to judge the maturity index in sweet pepper [*Capsicum annuum* L. var *grossum* (L.). Sendt.] varieties during 2001–2002 grown under low-cost polyhouse at New Delhi. The results indicated that 40 days after anthesis is the appropriate stage of harvesting green fruits of 'California Wonder', 'Yolo Wonder' and 'Golden Bell', whereas 30 days after anthesis for 'Pusa Deepti', 'Russian Yellow' and 'Purple Beauty' grown under low-cost polyhouse. The surface colour and fruit firmness can be used to judge the fruit maturity in all the varieties under study.

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Yield and quality of wheat (*Triticum aestivum*) as influenced by sulphur nutrition and weed management*

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Wheat (*Triticum aestivum* L.emend. Fiori & Paol.), being the most indispensable cereal crop next to rice (*oryza sativa* L.), is of great significance in Indian agriculture for triggering green revolution. It plays a vital role in stabilizing national food supply in coming decades. Sulphur, one of the essential nutrients for proper growth and development of plants, is required in amount similar to P and one-third of nitrogen. Exploitive agriculture making use of high-analysis sulphur-free NPK fertilizers like urea, diammonium phosphate and muriate of potash has depleted the soils of their sulphur reserves. According to an estimate, the sulphur removal by crop annually from Indian soils is around 1 million tonne and replenishment through fertilizer is about 0.3 million tonne (Tandon 1988). This wide gap has resulted in the emergence of S-deficiency which is expected to intensify in the coming years. Grassy weeds like little small canary grass (*Phalaris minor* Retz.) and wild oat (*Avena fatua* L.) growing in dwarf wheat puzzle the farmers due to their morphological similarities with the crop. They are not easily identified by the farmers and defy all manual and mechanical attempts to control them. Uptake of nutrients by these weeds are more in comparison with the crop (Dixit and Bhan 1998). Therefore, there is need to device base to check the loss of scarce and costly inputs. Hence the present investigation was aimed to find out the optimum dose of sulphur and suitable method of weed control for obtaining higher yield and quality wheat.

A field experiment was conducted at Pusa, Samastipur, Bihar, during the winter season of 2000–2001 in factorial randomized block design, with 4 sulphur levels (0, 15, 30 and 45 kg S/ha) and 3 weed-control methods (weedy check, hand-weeding and isoproturon, ie 3- (4-isopropyl phenyl) - 1,1-dimethyle urea @ 1.5 kg ai/ha). Wheat variety 'HP 1744' was sown in rows, 20 cm apart using a seed rate of 150 kg/ha on 12 December 2000. The soil was clay loam having pH 8.2, low in available nitrogen (188.0 kg/ha), phosphorus (21.2 kg/ha) and potassium (84.8 kg/ha). The available sulphur in the experimental plot was 8.26 mg/kg. Mean maximum temperature during crop season ranged from 20.8 to 36.1°C, whereas mean minimum temperature from 7.6 to 20.4°C. The crop received 7.5 and 6.0 mm rainfall during January and April 2001 respectively. Relative humidity ranged from from 91 to 32% during crop growth period.

Sulphur nutrient influenced the yield and yield attributes of wheat. Dry-matter accumulation, ears/m running length, ear length, spikelets/ear, grains/ear, 1 000-seed weight, grain yield and straw yield were significantly higher with 30 kg S/ha compared to its lower levels, but was found at par with 45 kg S/ha. Application of 30 kg S/ha increased dry-matter accumulation by 3.6%, number of ears by 2.4% and 1 000-seed weight by 5.7%, respectively, over 15 kg S/ha (Table 1). Besides these parameters, sulphur nutrition had significant impact on protein content which increased by 6% with 15 kg, 10% with 30 kg and 13% with 45 kg S/ha over no-sulphur treatment. The increase at 30 kg S/ha might be owing to the fact that in sulphur-deficient soil an application of 30 kg S/ha proved sufficient to meet the sulphur need of the crop and ultimately resulted in increased photosynthetic activity, better growth owing to enzyme activation, better resistance in plant to insect-pests, diseases and to other hazards (Sakal *et al.* 2000, Shivran *et al.* 2000). No significant differences were observed for harvest index. Hand-weeding and application of isoproturon @ 1.5 kg ai / ha at 30 days after sowing being at par with each other gave significantly higher number of tillers, dry-matter accumulation, yield-attributing characters, grain and straw yield over weedy check, but harvest index and protein content in wheat grain were not affected significantly due to different weed-management practices (Table 1). The higher yield under hand-weeding and chemical (isoproturon) weeding might be due to reduced crop–weed competition during the early

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Table 1 Growth, yield attributes and yield as affected by sulphur and weed-management practices

Treatment	Tillers/m running length	Dry-matter accumulation (g)	Ears/m running length	Ear length (cm)	Spikelets/ ear	Grains/ ear	1 000-seed weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Protein content in wheat grain (%)	Harvest index (%)
Sulphur (kg/ha)											
0	69.75	100.72	69.57	7.73	16.41	43.30	34.50	2 270	3 330	12.41	40.63
15	72.58	106.90	72.88	8.13	17.96	45.83	36.23	2 605	3 803	13.16	40.68
30	75.33	110.50	74.53	9.11	20.73	48.60	38.18	2 811	3 996	13.67	41.19
45	75.68	113.60	75.32	9.50	21.91	49.73	38.66	2 839	4 003	14.09	41.40
CD (P = 0.05)	1.39	1.81	1.42	0.54	1.11	1.73	1.12	148	96	1.37	NS
Weed management											
Weedy check	66.50	98.86	69.43	7.60	16.90	43.37	34.14	2 294	3 380	12.70	40.43
Hand-weeding	77.38	115.72	75.23	9.17	20.85	49.07	38.57	2 842	4 015	13.79	41.35
Isoproturon 1.5 kg ai/ha	76.13	109.23	74.57	9.07	20.01	48.15	37.57	2 758	3 955	13.51	41.14
CD (P = 0.05)	1.31	1.44	1.19	0.49	0.96	1.51	0.97	126	85	NS	NS

Table 2 Effect of sulphur and weed management on weeds growth, population and S- content

Treatment	Weed population/ m^2 (harvest)	Weed dry weight (g/m^2) (harvest)	Weed growth rate (g/m^2/day) (90 DAS–harvest)	Weed-control efficiency (%) (90 DAS)	Weed index (%)	Sulphur content in weeds (%)	Sulphur content in wheat grain (%)	Sulphur content in straw (%)
Sulphur (kg/ha)								
0	84.35	54.43	0.60	44.96	7.36	0.521	0.102	0.097
15	85.02	55.85	0.58	44.83	7.11	0.592	0.152	0.147
30	84.52	56.82	0.54	44.60	7.25	0.620	0.165	0.154
45	83.87	57.26	0.56	44.92	7.83	0.654	0.176	0.170
CD (P = 0.05)	NS	1.58	NS	NS	NS	0.058	0.016	0.016
Weed management								
Weedy check	168.53	99.50	0.77		19.15	0.571	0.121	0.116
Hand-weeding	31.56	26.25	0.39	74.61		0.674	0.166	0.159
Isoproturon 1.5 kg ai/ha	53.24	42.57	0.56	59.88	3.01	0.547	0.161	0.155
CD (P = 0.05)	1.16	1.16	0.054	1.12	0.97	0.051	0.014	0.013

DAS, Days after sowing

growth stage. Plants grow freely to receive enough sunshine for carbohydrate synthesis resulting in better growth of plants, more number of ears/m, spikelets/ear and grains/ear. Ultimately, better expression of all these attributes resulted in increased grain yield of wheat. These findings are in agreement with those of Azad and Singh (1997).

No significant differences were recorded for weed population/m^2, weed dry weight and weed-control efficiency 90 days after sowing due to different levels of sulphur application. Application of sulphur significantly increased weed dry weight over the control. One hand-weeding 30 days after sowing resulted in significantly lower weed population (31.56/m^2), weed dry weight (26.2 g/m^2), weed growth rate (0.39 g/m^2/day) and showed higher weed-control efficiency (74.6%) compared to all other treatments (Table 2). The results confirm the findings of Tandon and Messick (2002).

Each successive doses of sulphur application resulted in increased S content in wheat grain, straw and in weeds. The maximum sulphur content in grain (0.176%), straw (0.170%) and weeds(0.654%) was recorded with 45 kg S/ha, being at par with 30 kg S/ha and significantly superior to other 2treatments. This might be due to the fact that application of sulphur in sulphur-deficient soil increases the available sulphur in soil which facilitates higher uptake of sulphur by the wheat crop and weeds. Weed-management practices, viz hand-weeding and application of isoproturon @ 1.5 kg ai/ ha30 days after sowing, also influenced the sulphur content in wheat grain, wheat straw but was found at par with each other over weedy check. Sulphur content in weeds was found significantly higher with 1 hand-weeding 30 days after sowing (Table 2).

SUMMARY

An experiment was conducted during 2000–2001 to study the optimum dose of sulphur and suitable method of weed control for obtaining higher yield and quality wheat. (*Triticum aestivum* L. emend. Fiori & Paol.). Overall results revealed that in S-deficient soils, potential yield with desirable quality are possible by applying optimum dose of sulphur in association with effective control of weeds. This is virtually essential to optimize the complimentarity among yield maximising factors by retarding the negative yield factors like nutrient deficiency and weed competition. Application of sulphur @ 30 kg/ha in combination with isoproturon @1.5 kg ai/ha or 1 hand-weeding 30 days after sowing significantly increased wheat production in sulphur-deficient soil.

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Effect of irrigation and sulphur on yield attributes, productivity, consumptive use, consumptive use efficiency of wheat (*Triticum aestivum*)*

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Among foodgrains, wheat (*Triticum aestivum* L.emend. Fiori & Paol.) is the world's leading cereal crop. Irrigation is one of the most important factors for crop production. Wheat productivity can be increased by providing copious water at the right time according to the availability of irrigation water. Rice (*Oryza sativa* L.)–wheat cropping system is the most dominant cropping system in India, being practised in about 9.5 million ha. The productivity of this system is declining over time, may be due to deficiency of some nutrients like sulphur. Increased use of S-free fertilizers like urea, diammonium phosphate and muriate of potash, intensive cropping with high-yielding crop cultivars without recycling of their residues and restricted supply of organic matter have aggravated S deficiency in soils. It has been reported that wheat yield increased by 25% with the sulphur application and application of 40 kg S/ha increased protein content of wheat by 1.6% (Malik 1999). Considering the importance and possibilities of increasing grain yield of wheat, the present study was carried out to evaluate the growth and productivity of this crop at varying levels of irrigation and sulphur under red and lateritic tract of West Bengal.

The field experiment was conducted during the winter season of 1997–98 and 1989–99 at the Agricultural Farm (23^0 39′N, 87^0 42′E and 58.9 m altitude) of the Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal. The experiment was laid out in split-plot design with 3 replications. Four levels of irrigation (1 irrigation at crown-root-initiation stage, 2 irrigations at crown-root initiation and tillering stages, 3 irrigations at crown-root initiation , tillering, flowering stages and 4 irrigations at crown-root initiation , tillering, flowering and grain-development stages) were allotted in the main plots and 4 levels of sulphur (0, 15, 30 and 45 kg/ha) in subplots. The experimental soil was lateritic sandy loam, slightly acidic (*p*H 6.0) with 0.34% organic carbon, 0.032% total N, 39.2 kg/ha available P, 130.8 kg/ha available K and 26.42 kg/ha available S. The seed was sown at 25 cm row spacing on 20 December and 15 December and was harvested on 16 April and 11 April during 1997–98 and 1998–99 respectively. A basal dose of 60 kg N/ha, 60 kg P/ha and 60 kg K/ha were applied through urea, diammonium phosphate and muriate of potash at the time of final land preparation as a general fertilizer dose. The remaining 60 kg N/ha was top-dressed at crown-root-initiation stage during the first irrigation. Irrigations were applied as per treatment and elemental S was applied for S treatment at the time of final land preparation. Periodical observations were taken for growth attributes and yield components and yields were recorded at maturity. The water-use consumption was computed by moisture-depletion study and consumptive use efficiency was calculated dividing the grain yield by consumptive use. Average S content was determined from the soil samples (0–30 depth) collected before starting the experiment and after harvesting the crop using the method described by Williams and Steinbergs (1959). The crop received 199.3 and 23.6 mm total rainfall during the crop season of 1997–98 and 1998–99 respectively.

Plant highest and dry-matter accumulation (g/m^2) of wheat was significantly increased due to different levels of irrigation. The crop receiving highest number of irrigation recorded the maximum height and dry-matter accumulation (g/m^2) of the plants (Table 1). One irrigation at the crown-root-initiation stage recorded the lowest plant height and dry-matter accumulation (g/m^2)] might be due to moisture stress experienced by the crop caused lower growth. Highest plant height and dry-matter accumulation (g/m^2) were obtained with highest level of sulphur (45 kg/ha) and the lowest in control (with no sulphur).

The maximum leaf-area index (Table 1) at 60 days after sowing was observed with the application of highest level of irrigation (4 irrigations) and highest level of sulphur (45 kg/ha). The results indicated that 4 irrigations helped in proper leaf expansion of the crop.

*Short note

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Table 1 Effect of irrigation and sulphur on plant height, dry-matter accumulation, leaf-area index and crop-growth rate of wheat at 60 days after sowing and maturity (mean data of 2 years)

Treatment	Levels of irrigation									
	CRI		CRI+T		CRI+T+F		CRI+T+F+Gd		Mean	
	60	M	60	M	60	M	60	M	60	M
Sulphur (kg/ha)					*Plant height(cm)*					
0	73.36	90.01	76.11	90.39	78.85	90.87	81.60	93.41	77.56	91.17
15	73.37	90.25	77.12	90.88	81.82	93.03	82.37	95.53	78.52	92.43
30	73.54	90.47	80.20	90.89	83.08	94.64	82.46	98.68	79.82	93.67
45	74.81	91.87	80.90	92.00	84.93	95.67	84.85	98.94	81.28	94.62
Mean	73.76	90.65	78.58	91.04	82.02	93.56	82.83	96.64		
CD (P=0.005)		*60 DAS*	*Maturity*							
Irrigation		4.21	2.11							
Sulphur		1.38	0.81							
Interaction										
Difference between 2 subplots at same level of main plot		NS	NS							
Difference between 2 main plot at same level of subplot		NS	NS							
					Dry-matter accumulation (g/m²)					
0	304.66	468.10	327.63	513.13	356.73	544.26	360.56	548.66	337.40	518.54
15	608.56	476.83	338.40	525.63	365.80	555.06	365.90	554.80	344.64	528.08
30	314.03	489.13	354.23	542.80	375.00	564.73	377.00	566.73	355.14	540.85
45	325.50	500.66	364.20	555.00	389.83	583.73	391.50	585.20	367.76	556.15
Mean	313.27	483.68	346.12	534.14	371.84	561.95	373.74	563.85		
CD (P=0.005)		*60 DAS*	*Maturity*							
Irrigation		1.94	2.77							
Sulphur	1	.93	2.00							
Interaction										
Difference between 2 subplots at same level of main plot		3.87	4.01							
Difference between 2 main plot at same level of subplot		3.71	4.15							
					Leaf-area index					
0	2.041	1.950	2.098	2.333	2.567	2.600	2.482	2.813	2.297	2.424
15	2.089	2.120	2.139	2.400	2.581	2.640	2.915	2.846	2.481	2.502
30	2.179	2.073	2.187	2.353	2.991	2.720	3.010	3.063	2.521	2.552
45	2.183	2.120	2.292	2.380	2.993	3.000	3.409	3.093	2.714	2.648
Mean	2.123	2.066	2.154	2.366	2.783	2.740	2.954	2.954		
CD (P=0.005)		*60 DAS*	*Maturity*							
Irrigation		0.076	0.065							
Sulphur		0.110	0.023							
Interaction										
Difference between 2 subplots at same level of main plot		NS	0.046							
Difference between 2 main plot at same level of sub plot		NS	0.066							
					Crop-growth rate(g/m²/day)					
0	11.07	11.56	10.99	13.03	12.98	13.17	13.24	13.20	12.072	12.741
15	11.14	11.88	11.47	13.15	13.21	13.28	13.20	13.26	12.259	12.895
30	11.04	12.32	12.14	13.23	13.53	13.31	13.64	13.31	12.589	13.046
45	11.31	13.34	12.35	13.38	13.99	13.59	14.14	13.58	12.951	13.225
Mean	11.142	12.028	11.741	13.200	13.430	13.349	13.558	13.339		
CD (P=0.005)		*60 DAS*	*Maturity*							
Irrigation		0.148	0.140							
Sulphur		0.145	0.108							
Interaction										
Difference between two subplots at same level of main plot		0.291	0.215							
Difference between 2 main plot at same level of subplot		0.280	0.220							

* CRI, Crown-root initiation; T, tillering; F, flowering; Gd, grain development; M, maturity

Table 2 Effect of irrigation and sulphur on yield attributes, grain yield, straw yield and harvest index of wheat (mean data of 2 years)

Treatment	Levels of irrigation				
	CRI	CRI+T	CRI+T+F	CRI+T+F+Gd	Mean
Sulphur level (kg/ha)					
	Effective tillers/m^2				
0	193.87	194.09	194.37	196.31	194.99
15	195.65	196.56	197.97	203.82	198.50
30	196.44	199.01	209.43	219.12	206.00
45	201.04	205.34	220.87	221.07	212.08
Mean	196.75	198.75	205.66	210.08	
CD (P = 0.005)					
Irrigation				2.39	
Sulphur				1.17	
Interaction[1,2]				NS	
	Number of grains/ear				
0	23.96	24.88	27.12	28.04	26.00
15	24.07	24.93	27.99	32.01	27.25
30	24.18	27.02	29.67	32.13	28.25
45	24.43	27.17	30.54	34.18	29.08
Mean	24.16	26.00	28.83	31.58	
CD (P = 0.005)					
Irrigation				1.06	
Sulphur				1.05	
Interaction[1,2]				NS	
	Panicle length (cm)				
0	8.03	8.52	9.21	9.92	8.92
15	8.15	8.55	9.33	9.93	8.99
30	8.41	8.56	9.55	10.08	9.15
45	8.61	8.69	9.59	10.19	9.27
Mean	8.3	8.58	9.42	10.03	
CD (P=0.005)					
Irrigation				0.99	
Sulphur				0.23	
Interaction[1,2]				NS	
	1 000-grain weight (g)				
0	37.18	38.23	39.20	40.03	38.66
15	37.69	38.47	39.97	40.52	39.16
30	38.33	39.14	40.05	40.80	39.58
45	38.44	39.49	40.46	41.29	39.92
Mean	37.91	38.83	39.92	40.66	
CD (P=0.005)					
Irrigation				1.42	
Sulphur				NS	
Interaction[1,2]				NS	
	Grain yield (tonnes/ha)				
0	2.16	2.17	2.32	2.63	2.32
15	2.18	2.24	2.48	2.82	2.43
30	2.25	2.33	2.54	2.83	2.49
45	2.32	2.47	2.64	2.86	2.57
Mean	2.23	2.30	2.49	2.79	
CD (P=0.005)					
Irrigation				0.132	
Sulphur				0.055	
Interaction[1,2]				NS	
	Straw yield (tonnes/ha)				
0	4.34	4.62	5.06	5.39	4.85
15	4.39	4.79	5.18	5.40	4.94
30	4.44	5.02	5.20	5.38	5.01
45	4.47	5.22	5.33	5.38	5.10
Mean	4.41	4.91	5.19	5.39	
CD (P=0.005)					
Irrigation				0.133	
Sulphur				0.063	
Interaction[1,2]				NS	
	Harvest index (%)				
0	32.38	31.48	31.89	33.85	32.4
15	32.70	31.74	32.50	34.58	32.88
30	34.40	32.42	32.63	33.23	33.17
45	34.80	31.92	32.62	34.78	33.53
Mean	33.57	31.48	32.41	34.11	
CD (P=0.005)					
Irrigation				1.46	
Sulphur				0.54	
Interaction[1,2]				NS	

*CRI, Crown-root initiation; T, Tillering; F, flowering; Gd, grain development; M, maturity

[1] difference between 2 subplots at same level of main plot;

[2] difference between 2 main plot at same leve of subplot

Table 3 Effect of irrigation and sulphur on consumptive use (cm) and consumptive use efficiency (kg/ha-mm) of wheat (mean data of 2 years)

Treatment	Levels of irrigation				
	CRI	CRI+T	CRI+T+F	CRI+T+F+Gd	Mean
Sulphur (kg/ha)					
	Consumptive use (cm)				
0	18.42	20.30	23.64	25.24	21.90
15	18.81	20.72	24.20	26.31	22.51
30	19.24	21.61	24.88	26.92	23.16
45	20.83	22.47	25.22	27.23	23.94
Mean	19.32	21.27	24.48	26.42	
CD (P=0.005)					
Irrigation				2.87	
Sulphur				1.44	
Interaction					
Difference between 2 subplots at same level of main plot				2.87	
Difference between 2 main plot at same level of subplot				3.45	
	Consumptive use efficiency (kg/ha-mm)				
0	11.74	10.69	9.83	10.42	10.67
15	11.57	10.82	10.19	10.70	10.82
30	11.71	10.78	10.21	10.53	10.81
45	11.15	10.99	10.45	10.52	10.78
Mean	11.54	10.82	10.17	10.54	
CD (P=0.005)					
Irrigation				0.81	
Sulphur				*0.63*	
Interaction					
Difference between 2 subplots at same level of main plot				1.26	
Difference between 2 main plot at same level of subplot				1.28	

*CRI, Crown-root initiation; T, tillering; F, flowering; Gd, grain development; M, maturity

The crop-growth rates (Table 1) increased positively and significantly with an increase in level of irrigation application at both the growth stages, but the effect of 3 and 4 irrigations was not significant and the highest value of crop-growth rate was recorded in plots receiving 4 levels of irrigation. The crop-growth rate of wheat increased significantly with the increase in sulphur doses and it was the highest with the highest sulphur dose (45 kg S/ha). The lowest crop-growth rate was found with no S application might be due to S along with NPK improved growth of the crop in greater extent compared with the control. Four irrigations with 45 kg S/ha improved all the growth attributes of wheat.

Effective tillers/m^2, length of panicle, grains/panicle, 1 000-grain weight increased significantly with the increase in irrigation level. The maximum effective tillers/m^2, panicle length, and 1 000-grain weight were recorded with the application of highest level of irrigation (4 irrigations) (Table 2). One irrigation applied at crown-root initiation stage resulted in the lowest yield components indicating that higher irrigations were more effective than the lower ones for improving reproductive growth of the crop. Similarly, highest number of effective tillers, panicle length, grain number and 1 000-grain weight were observed under 45 kg S /ha and the control plots showed the lowest value of yield attributes (Table 2). Sulphur nutrition might helped the crop for increasing effective tillers with long panicle and number of bold grains when it was combined with NPK fertilizers.

The highest level of irrigation (4 irrigations) resulted significantly higher grain yield than that of straw yield and harvest index (34.11%) obtained from other level of irrigation (Table 2). Four irrigations applied at all the growth stages improved all the growth and yield component contributing to maximum grain and straw yields of the crop. Four irrigation recorded 25.26, 21.23 and 12.04 % more grain yield than 1, 2 and 3 irrigations respectively. Sulphur fertilization also improved grain and straw yields and harvest index of wheat. Sulphur level of 45 kg/ha resulted 10.66, 6.10 and 3.37% more grain yield than that of 0,15 and 30 kg S/ha respectively. The lowest straw yield and harvest index were observed with no-sulphur application. Application of sulphur was conducive for obtaining higher yields under this agro-ecological condition of West Bengal. The similar findings were reported by Singh *et al.* (2004). Interaction effect of irrigation and sulphur on grain and straw yields, yield attributes and harvest index was not significant.

Consumptive use of water increased with the increase in irrigation levels and it was highest under 4 levels of irrigation (Table 3). Retention of soil moisture decreased in dry soil due to high moisture tension, resulting lower loss of moisture through evapo-transpiration caused lower water used consumptively in lower irrigation level. An increase in consumptive use of water with the increase in irrigation levels was also reported by Chauhan (1999). Similarly, sulphur levels of 45 kg/ha recorded the highest consumptive use, whereas appreciably lower consumptive use was found with 0 level of sulphur. Sulphur fertilization improved growth, yield and yield attributes which augmented higher productivity and consumptive use of the crop.

Table 4 Effect of irrigation and sulphur on available sulphur (kg/ha) after harvest in soil (30 cm soil depth) of wheat.

Treatment	Levels of irrigation				
	CRI	CRI+T	CRI+T+F	CRI+T+F+Gd	Mean
Sulphur (kg/ha)					
0	26.62	23.44	20.83	18.38	21.82
15	28.35	26.48	25.25	24.18	26.06
30	30.42	28.61	27.44	26.06	28.13
45	32.03	29.19	28.01	27.18	29.10
Mean	28.85	26.93	25.38	23.95	
CD (P=0.005)					
Irrigation				3.690	
Sulphur				3.293	
Interaction					
Difference between 2 subplots at same level of main plot				6.587	
Difference between 2 main plot at same level of subplot				6.481	

* CRI, Crown-root initiation; T, tillering; F, flowering; Gd, grain development; M, maturity

Maximum consumptive use efficiency was found under 1 irrigation at crown-root-initiation stage and it was minimum at 3 irrigations and significantly difference of consumptive use efficiency was not found in other levels of irrigations might be due to occurrence of effective rainfall during early tillering and late flowering stage. Sulphur levels did not have significant effect on consumptive use efficiency (Table 3). Sulphur levels improved the yield of wheat as compared to water used consumptively, caused higher consumptive use efficiency under different S level over no sulphur treatment.

Available sulphur level of soil was reduced with increase in irrigation levels. Application of reduced number of irrigation water might be insufficient to absorb S by the crop plant and get accumulated within the soil and caused higher S level under 1 irrigation. Without S, treatment showed the lowest available S content in soil and it was the highest with 45 kg S /ha (Table 4). Sulphur was absorbed by the crop plant from initial soil sulphur and hence its content was depleted under the control treatment. Part of applied S was added to the soil due to application of higher doses of S. Therefore, available S content increased with the application of 30 and 45 kg S/ha.

Thus application of 4 irrigations at crown-root initiation, tillering, flowering and grain-development stages and 30–45 kg S/ha were very much conducive for higher growth and yield of wheat grown on sandy-loam soil of this red and lateritic belt of West Bengal.

SUMMARY

A field experiment was conducted during the winter season of 1997–98 and 1998–99 on well-drained sandy-loam soil at experimental farm of Sriniketan, to study the effect of levels of irrigation and sulphur on 'Sonalika' wheat (*Triticum aestivum* L. emend. Fiori &Paol.) under sub-humid lateritic tract of West Bengal. Four irrigations applied at crown-root initiation, tillering, flowering and grain-development stages resulted in the maximum plant height (96.64 cm), dry-matter accumulation (563.85 g/m^2), leaf-area index (2.954) and crop-growth rate(13.558 g/m^2/day) of wheat. Grain yield (2.79 tonnes/ha), straw yield (5.39 tonnes/ha), harvest index (34.11%) and yield components of wheat also improved greatly with application of 4 irrigations. Four irrigations resulted in 25.26, 21.23 and 12.04% higher grain yield over 1, 2 and 3 levels of irrigation respectively. Application of 45 kg S/ha resulted in maximum, whereas control plots (0 level of S) recorded minimum growth and yield attributes of wheat crop. Significantly higher grain (2.57 tonnes/ha) and straw yields (5.10 tonnes/ha) were observed under 45 kg S/ha, being 10.66, 6.10 and 3.37% more grain yield over 0, 15 and 30 kg S/ha respectively. Interaction effect 4 irrigations with 45 kg S/ha resulted in maximum growth and yield attributes as well as grain and straw yields of wheat. The highest consumptive use (27.23 cm) was recorded by 4 irrigations and 45 kg S/ha, but consumptive use efficiency (11.74 kg/ha-mm) was found maximum under 1 irrigation applied at crown-root-initiation stage and 0 kg S/ha. Maximum depletion of soil S was recorded with the application of highest number irrigation and under 0 level of S.

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Effect of pre-harvest spray of different growth regulators on growth, yield and quality of baby corn (*Zea mays*)*

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Keywords : Baby corn, Growth regulators, Growth, Quality, *Zea mays*

Baby corn *(Zea mays* L.*)* is the unfertilized dehusked maize cob harvested within 2–3 days of silk emergence. The importance and use of the maize product is little known to the Indian farmers in spite of the fact that it fetches very lucrative prices in the national and international markets. The production of any crop is the ultimate resultant of its growth and development. The growth can be modified or controlled by the exogenous application of various growth-regulating substances. The discovery of hormone system in plant culminating in the isolation and later the synthetic production of numerous substances, which regulate the growth of plants, has been one of the outstanding achievements of molecular plant sciences. With the above objectives, the present investigation is aimed to find the effect of pre-harvest spray of growth regulators on the growth, yield and quality of baby corn.

A field experiment was carried out with the baby corn 'G 5406' during the rainy season 2001. The trial was laid out in simple randomized block design with 3 replications using 16 treatments. The tre · ments comprised 3 growth promoters, viz gibberellic acid (GA_3 20,40,60 ppm), benzyladenine (BA 10,20,30 ppm), indole acetic acid (IA 10,20 and 30 ppm), and 2 growth retardants, viz cycocel (CCC 500, 1 000, 1 500 ppm) and paclobutrazol (200,400,600 ppm) including control (water spray). The above growth regulators were sprayed twice at tassel-emergence stage at 5-day intervals. Data were recorded on plant height, number of functional leaves, days

* Short note

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Table 1 Effect of pre-harvest spray of growth regulators on growth and yield of baby corn

Treatment	Plant height (cm)	No. of functional leaves	First cob height (cm)	Second cob height (cm)	Days to first silk emergence (days)	Days to first harvest (days)	Yield/ plant (g/plant)	Moisture content of cob (%)
GA_3 20 ppm	213.33	13.00	107.33	94.83	52.00	54.00	72.00	82.50
GA_3 40 ppm	216.33	13.33	114.16	102.33	52.33	54.33	71.00	82.43
GA_3 60 ppm	222.60	13.66	116.83	104.83	53.33	55.33	71.00	81.83
Benzyl adenine 10 ppm	204.66	13.00	100.16	87.16	51.00	53.00	72.00	82.00
Benzyl adenine 20 ppm	206.00	13.00	101.83	89.00	49.33	51.33	71.66	81.60
Benzyl adenine 30 ppm	209.00	13.33	103.66	91.33	49.33	51.33	71.00	81.66
Indole acetic acid 10 ppm	206.60	13.00	105.00	92.83	49.00	51.33	72.00	82.16
Indole acetic acid 20 ppm	207.66	13.33	104.33	93.16	49.66	52.00	71.00	82.40
Indole acetic acid 30 ppm	209.66	13.33	106.00	94.00	50.33	52.66	71.00	82.06
Cycocel 500 ppm	197.33	12.33	94.33	82.33	49.00	51.00	72.00	82.03
Cycocel 1 000 ppm	193.66	12.00	91.00	77.50	48.33	50.33	72.66	82.36
Cycocel 1 500 ppm	192.00	12.00	87.66	74.16	48.00	50.00	73.00	80.93
Paclobutrazol 200 ppm	194.66	12.00	87.00	74.00	47.00	49.00	73.16	80.70
Paclobutrazol 400 ppm	191.33	11.66	85.66	74.16	46.33	48.33	73.66	81.66
Paclobutrazol 600 ppm	187.00	11.00	83.00	68.50	46.00	48.00	74.00	81.50
Control	200.66	12.33	95.00	83.00	49.66	51.66	69.00	82.23
SEd	3.21	0.40	0.84	0.86	0.68	0.68	0.71	0.81
CD (P = 0.05)	6.56	0.82	1.72	1.77	1.39	1.39	1.46	1.60

NS, Non-significant

to silk emergence, height of the cobs and moisture content of cob. Yield/plant was recorded at the time of harvest. Cobs were harvested at optimum picking stage and tested for quality parameters like total soluable solids (TSS °Brix), titrable acidity (%), reducing sugars (%), crude protein (%) and ascorbic acid (mg/ 100 g) as per standard procedures (AOAC 1980).

Plants treated with GA_3 were taller than those treated with cycocel, paclobutrazol and the control. All the GA_3 concentrations produced taller plants, the tallest plants were noted from GA_3 60 ppm treatment. A similar increase in plant height with GA_3, IAA and kinetin were reported earlier in maize (Shafshak *et al.* 1984) and in sweet corn (Dogra *et al.* 1998). The mechanism involved in the promotory effect of GA_3 on growth may be due to the elongation of internodes and rapid cell multiplication in the growing portion by lowering the IAA oxidase activity (Weaver 1972).

Application of paclobutrazol and CCC resulted in the production of shortest plants, even shorter than the control plants. The retardants produced shorter stems through

Table 2 Effect of pre-harvest spray of growth regulators on quality of baby corn at harvest

Treatment	TSS (°Brix)	Titrable acidity (%)	Reducing sugars (%)	Crude protein (%)	Ascorbic acid (mg/ 100 g)
GA_3 20 ppm	10.16	0.320	2.43	12.34	12.48
GA_3 40 ppm	10.33	0.373	2.57	13.12	13.00
GA_3 60 ppm	10.16	0.320	2.41	12.54	12.48
Benzyl adenine 10 ppm	10.13	0.320	2.38	12.25	12.48
Benzyl adenine 20 ppm	10.20	0.330	2.42	12.54	12.48
Benzyl adenine 30 ppm	10.13	0.320	2.37	12.25	12.48
Indole acetic acid 10 ppm	10.13	0.320	2.34	12.25	12.48
Indole acetic acid 20 ppm	10.20	0.330	2.38	12.54	12.48
Indole acetic acid 30 ppm	10.06	0.320	2.35	12.25	12.48
Cycocel 500 ppm	10.13	0.350	2.42	12.54	12.48
Cycocel 1000 ppm	10.26	0.352	2.53	12.83	12.74
Cycocel 1500 ppm	10.13	0.320	2.42	12.54	12.48
Paclobutrazol 200 ppm	10.00	0.320	2.34	12.25	12.48
Paclobutrazol 400 ppm	10.10	0.320	2.37	12.54	12.48
Paclobutrazol 600 ppm	10.00	0.320	2.35	12.25	12.48
Control	9.46	0.309	2.28	11.66	12.22
SEd	0.04	0.07	0.02	0.27	0.16
CD (P = 0.05)	0.09	0.02	0.05	0.56	0.33

NS, Non significant

inhibition of cell-division and cell-elongation of sub-apical meristem by interfering with the synthesis of gibberellic acid pathway, specially by inhibiting the first 3 steps of ent-kaurene oxidation in cell-free systems of higher plants. Consequently formation of ent-kaurenol, ent-kaurenal and ent-kaurenoic acid is inhibited. Akcin *et al.* (1994) reported a similar reduction in the height of the plant in maize.

Plants sprayed with GA_3, IAA and BA produced more number of leaves than the control and growth retardants. Leaves form an essential source from which the photosynthates are chanelled to the sink. Hence leaves have a major role in influencing the growth and yield. Similar increases in the leaf number and leaf area thereby increasing the photosynthetic area and apparently the plant height was noticed by Paul *et al.* (1956) in sweet corn when sprayed with GA_3 at the rate of 10–20 mg/plant and in maize by Shaddad and Tayeb (1990) when sprayed with 50 ppm IAA. In the present study, plants sprayed with paclobutrazol and cycocel produced significantly less number of leaves than the control which may be due to the inhibitory effect on cell-division by specifically blocking some steps in the pathway of hormone synthesis thereby suppressing the vegetative growth. Akcin *et al.* (1994) and Ali *et al.* (1988) also reported a similar reduction in leaf number in maize.

Plants treated with GA_3, BA and IAA produced cobs at a greater height than the cobs produced on plants treated with paclobutrazol, cycocel and the control. This is due to the enhanced height of the plants as a result of the promotory effect of application of growth promoters and the production of cobs at a corresponding height.

There was a delayed silk emergence in GA_3-treated plants and as a result harvest was delayed due to the increased vegetative growth. In case of plants treated with paclobutrazol and cycocel of all concentrations, the onset to harvest was earlier than the control because of the diversion of assimilates from the vegetative to reproductive parts of the plants. A similar delay was observed in maize plants with 40 ppm GA_3 and 20 ppm IAA by Shafshak *et al.* (1984).

Pre-harvest spray of growth regulators enhanced yield/plant compared with the control. Wareing *et al.* (1968) reported similar increase in yield by foliar application with gibberellins. Similarly, Ali *et al.* (1988) and Akcin *et al.* (1994) reported enhanced yields with cycocel and paclobutrazol.

Growth regulators are known to influence not only the growth and yield but also quality parameters in baby corn. Yield coupled with quality is of paramount importance for the farmer for consumer acceptance.

The total soluble solids were highest in the cobs of plants treated with GA_3 40 ppm (Table 2). In the absence of starch and amylase activity, the increase in TSS with GA_3 40 ppm is not clearly understood.

There was an increase in the titrable acidity as a result of pre-harvest spray of GA_3 40 ppm. Similar increases in acidity by application of GA_3-treated berries due to the enhanced mobilizing ability was reported by Pool *et al.* (1972) in grape (*Vitis* sp).

The reducing sugar content of cobs was increased as a result of pre-harvest spray of GA_3 40 ppm due to the increase in the invariable activity which resulted in the hydrolysis of sucrose and synthesis of reducing sugars. Similar reports were given by other scientists in view of the fact that GA_3 has been reported to augment increasable synthesis in other systems, viz isolated sugarcane stem segments (Sacher *et al.* 1963), Jerusalem artichoke tuber tissue (Edelman and Hall 1964).

The crude protein content of the cobs were found to be increased as a result of pre-harvest spray of growth regulators, the maximum increase being noticed in cobs treated with GA_3 40 ppm. This may be due to the increase in the nucleic acids and enhanced synthesis of endoplasmic reticulum which provides larger surface area for the synthesis of proteins.

Pre-harvest spray of growth regulators had no influence on the ascorbic acid content of cobs. In general vitamin C is a genetic factor and cannot be altered. These results are in confirmation with those of Mozafar (1993).

SUMMARY

The results of the experiment conducted during the rainy reason 2001 showed that pre-harvest application of various growth regulators, viz GA_3 (20,40,60 ppm) benzyladenine (10,20,30 ppm), indole acetic acid (10,20,30 ppm), cycocel (500,1 000,1 500 ppm), and paclobutrazol (20,400,600 ppm) affected the growth, yield and quality of baby corn (*Zea mays* L.) under field conditions. Pre-harvest application of all the concentrations of GA_3 enhanced plant height, number of leaves but delayed days to silk emergence and harvest period. On the other hand, pre-harvest spray of cycocel and paclobutrazol reduced the same but enhanced the yield. All the growth regulators showed an improvement of quality of cobs over the control. Vitamin C content remained unaltered by spray of growth regulators. However, GA_3 @ 40 ppm followed by cycocel @1 000 ppm were found to be best in improving growth, yield and quality of baby corn.

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Effect of different seed proportion on yield of forage, seed and quality of annual legume and barley (*Hordeum vulgare*) mixture*

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Poor rainfall distribution and heavy grazing affect pasture yield and quality outcome that severely limits animal production in many regions of Turkey (Buyukburc 1993). One of the alternative ways to improve animal performance is the growing of fodder plants. Annual legumes and cereals such as common vetch (*Vicia sativa* L.), hairy vetch (*Vicia villosa* Roth.), Hungarian vetch (*Vicia pannonica* Crantz.), grasspea (*Lathyrus sativus* L.), oat (*Avena sativa* L.), barley (*Hordeum vulgare* L., s.l.) and triticale (*Triticosecale* Wittmack.) could be the most viable fodder sources. Mixtures produce higher fodder yields than pure stands. The forage quality of cereal hay is generally lower than that required to meet production goal for many livestock classes, whereas annual legume–cereal mixtures are important protein and carbohydrate sources for livestock (Al-Masri 1998, Raueber *et al.* 2000).

Qamar *et al.* (1999 a) reported that annual legumes and cereal mixture has an important role in arable systems in maintaining soil fertility and regulating the crop specific weeds, diseases and pests. Vetch and grasspea are used for the production of grain, green-manure, fodder or hay, either in pure stands or in mixtures with cereal, also providing the rotational benefits of legumes (Qamar *et al.* 1999 a, Kokten and Tansi 1999). The objective of this study was to determine the optimum mix of legume and barley grown under rainfed conditions in the north–east of Turkey.

This study was conducted in the experimental area of the Field Crop Department, Faculty of Agriculture, University of Gaziosmanpasa, Tokat, Turkey (40 °13'–40 °22' N, 36°1'–36°40' E, elevation 623 m) in 2001 and 2002. Average temperature in growing season (March–July) was 15.4° C, the highest temperature was recorded 23.6 °C, in July. The lowest temperature was recorded 9.3 °C, in March. Precipitation in the second year's growing season (244 mm) was higher than that in the first year (124 mm) and in the long term (215 mm). The soil was alkaline (pH 8.04), medium in calcium carbonate content (10.9 %) and low in P content (63.0 kg/ha P_2O_5), in high in K_2O content (534.0 kg/ha) and poor in organic matter (1.45 %) content. Local cultivars of common vetch 'Kubilay 82', barley. 'Bulbul 89' and grasspea Line 455 were used. The experiment was conducted in factorial randomized complete block design with 3 replications. Mixture rates were: pure common vetch, pure grasspea, pure barley, one-fourth vetch and three-fourths barley, two-fourths vetch and two-fourths barley, three-fourths vetch and one-fourth barley, one-fourth grasspea and three-fourths barley, two-fourths grasspea and two-fourths barley, three-fourths grasspea and one-fourth barley. Plot size was 5.0 m × 1.75 m, and half of the each plot was used to measure the forage yield and the other half to measure the grain yield.

Forage was harvested at beginning of the pod-formation stage of legume. Subsamples were dried at 70 °C for 48 hr, to determine dry-matter yield. The rest of the plots were harvested at maturity for grain yields. Seed rates of pure vetch, grasspea and barley was 100 kg/ha, 120 kg/ha and 200 kg/ha respectively. The N and P fertilizer @ 30 kg/ha and 80 kg/ha, were uniformly applied to soil before sowing. Crude protein analysis was done in ground subsamples of legume hays and barley straw. Crude protein concentration was determined by micro-Kjeldahl procedure (AOAC 1984), and crude protein concentration was calculated (N×6.25). Crude protein yield was calculated by multiplying dry-matter yield with crude protein concentration. Analysis of variance and Duncan analysis for mean comparisons were conducted as per Gomez and Gomez (1984). Results from the 2 years were combined and analysed as a factorial randomized complete block.

Highly significant differences were found for green forage yield (Table 1). Average green forage yield varied from 8.36 tonnes/ha for pure sowing of grasspea to 39.65 tonnes/ha for 25 % vetch and 75 % barley (Table 1). Tukel *et al.* (1997) and Kokten and Tansi (1999) indicated that the most suitable forage production was in 25 % vetch and 75 %

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Table 1 Green-forage yield, dry-matter yield, seed yield and crude protein yield under pure and mixture sowings at Tokat in 2001 and 2002

Pure and mixture sowing	Green-forage yield (tonnes/ha)			Dry-matter yield (tonnes/ha)			Seed yield (tonnes /ha)			Crude protein yield (tonnes/ha)		
	2001	2002	Mean	2001	2002	Mean	2001	2002	Mean	2001	2002	Mean
100 % CV	4.25 d*	15.74 ef*	9.99 d*	0.97 d*	2.99 de*	1.98 d*	0.62 d*	0.68 c*	0.65 e*	0.19 d*	0.55 cd*	0.38 c*
100 % G	7.17 d	9.56 f	8.36 d	1.52 cd	2.05 e	1.79 d	0.75 d	1.10 bc	0.93 de	0.33 cd	0.40 d	0.37 c
100 % B	19.17 c	26.50 de	22.84 c	4.80 bc	6.57 cd	5.69 c	1.22 cd	1.65 bc	1.43 cd	0.51 bcd	0.59 cd	0.55 c
75 % CV + 25 % B	19.50 c	34.22 bcd	26.86 c	4.49 bc	7.90 bc	6.20 c	1.23 cd	1.82 b	1.52 c	0.80 abc	1.25 bc	1.03 b
50 % CV + 50 % B	30.56 ab	28.39 cde	29.47 bc	7.71 ab	7.92 bc	7.81 bc	1.52 bc	2.84 a	2.18 b	1.11 a	0.99 cd	1.05 b
25 % CV + 75 % B	32.78 a	46.52 ab	39.65 a	9.04 a	12.39 ab	10.71 a	2.10 ab	3.52 a	2.81 a	1.06 ab	1.22 bc	1.14 ab
75 % G + 25 % B	24.33 bc	47.00 ab	35.67 ab	4.80 bc	11.32 ab	8.06 bc	1.51 bc	2.78 a	2.14 b	0.94 ab	2.06 a	1.50 a
50 % G + 50 % B	19.50 c	51.86 a	35.68 ab	4.32 bc	13.34 a	8.83 ab	2.11 ab	3.05 a	2.58 ab	0.78 abc	2.27 a	1.53 a
25 % G + 75 % B	28.94 ab	42.97 abc	35.96 ab	7.22 ab	11.35 ab	9.29 ab	2.38 a	3.51 a	2.95 a	1.17 a	1.73 ab	1.45 ab
Mean	20.69 b^{++}	33.64 a	27.16	4.99 b^{+}	8.43 a	6.71	1.49 b^{+}	2.33 a	1.91	0.77 b^{+}	1.23 a	1.00
CV (%)	14.71	18.28	17.86	25.86	21.10	23.16	18.04	16.95	17.68	28.11	23.08	25.24

CV, Common vetch; G, grasspea; B, barley

*Values with the same letters do not differ significantly ($P < 0.05$) according to Duncan test, $^{+}$values with the same letters do not differ significantly ($P < 0.05$) according to Duncan test, $^{++}$values with the same letters do not differ significantly ($P < 0.01$) according to Duncan test

cereal mixtures. Our results confirm the findings of Soya *et al.* (1999). The values in our results were lower than those of Altinok and Hakyemez (2002). These differences might be due to ecological conditions, such as precipitation and temperature recorded during the vegetative growth cycle, and the cultivars used in the experiment. In addition, the differences between the yield values of the studies might be due to the time of the experiments (summer and winter sowings) and or the differences in mixture rates of legume and barley plants. Mean green forage yields obtained from the pure annual legume plots were lower than the pure barley and mixture plots, confirming the findings of Altinok and Hakyemez (2002) with vetch and barley mixtures. Due to the higher precipitation during 2002, the mean green forage yields of mixtures were higher than that in 2001 (Table 1). In general, mixtures gave higher green forage yields than the pure stands, confirming the reports of Tukel *et al.* (1997) and Altinok and Hakyemez (2002). In addition, average green forage yield obtained from the pure barley plot was not statistically different from the average green forage yields obtained from the mixtures (75 % vetch and 25 % barley and 50 % vetch and 50 % barley), as also reported by Tukel *et al.* (1997) with vetch and triticale mixtures.

Dry-matter yields of the pure sowings and the mixtures were significant ($P < 0.01$) in both years (Table 1). In the first year, the maximum dry-matter yield was obtained from the 25 % vetch and 75 % barley mixture, and the minimum yield from the pure vetch sowing (Table 1). Dry-matter yield was 2.05–13.34 tonnes/ha in the second year. On the bases 2-year average, the lowest dry-matter yield was obtained from the grasspea, and the highest from the 25 % vetch and 75 % barley mixture (Table 1). Although Tukel *et al.* (1997) and Soya *et al.* (1999) found similar results, Altinok and Hakyemez (2002) reported higher results for the same treatments. These differences might be due to ecological conditions such as precipitation and temperature recorded during the vegetative cycle of growth and cultivars in the experiment. The precipitation and temperature values at vegetative growth period of this experiment were lower, resulting lower yield than that reported by Altinok and Hakyemez (2002), the mean dry-matter yields of mixtures were higher than that in 2001 (Table 1). Average dry-matter yield of the pure barley plots was not statistically different from the average dry-matter yield of the mixtures. Tukel *et al.* (1997) also reported similar results in cereal and annual legume mixtures.

Seed yields under pure and the mixture sowings were significant in both years (Table 1). The average seed yield varied from 0.65 tonne/ha for pure vetch to 2.95 tonnes/ha for 25 % grasspea and 75 % barley mixture (Table 1). However, Tukel *et al.* (1997) and Rauber *et al.* (2000) found higher values for the treatments. Precipitation and temperature and cultivars in the field experiments could result such a difference. The mean seed yield in the first year was less than that of the second year (Table 1). In the first year, low seed production was likely related to the delayed appearanece of floral buds, corresponding with the onset of drought periods (low precipitation) in the late spring, particularly in May and the beginning of June, caused high abortion rates in flowering and young pods after fertilization. This is because, drought periods in spring (onset of flowering, fertilization and pod-development stage) was the main reason for low seed yield production. Nelson and Volonec (1995) indicated the critical period for forage legumes water need from the beginning of flowering to the seed formation. Yield is going to be low even if water requirement is met after this critical period.

Significant differences were found for crude protein yields in both years (Table 1). The mean crude protein yield varied from 0.37 tonne/ha for pure grasspea to 1.53 tonnes/ha for 50 % grassepea and 50 % barley (Table 1). These results confirm the findings of Tukel *et al.* (1997). However, our results showed higher values than those reported by Qamar *et al.* (1996 b), may be due to environment conditions and cultivars used in the trials. In addition, the high total dry-matter yield could be another reason for the difference. Dry-matter yields in this trial were higher, resulting in higher crude protein yield than those of Qamar *et al.* (1996 b). Crude protein yields of the mixtures were higher than those of the pure sowings, as also reported by Altinok and Hakyemez (2002). Tukel *et al.* (1997) reported that the lowest crude protein yield was obtained from pure legumes.

SUMMARY

An experiment was conducted during 2001 and 2002 to determine the suitable mixture rate of legume and barley (*Hordeum vulgare* L., s.l.) grown under the rainfed conditions in north-east of Turkey. 'Kubilay 82' common vetch (*Vicia sativa* L.), Line 455 grasspea (*Lathyrus sativus* L.) and 'Bulbul 89' barley were used as plant materials. Two legume species were grown as pure and 3 different mixture rates with barley. The mixtures including 25 % vetch and grasspea were the highest yielding mixtures for forage and protein yields. Dry-matter yield, especially in the mixtures including lower rates of barley, was decreased. Vetch or grasspea 25 % and barley 75 % mixture may be recommended for green-forage, dry-matter and seed yields for rainfed condition of north-east Turkey and for crude protein yields, grasspea 50 % and barley 50 % mixture. Forage, seed and crude protein yields of mixture sowings were found potentially better than those of pure sowings.

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Interference of small canary grass (*Phalaris minor*) in late-sown gram (*Cicer arietinum*)*

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Keywords: Weed Science, Gram, *Cicer arietinum*, Interference, Small canary grass, *Phalaris minor*

Interference is the total adverse effect that plants exerts on one another when growing in a common ecosystem (Zimdahl 1980). Gram or chickpea (*Cicer arietinum* L.) is a major winter season pulse crop grown in India. However, its sowing is delayed when grown after rice (*Oryza sativa* L.). Weeds particularly small canary grass (*Phalaris minor* Retz.) pose severe threat to its cultivation under late-sown conditions and reduces its yield considerably depending on their densities. Late planting in December increases the germination (Malik and Singh 1993) and tillering (Bhan and Chaudhary 1976) of canary grass due to low temperature. A temperature range of 10–20°C was found to be ideal for its germination (Bhan and Chaudhary 1976, Singh and Ghosh 1982).

The decision to implement weed control is dependent on the ability of the weed to reduce crop yield, on how much seed will be added to the seed bank if not controlled and on the monetary costs associated with the control. The present study was therefore undertaken with the objective to know the competitive ability, seed-production capacity and threshold limit of small canary grass in late-sown gram.

A field experiment was conducted during the winter season of 2000–2001 at the National Research Centre for Weed Science, Jabalpur, Madhya Pradesh, India. The soil was clay loam (Typic Chromusterts), low in available nitrogen (235 kg/ha), medium in available phosphorus (16.5 kg P/ha) and high in exchangeable potassium (405 kg K/ha), with organic carbon content of 0.56% with pH 6.7. Treatments consisted of 8 levels of small canary grass densities (0, 10, 20, 40, 80, 160, 320 and 640/m^2) with uniform density (80/m^2) of gram. The treatments were replicated thrice in arandomized block design. Gram variety 'JG 315, was sown in rows 25 cm apart in 1 m^2 micro-plots on 12 December 2000. There was a natural infestation of small canary grass in the field and densities were maintained as per the treatments 20 days after sowing.

All the other weeds except the test weed were removed from each plot by hand pulling. However, after 45 days, no attempt was made to remove freshly germinated weeds, if any, except in weed-free plots. In weedfree plots, all weeds were removed as and when they emerged by hand-pulling. A common dose of 18 kg N and 20 kg P/ha was applied basal through diammonium phosphate.

The effect of small canary grass density on its dry weight, seed yield and per cent reduction in seed yield of gra, were evaluated using simple empirical model. The data were fitted to non-linear equations available in 'Curve Expert 1.3' statistical package using Logarithm Fit as :

$$Y = a + b\,ln.x$$

where Y, seed yield or weed dry weight or per cent reduction in seed yield; a, estimate of Y in the absence of small canary grass; b, estimate of the rate of reduction or increase in Y as small canary grass infestation increases; In, natural log; and x, small canary grass density

An increase in weed density increased its total dry matter

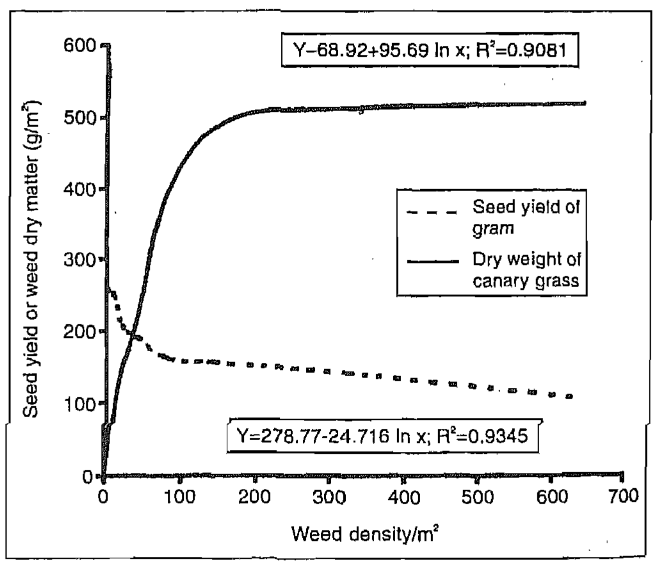

Fig 1 Effect of small canary grass density on its dry weight and seed yield of gram

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Table 1 Effect of small canary grass density on its dry weight and reproductive behaviour and yield of gram

Weed density/m²	Weed dry weight (g/m²)	Weed dry weight (g/plant)	Reproductive characters of small canary grass								Seed yield of gram (g/m²)	Reduction in seed yield (%)
			Ears/m²	Ears/plant	Seeds/ear	Seed weight (g/ear)	Seeds/plant	1 000-seed weight (g)	Seed weight (g/plant)	Seed weight (g/m²)		
0	0	0									261	
10	93	9.30	147	14.7	348	0.37	5032	1.06	5.41	53.3	248	4.98
20	147	7.35	260	13.0	352	0.30	4372	0.85	3.90	92.6	207	20.69
40	217	5.43	378	9.45	288	0.31	2730	1.08	2.93	115.7	191	26.82
80	397	4.96	497	6.21	290	0.31	1799	1.07	1.93	152.5	162	37.93
160	497	3.11	828	5.18	309	0.31	1609	1.00	1.61	272.7	155	40.61
320	513	1.60	900	2.81	282	0.30	794	1.06	0.84	269.3	142	45.59
640	520	0.81	1 159	1.81	262	0.28	473	1.07	0.51	320.6	106	59.39
LSD (P = 0.05)	89		107		NS	0.07	858	NS		49.4	30	

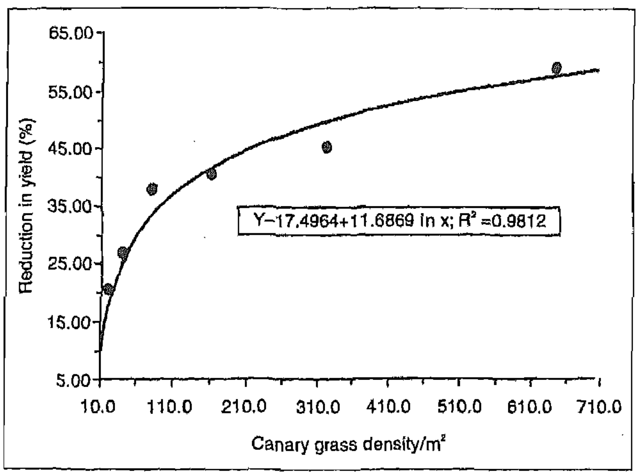

Fig 2 Reduction (%) in seed yield of gram as influenced by small canary grass density

production/m² (Fig 1) but decreased dry weight/plant. Maximum dry biomass (520 g/m²) was recorded at its highest density (640/m²), which was at par with 320 and 160/m² but significantly higher than rest of the densities (Table 1). Similarly, the total number of ears/m² of small canary grass increased significantly with successive increase of its density, mainly due to increased number of plants/m² but, the ears/plant decreased due to increased plant competition for resources at higher weed densities. Number of seeds/ear due to increase in weed density was not significant. The lowest seed weight/ear (0.28 g) was obtained at the highest weed density, which was at par with remaining weed densities except at 10 weeds/m² (0.37 g).

Increasing weed densities significantly reduced the seed-production capacity of the weed. Maximum number of seeds/plant (5 032) was produced at 10-weed density, which was at par with 20 weeds/m² (4 372). Further increase in the weed density significantly reduced the seed-production capacity of the weed. The 1 000-seed weight due to increase in weed densities was unaffected. Seed weight (g/m²) increased significantly from 53.3 to 320.6 with increase in the weed density from 10 to 640/m², but the seed weight/plant decreased considerably from 5.14 to 0.51 g.

The highest seed yield (261 g/m²) of gram was obtained at 0 density (weed-free) of this weed which was at par with 10 weeds/m² (248 g/m²) but significantly higher than rest of the weed densities. Presence of 10 to 640 weeds/m² caused 5 to 59% reduction in seed yield of late-sown gram compared to weed-free plot. The relationship of small canary grass density with its weed dry weight, seed yield and per cent yield reduction of gram fitted well with Logarithm model (Figs 1, 2).

SUMMARY

The competitive behaviour of small canary grass (*Phalaris minor* Retz.) at its varying densities in late-sown gram or chickpea (*Cicer arietinum* L.) was under field conditions in micro-plots (1 m²) during the winter season of 2000–2001 at Jabalpur, Madhya Pradesh. Treatments consisting of 8 levels of small canary grass densities (0, 10, 20, 40, 80, 160, 320 and 640/m²) with uniform density (80/m²) were replicated thrice in randomized block design. 'JG 314' gram was sown on 12 December 2000 and small canary grass densities were maintained as per the treatments 20 days after sowing. The highest seed yield (261 g/m²) of gram was obtained at 0 density (weed-free) of this weed which was at par with 10 weeds/m² (248 g/m²) but significantly higher than rest of the weed densities. Presence of 10 to 640 weeds/m² caused 5 to 59% reduction in seed yield of late-sown gram compared to weed-free plot. The study clearly indicates that small canary grass density at 20 plants/m² significantly reduces the seed yield of late-sown gram necessitating its control.

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Effect of plant growth regulators on greengram (*Phaseolus radiatus*)*

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Keywords: Plant growth regulators, NAA, CCC, Greengram, *Phaseolus radiatus*

Low seed yield in legumes is attributed to excessive vegetative growth, poor harvest index, flower and fruit shedding, low seed setting, disintegration and ineffectiveness of nodules in post-flowering period (Summerfield 1980). Plant growth regulators (PGRs) can play an important role in increasing its yield by making the plants photosynthetically more effective (Sinha and Ghildyal 1973), enhancing the flower buds and checking their abscission (Murthy and Singh 1983). Growth promoting PGRs such as NAA (α-naphthalene acetic acid) are used for preventing pre-harvest fruit drop, *increasing fruit set and parthenocarpy and control of* flowering. Similarly, several physiological alterations have been reported due to growth retardants such as cycocel (CCC) for optimizing yield in various crops (Oshio and Izumi 1986). Hence an experiment was conducted to study the effect of plant growth regulators on growth and yield of mungbean or greengram (*Phaseolus radiatus* L.).

A field experiment was conducted during summer season of 1999 at the Indian Agricultural Research Institute, New Delhi, using 3 varieties of greengram ('Pusa Baisakhi', 'PS 16' and 'Asha') in split-plot design with 3 replications. 'Pusa Baisakhi' and 'PS 16' are short-duration (60–65 days) varieties, while 'Asha' is a long-duration (90 days) variety. The main plots were varieties, while the subplots were 5 PGR treatments (control, 750 and 1 500 ppm CCC, 20 and 40 ppm NAA). Application NAA or CCC was made by spraying the solution @ 600 litres/ha of desired concentration twice is 30 days after sowing and at flowering. Normal cultural practices were followed for raising the crop.

'Asha' had the highest number of leaves/plant, significantly more than those of 'PS 16', while 'Pusa Baisakhi' had significantly more branches than 'PS 16' and 'Asha'. NAA @ 20 ppm significantly increased the number of leaves as well as branches over the control, there being no significant increase when the level of NAA was raised to 40 ppm. Application of CCC @ 750 ppm also significantly increased

Table 1 Effect of varieties and plant growth regulators on leaves, branches and pods/plant, seeds/pod, days to 50% flowering and seed and straw yield of summer greengram

Treatment	Leaves/ plant	Branches/ plant	Days to 50% flowering	Pods/ plant	Seeds/ pod	Seed yield (tonnes/ha)	Straw yield (tonnes/ha)
Variety							
'Pusa Baisakhi'	60.5	40.1	45.1	19.7	7.0	0.94	3.31
'PS 16'	47.5	31.1	45.4	20.9	6.5	0.88	3.22
'Asha'	71.5	27.7	68.3	15.7	7.3	0.94	3.97
SEm ±	3.87	2.26	0.66	0.52	0.13	0.05	0.13
CD(P = 0.05)	15.2	8.9	2.62	2.0	0.5	NS	0.50
Plant growth regulator							
Control	57.2	28.7	54.5	15.7	6.6	0.82	2.92
CCC @ 750 ppm	59.5	32.9	50.9	19.3	7.0	0.93	3.34
CCC @ 1 500 ppm	55.7	31.7	52.1	16.3	6.7	0.88	3.87
NAA @ 20 ppm	63.1	34.7	53.3	20.2	7.1	0.94	3.69
NAA @ 40 ppm	63.5	34.8	53.9	22.0	7.3	1.03	3.90
SEm ±	1.99	1.2	0.44	1.08	0.15	0.03	0.17
CD (P = 0.05)	5.8	3.5	1.3	3.1	0.4	0.08	0.51

NS, Non-significant

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the number of branches over the control. An increase in the branches/plant due to CCC @ 100 ppm was also reported by Mandal *et al.* (1997). 'Asha' the long-duration variety took 23 more days to 50% flowering than 'Pusa Baisakhi' and 'PS 16' and the difference was significant. Application of CCC @ 750 ppm was the most effective in reducing the days to 50% flowering, significantly superior to all other PGR treatments. Furthermore, the variety × PGR interaction was significant and showed that CCC @ 750 ppm was effective in 'Pusa Baisakhi' and 'PS 16' but not in 'Asha'. Coyne (1969) reported an early induction of flowering in field bean (*Phaseolus vulgaris* L.) due to CCC application. These results are important from the viewpoint of shortening the period taken by summer mungbean, when it is grown between wheat (*Triticum aestivum* L. emend. Fiori & Paol.) harvest and rice (*Oryza sativa* L.) transplanting where the turnaround period is only 8–10 weeks (Prasad *et al.* 1999).

In respect of pods/plant 'Pusa Baisakhi' and 'PS 16' were at par and significantly superior to 'Asha', while for seeds/pod 'Pusa Baisakhi' and 'Asha' were significantly superior to 'PS 16'. Application of CCC @ 750 ppm and NAA at 20 or 40 ppm significantly increased the pods/plant as well as seeds/pod. The 3 varieties tested did not differ significantly in respect of seed yield; however, 'Asha' produced significantly more straw than 'Pusa Baisakhi' and 'PS 16'. Application of NAA at 40 ppm produced most seeds significantly more than NAA @ 20 ppm and CCC @ 750 ppm, which in turn were superior to the control. Subbian and Chamy (1984) and Kalita (1989) also reported an increase in greengram yield by the application of NAA, while Mandal *et al.* (1997) reported an increase in greengram yield by an application of 1 or 2 sprays of CCC @ 100 ppm.

The results of our study show that application of NAA @ 20 or 40 ppm and CCC @ 750 ppm can be advantageously employed for increasing the seed yield of summer mungbean. CCC @ 750 ppm also reduces days to 50% flowering, which may hasten summer mungbean maturity and encourage its inclusion as a catch crop in rice–wheat cropping system.

SUMMARY

An experiment conducted during the summer season of 1999 at New Delhi showed that 2 sprays of naphthalene acetic acid (NAA) at 20 or 40 ppm, one at 30 days after sowing (DAS) and the second at flowering, significantly increased growth and yield attributes of summer greengram (*Phaseolus radiatus* L.). Applicaiton of cycocel (CCC) at 750 ppm reduced days to 50% flowering and enhanced maturity. Application of CCC at 750 ppm also showed benefits in modifying some growth characters and seed yield.

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Effect of mepiquat chloride, *Azotobacter* and nitrogen on cotton (*Gossypium hirsutum*) and their residual effect on succeeding transplanted Indian mustard (*Brassica juncea*)*

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Cotton (*Gossypium hirsutum* L.) responds well to nitrogen (Prasad and Prasad 1998) but heavy nitrogen fertilization results in luxurious vegetative growth (Gerick *et al.* 1998) which reduces seed-cotton yield. Growth retardants have been successfully employed to reduce the vegetative growth and to prevent boll shedding in plants Dong and Artica 1982, Prakash and Prasad 2000). Biofertilizers such as *Azotobacter* can partly reduce the need for fertilizer nitrogen in field crops (Chhonkar and Tilak 1997). The present study was therefore taken up to examine the possibility of reducing fertilizer nitrogen needs of cotton with the help of *Azotobacter* and for reducing the excessive vegetative growth with the help of mepiquat chloride.

Cotton–Indian mustard [*Brassica juncea* (L.) Czerij & Cosson] is an important crop rotation in north-western India. However, cotton fields are generally vacated by mid-December and this considerably delays the sowing of Indian mustard. Late-sown Indian mustard crop suffers heavily from the attack of white rust [*Albugo candida* (pers.) kuntz] and aphids (*Lipaphis erysimi Kalt.*) (Saran and Giri 1987). To overcome this, the advantage of transplanting of nursery raised seedling of Indian mustard was studied in the present study. The residual effects of treatments applied to cotton on succeeding Indian mustard were also studied.

The field experiment was conducted during crop years 1998–99 and 1999–2000 (cotton during rainy season and Indian mustard during winter season) at the research farm of the Indian Agricultural Research Institute, New Delhi. The soil of the experimental plot was sandy loam. The soil pH was 8.0. It was low in organic C (0.42%) and medium in available N (310 kg/ha), P (11 kg/ha), K (188 kg/ha). The experiment was laid out in randomized block design during the rainy season and strip plot design during the winter season with 3 replications. For cotton (rainy season) there were 12 treatments, viz 4 levels of N (0, 30, 60 and 90 kg N/ha) applied with *Azotobacter* or mepiquat chloride or without any of these 2). For Indian mustard each rainy season plot was divided into 2 subplots having 22 or 32 days old seedlings.

Two to three seeds of 'Pusa 8-6' cotton were dibbled per hill in the last week of May each year. The hills were spread at 75 cm × 30 cm. All plots received 30 kg P and 30 kg K/ha before final plouging and leveling. Nitrogen was applied as per treatment in 2 splits, half dose at seedling along with P and K and the remaining was banded between cotton rows and incorporated in soil at square formation.

For *Azotobacter* treatment the cotton seeds were inoculated with the culture obtained from the Division of Microbiology of the Indian Agricultural Research Institute, New Delhi. Mepiquat chloride (100 ppm solution) was sprayed at flowering in cotton. Cotton vacated the field in the second week of December, when it was prepared by discing twice followed by leveling for Indian mustard transplanting. Seedlings of 'Pusa Bold' Indian mustard were raised in the nursery on adjoining field in the first week of November (for obtaining 32 days old seedlings) and the third week of November (for obtaining 22 days old seedlings). Indian mustard seedlings were transplanted in the second week of December. No fertilizer was applied to Indian mustard to permit the study of residual effect of nitrogen applied to cotton. Nitrogen application significantly increased the plant height, bolls/plant and boll weight up to 90 kg N/ha; the increase due to each successive level of N was significant (Table 1). However, a significant increase in seed-cotton yield was recorded only up to 60 kg N/ha, the differences between 0 and 30 and 30 and 60 kg N/ha were significant in both the years of study. No benefit of *Azotobacter* was recorded in cotton. Spraying with mepiquat chloride significantly checked the increase in plant height where 60 kg N/ha was applied in 1998–99 or when 90 kg N/ha was applied in both the years of study. Spraying with mepiquat chloride also significantly increased boll weight in cotton in both the years and seed-cotton yield in 1999–2000 only when 90 kg N/ha was applied. Thus at high level of N application spraying with mepiquat is beneficial. Similar results were reported by Rajeswari and Ranganadhacharyulu (1997).

* Short note

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Table 1 Effect of mepiquat chloride, *Azotobacter* and nitrogen on growth and yield of cotton

Treatment	Plant height (cm)		Bolls/ plant		Boll weight (g)		Seed-cotton yield (tonnes/ha)	
	1998–99	1999–2000	1998–99	1999–2000	1998–99	1999–2000	1998–99	1999–2000
Control	75.6	78.5	16.0	16.1	3.1	3.2	1.7	1.8
Azotobacter	76.4	78.6	16.4	16.6	3.2	3.4	1.7	1.9
Mepiquat chloride	72.4	75.3	16.4	16.6	3.2	3.4	1.7	1.9
30 kg N/ha	88.7	90.4	18.4	19.5	3.5	3.8	2.0	2.1
30 kg N/ha + *Azotobacter*	90.4	92.6	18.3	19.6	3.5	3.9	2.1	2.1
30 kg N/ha + mepiquat chloride	87.8	90.0	17.9	17.8	3.5	4.0	2.1	2.1
60 kg N/ha	96.8	96.4	19.0	19.9	3.7	4.2	2.2	2.3
60 kg N/ha + *Azotobacter*	97.1	98.2	19.5	20.1	3.8	4.2	2.4	2.3
60 kg N/ha + mepiquat chloride	93.9	94.1	19.1	18.2	3.8	4.4	2.2	2.1
90 kg N/ha	100.0	101.7	20.3	20.5	4.1	4.5	2.3	2.2
90 kg N/ha + *Azotobacter*	100.9	101.7	20.4	20.6	4.2	4.6	2.4	2.4
90 kg N/ha + mepiquat chloride	98.0	96.2	20.4	19.8	4.3	4.7	2.3	2.4
CD (P=0.05)	2.55	2.56	1.01	1.01	0.15	0.16	0.12	0.12

Table 2 Residual effect of mepiquat chloride, *Azotobacter* and nitrogen applied to cotton on transplanted Indian mustard

Treatment	Plant height		Branches/plant		Seed (tones/ha)	
	1998–99	1999–2000	1998–99	1999–2000	1998–99	1999–2000
Treatments applied to cotton						
Control	98.0	99.2	3.6	3.7	1.45	1.55
Azotobacter	97.0	100.2	3.6	3.9	1.45	1.80
Mepiquat chloride	99.7	100.3	3.5	3.7	1.45	1.75
30 kg N/ha	107.0	109.6	3.5	3.6	1.60	1.85
30 kg N/ha + *Azotobacter*	107.9	109.6	3.5	3.6	1.75	2.00
30 kg N/ha + mepiquat chloride	107.3	110.3	3.9	4.0	1.65	1.80
60 kg N/ha	107.5	110.6	3.9	4.0	1.85	2.00
60 kg N/ha + *Azotobacter*	108.6	111.3	3.7	4.3	1.95	2.00
60 kg N/ha + mepiquat chloride	108.9	111.6	3.7	3.8	1.80	1.90
90 kg N/ha	109.0	112.6	4.0	4.7	1.95	2.15
90 kg N/ha + *Azotobacter*	109.8	112.6	3.8	3.8	2.00	1.95
90 kg N/ha + mepiquat chloride	109.7	106.6	3.7	3.9	1.90	1.95
CD (P=0.05)	6.32	6.50	0.47	0.48	0.18	0.18
Age of mustard seedling (days)						
32	101.7	102.9	4.0	4.2	1.86	2.00
22	109.5	112.9	3.4	3.6	1.60	1.78
CD (P=0.05)	5.14	5.23	0.43	0.44	0.20	0.28

Application of nitrogen had significant residual effect on plant height, branches/plant and seed yield of succeeding transplanted Indian mustard (Table 2). Indian mustard plants were significantly taller in plots which received fertilizer nitrogen for cotton, the difference between different levels of N was however, not significant. A significant increase in branches/plant was obtained only when 60 or 90 kg N/ha was applied to cotton. Application of N at 60 or 90 kg N/ha in 1998–99 and at all the 3 levels of N tested in cotton in 1999–2000 resulted in a significant increase in Indian mustard seed yield, the difference between the levels of N was, however, not significant. When no fertilizer nitrogen was applied to cotton *Azotobacter* inoculation of cotton seed and spraying of mepiquat chloride also recorded a significant increase in seed yield of Indian mustard.

Although 22-day-old seedlings gave taller plants, 32-day-old seedlings (obtained from nursery raised in the first week of November) grew more profusely, showed significantly more branches, early flowering and produced significantly more seed in transplanted mustard (Table 2). Cotton responds to nitrogen up to 60 kg N/ha and this or higher level of nitrogen application should a significant residual effect on succeeding transplanted Indian mustard. Application of *Azotobacter* or mepiquat chloride showed no advantage. Transplanting of 32-day-old seedlings of Indian mustard was better than 22-day-old seedlings.

SUMMARY

A field experiment was conducted during 1998–99 and 1999–2000 to determine the response of cotton (*Gossypium hirsutum* L.) to mepiquat chloride, *Azotobacter* and nitrogen, and its residual effects on Indian mustard [*Brassica juncea* (L.) Czernj. & Cossom] and also to find out the suitable age of seedlings of Indian mustard to be transplanted after the harvest of cotton under late-sown condition. Plant height, bolls/plant, boll weight (g) and seed-cotton yield were

increased with different levels of nitrogen, being highest at 90 kg N/ha. Application of *Azotabacter* with mepiquat chloride either alone or in combination with nitrogen did not improve the seed-cotton yield. The 23-days-old seedlings of Indian mustard gave significantly higher seed yield than 22-days-old seedlings.

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β-glucosidase and alkaline phosphatase activity as affected by organic and modern method of cotton (*Gossypium hirsutum*) cultivation of the rainfed Vertisols*

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Keywords : Alkaline phosphatase, Glucosidase, Gossypium hirsutum, Organic cotton, Vertisols

Human health and environmental concerns are the major driving forces for growing interest in crops grown organically. Furthermore, improvements in soil quality were observed in the organic compared to the high input systems. However, most of these studies are from temperate countries (Stockdale *et al.* 2000). Use of enzyme assays is suggested as a reliable tool for monitoring soil quality (Bandick and Dick 1999) because of its relationship to soil biology, ease of measurement and rapid response to changes in soil management.

β-glucosidase enzyme assays are considered as the most consistent in showing treatment differences and has potential for monitoring biological soil quality. While β-glucosidases are involved in C cycling, phosphatases play an important role in organic P mineralization (Jha *et al.* 1992). Information on the enzyme activities under contrasting conditions of cotton (*Gossypium hirsutum* L.) grown in the Vertisols under rainfed conditions (organic vs modern methods of cultivation) is not available.

The main objective of this study was to determine the effects of organic cultivation system (OCS) compared with the modern methods of cultivation (MMC) on β-glucosidase and alkaline phosphatase activities.

A field trial was initiated in 1994 to compare cotton production under organic cultivation and the modern methods of cultivation (Tarhalkar *et al.* 1996). The trial continued through 2002 on the fixed site. Cotton cv 'NHH 44' was grown every year with a spacing of 90 cm × 60 cm. In the plots of modern method of cultivation, cotton was fertilized with 90, 19 and 37 kg N, P and K/ha. Entire amount of P and K was applied basal. Nitrogen was applied in 3 splits, one-half at sowing and the remainder in 2 equal splits at squaring and boll formation.

Recommended pesticides were used for the control of insects whenever the infestation exceeded economic threshold levels. In the plots of organic cultivation system, nutrient demand was met through organic manure, green manure and loppings of *subabul* (*Leucaena* sp), while bollworms were controlled by manual picking and use of bird perches (Tarhalkar *et al.* 1996).

Soil samples collected at harvest in March 2002 were air-dried and ground to pass a 2-mm sieve prior to analyses. Alkaline phosphatase (EC 3.1.3.1 orthophosphoric monoester phosphohydrolase) and β-glucosidase (EC 3.2.1.21β -D-glucoside glucohydrolase) activity were determined in duplicate for each soil replicate sample collected as described by Tabatabai (1982).

Data were statistically analysed by performing analysis of variance using MSTAT-C and treatment differences were separated out with the least significant difference at 5% probability level. Correlation coefficients were calculated for the enzyme activity with the soil organic C content.

Treatment of organic cultivation system (OCS) had significantly greater β-glucosidase activity than the modern

Table 1 β-gluosidase and alkaline phosphatase enzyme activity in the soil profile of plots under organic cultivation (OCS) and modern methods of cultivation (MMC)

Treatment	Soil depth					
	0–0.1	0.1–0.2	0.2–0.3	0.3–0.6	0.6–0.9	Mean
β-glucosidase (mg p-Nitrophenol/kg soil/hr)						
OCS	106.9	56.1	46.4	36.5	4.3	50.0
MMC	54.9	41.7	30.1	25.3	2.4	30.9
Mean	80.9	48.9	38.3	30.9	3.2	
LSD ($P<0.05$)						
OCS vs MMC	6.5					
Depths	6.6					
Treatment × depth	9.4					
Alkaline phosphatase (mg p-Nitrophenol/kg soil/hr)						
OCS	287.2	155.1	110.2	109.4	80.9	148.6
MMC	158.6	126.4	94.4	66.1	61.9	101.5
Mean	222.9	140.7	102.3	87.7	71.4	
LSD ($P<0.05$)						
OCS vs MMS	7.8					
Depths	18.2					
Treatment × depth	25.8					

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* Short note

method of cultivation (Table 1). The greatest enzyme activity was noticed in the surface layer of the organic plots. Organic plots had significantly greater β-glucosidase activity in all soil depths, except 0.6–0.9 m, than the plots of modern method of cultivation (MMC). The β-glucosidase activity declined significantly with increasing depth. These enzymes are mainly produced by fungi and their activity is sensitive to soil C content. The soil organic carbon ranged from 0.54 to 0.74% in the surface layer (0–0.1 m) in the MMC and OCS plots and the C content decreased with depth (Blaise *et al.* 2003). This explains the decline in β-glucosidase enzyme activity with depth.

A significant ($P<0.01$) positive correlation with soil organic carbon (Fig 1*a*) confirms the cause for decline in the enzyme activity with depth. Strong positive correlation of the enzyme activity with C content was also observed by Jimenez *et al.* (2002).

Alkaline phosphatase activity was the greatest in the top soil (0–0.1 m) and declined with depth (Table 1). The OCS plots had 0.6-fold greater phosphatase activity than the MMC plots and the differences were significant. For a given depth, the OCS plots had significantly greater alkaline phosphatase activity than the MMC plots in the 0–0.1, 0.1–0.2 and 0.3–0.6 m soil depths. Differences were not significant for the 0.2–0.3 and 0.6–0.9 m soil depth. Linear regression analyses showed a significant positive correlation with soil organic carbon (Fig 1*b*).

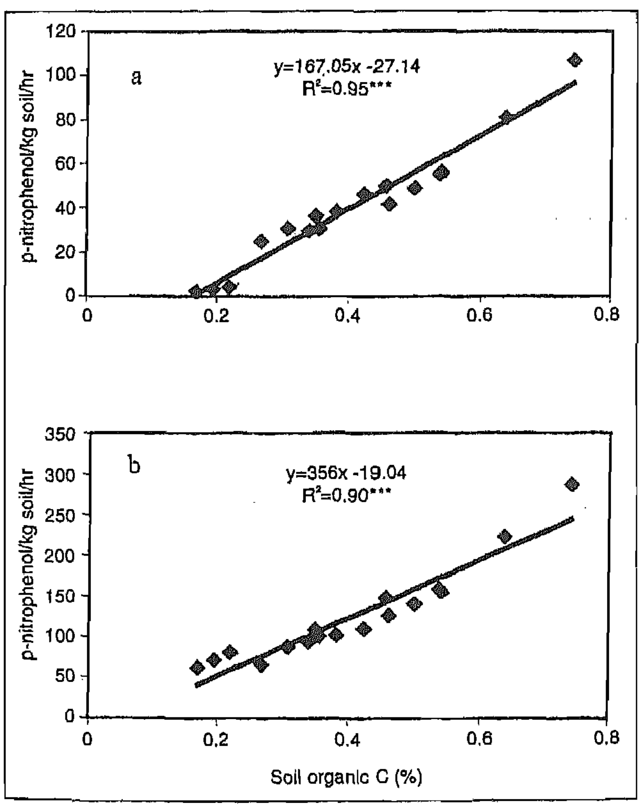

Fig. 1 Correlation of β-glucosidase (a) and alkaline phosphatase activity (b) with soil organic C-content.

Long-term addition of farmyard manure and crop residues stimulated enzyme activities mainly because of elevated levels of C inputs (Goyal *et al.* 1993, Manna *et al.* 1996). Intensity of phosphatase is important, as it affects the rate of P cycling. Considering the low P status of the soils (Blaise 2003) and the high P-fixation capacity of the Vertisols, enhanced phosphatase activity would mean greater amounts of organic P would be available to the crop. Blaise *et al.* (2003) observed a better nutrient status in the organic plots compared to the MMC plots. In the present study, greater enzyme activities in the OCS than the MMC plots were observed.

These studies indicate a close relationship between these enzymes and nutrient cycling.

SUMMARY

A field study was conducted during 1994–2002 to evaluate organic vis-a-vis the modern methods of cotton (*Gossypium hirsutum* L.) cultivation. β-glucosidase and alkaline phosphatase enzyme assays were done on the soil profile (0–0.90 m) samples collected at the end of 8 years. Both the enzyme activities were greater in the organic plots compared to the plots receiving continuous application of fertilizers and pesticides. Enzyme activities were the greatest in the surface layer and declined with depth. The enzyme activities were also strongly correlated with soil organic carbon content. β-glucosidase and alkaline phosphatase enzyme assays could serve as potential indicators of improvement in soil quality. However, a range of enzymes need to be evaluated to identify the most sensitive indicator.

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Phenotypic stability for berry yield in black pepper (*Piper nigrum*)

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Keywords : Spice improment, Black pepper, *Piper nigrum* Phenotypic stability, Berry yield,

Black pepper (*Piper nigrum* L.) is an important perennial spice cultivated mainly in Kerala, Karnataka, Tamil Nadu and Andhra Pradesh in addition to limited extent in North-Eastern states. Year-to-year fluctuation in yield even within a location is often encountered in black pepper (Pradeepkumar *et al.* 1999). An attempt was made to understand the stability parameter of 3 new lines (a selection and 2 hybrids) along with a released hybrid ('Panniyur 1') and 2 released selections of Karimunda ('KS 14' and 'KS 27'). The experiment, set to randomized block design with 4 replications, was conducted at Valparai (Tamil Nadu) for 7 years from 1995–96 to 2001–2002. Fresh yield/vine (weight of berries) was recorded every year on per plant basis. The stability parameters were worked out for berry ield (Eberhart and Russell 1996).

Pooled analysis of variance for berry yield revealed significant difference among the genotypes as well as environments (Table 1). Significant genotype × environment interaction indicates that the genotypes showed different reactions in different years. The results confirm the findings of Ibrahim *et al.* (1985) for spike weight in black pepper.

Both linear and non-linear components were important. Eberhart and Russell (1966) suggested that both linear and non-linear components of genotypes × environment interaction should be used in judging the stablity of different varieties. According to Eberhart and Russell (1966), the ideal variety is one which has high means yield (μ), unit regression coefficient (b=1.0) and the least deviation from regression (S^2D=0). The stability parameters of the black pepper genotypes are presented in Table 2. High mean yield/vine was recorded by the genotype 'HP 105', followed by 'Coll. 1041' and 'Panniyur 1'. The value of 'b' was different for different genotypes, indicating their differential response to changing environments. Regression coefficient was more or less 1 in 2 of the lines, 'HP 105' and 'HP 813'. 'Panniyur 1' and 'KS 14' showed the highest deviation from regression coefficient. The new lines 'Coll. 1041' revealed good yield and rather high regression slope coupled with significant deviation from regression, whereas 'HP 105' high mean yield, regression value near to 1 and significant deviation from regression. The third new line, 'HP 813' though had moderate mean yield and regression value more or less 1, showed significant deviation from regression.

Among the released lines, 'Panniyur 1' though had moderate mean yield, showed the highest regression slope and significant deviation from regression. The other 2 varieties, viz 'KS 14' and 'KS 27, had low mean yield and low values of b. However, 'KS 14' had non-significant deviation from regression.

Though, in general, the black pepper genotypes exhibited unpreditable behaviour by judging the regression slope and significant deviation from regression, the 2 new lines, viz 'HP 105' and 'Coll. 1041' should be regarded as superior to

Table 1 Pooled analysis of variance for berry yield of black pepper

Source	df	MSS
Total	41	6.283
Lines (G)	5	34.28**
Environment (E)	6	8.19**
G × E	30	1.23**
Environment + (G×E)	36	2.39*
Environment (Linear)	1	44.17**
Genotype × Environment (Linear)	5	2.39*
Pooled deviation	30	0.84**
Pooled error	126	0.0035

*P, 0.05; **P, 0.01

Table 2 Stability parameters for berry yield in black pepper

Line variety	Berry yield (kg/plant) (fresh)	bi (regression coefficient)	S^2d (deviation from regression)
'Coll. 1041'	5.21	1.59	1.38**
'HP 105'	6.14	0.92	1.96**
'HP 813'	2.78	1.05	0.76**
'Panniyur 1'	3.27	1.61	0.26**
'KS 14'	0.58	0.27	0.01 ns
'KS 27'	1.01	0.56	0.47**

**P-0.01

*Short note

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'Panniyur 1', 'KS 14' and 'KS 27' (the released varieties) since these 2 lines proved superior in the most important parameters of stability, viz yield. 'HP 105' will be more sutiable for high-yielding environment. 'HP 813' also had moderately good mean yield and regression coefficient near 1, making it more suited to low-yielding environments. Frey (1964) reported and good adaptable variety gives superior production over a wide range of environments. Bains and Gupta (1972) also suggested that the potential of genotype to express greater mean (for yield and or quality) over environments should be the most important parameter, since the other parameters may not be of any particular utility, if the genotype is potentially weak. Thus the new lines 'HP 105', 'Coll. 1041' and 'HP 813, fall very much in lines with these thinking and are thus superior to the released varieties.

'HP 813', though moderate in mean yield recorded about 12% oleoresin, 2.8% essential oil (quality parameters of black pepper) compared to 9.4% oleoresin and 2% essential oil in 'Panniyer 1'. Ibrahim *etal.* (1985) also reached similar conclusion while working with 5 black pepper genotypes including'Panniyur 1.'

SUMMARY

Three balck pepper lines along with 'Panniyur 1' (released hybrid) and 'KS 15' and 'KS 27' (released clones) were evaluated for berry yield for 7 years (1995–96 to 2001–2002) at Valparai, Tamil Nadu. Phenotypic stability for berry yield indicated that the new lines, viz 'Coll. 1041' and 'HP 105' were superior to the released hybrid and clones for the important parameters of stability, viz mean yield. The other new line 'HP 813', though at par with 'Panniyur 1' for mean yield, had the other stability parameter (bi) better than 'Panniyur 1'. 'HP 105' was found more suited to better environment, while 'HP 813' for marginal environment.

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Genetic diversity for white rust (*Albugo candida*) resistance in rapeseed – mustard*

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Keywords : Crop improvement, Disease resistance, Indian mustard , Rapeseed, White rust, *Albugo candida*

White rust [*Albugo candida* (Pers ex. Lev.) Kuntze] is an important disease of Indian mustard [*Brassica. juncea* (L.) Czernj. & Cosson] causing significant losses both in terms of yield and quality (Saharan 1998, Verma and Bhowmik 1989). At present 12 varieties of Indian mustard are grown predominately in India (AICRP-RM 2002) and out of these only one is reported to be resistant (Yadav and Meena 2000). Therefore, it was felt necessary to verify the diversity with respect to white-rust resistance in Indian mustard varieties. A large number of sources of resistance to white rust have been reported in India but very few of them were actually used in the breeding programme. Despite of extensive physiological specialization in this fungus (Verma *et al*, 1975, Verma *et al.* 1999), pathogenic variability in Rajasthan is limited (Yadav *et al.* 2002). It was therefore assumed that entries found resistant at Bharatpur would find application over very wide area in Rajasthan. Canadian *B. napus* L. varieties have shown their resistance against race 2 V of *A. candida* (Franke *et al.* 1999) and Indian pathotype infecting *B.juncea* shows very high similarity to Canadian race 2 in their reaction on number of host species (Verma *et al.* 1999). The resistance to white rust from other species, if transferred to Indian mustard can provide much-needed diversity to white rust.

Breeder seeds for 21 released varieties of Indian mustard, 3 of toria [*B. campestris* L. ssp *oleifera* (Metzger) Sinsk. var toria; syn *B. rapa* (L.) Thell. emend. Metzger var *napus*] 2 of yellow sarson [*B. campestris* L. ssp *oleifera* (Metzger) Sinsk. var yellow sarson; syn *B. rapa* (L.) Thell. emend. Metzger var *glauca* (Roxb.) Schulz.], 3 of gobhi sarson (*B.napus* L. ssp *oleifera* DC. var *annua* L.) and 2 varieties of Ethiopian mustard (*B. carinata* Braun.) were sown to raise 30–50 seedlings in a tray containing the mixture of sand, soil and farmyard manuire in equal proportion during 2000–2001 and 2001–2002. The zoospores collected from a single pustule on the leaf of variety 'Varuna' were multiplied on the seedlings of the same variety and were used for further study. The suspension of zoospores was sprayed (misting until run-off) on 8–9 days old seedlings. The inoculated seedlings were maintained under high humidity (more than 90%) and low temperature (6–24°C) for 24 hr. Seedlings were scored for white-rust infection after 7 days of inoculation. The complete absence of pustules on leaf was considered as resistant, while all other classes were clubbed under susceptible. The same set of released varieties and resistant sources identified under All-India Co-ordinated Research Project on Rapeseed–Mustard were grown in field trial at Bharatpur during 2001–2002 (under artificial epiphytotic conditions) and Wellington in 2001 (under natural condition). White-rust infection on the leaves was scored on 0–5 scale at adult stage. The phenotype of pustules on the adaxial surface of leaves was also observed at the adult stage.

All released varieties of Indian mustard except 'JM 1' were found uniformly susceptible against white rust at the seedling stage. 'JM 1', reported to be only white rust-resistant variety in India, showed segregation with only 27% resistant seedlings under the controlled conditions at Bharatpur (Table 1). The situation is, therefore, highly alarming and may favour an epidemic outbreak of white rust as it has already happened in 1997–98 when the weather conditions were favourable for disease development. There is an urgent need to develop white rust-resistant Indian mustard varieties. Highly variable reaction was observed on the varieties of yellow sarson and toria (Table 1). In these species, the size of pustules on the leaves of susceptible plants were very small and were put under the category 1 of 0–5 scale. The varieties of *B. campestris* showing susceptible or variable reaction ('Jhumka' and 'PT 303') at Bharatpur were uniformly resistant at Wellington at seedling stage. The varieties exhibiting differential host response at Bharatpur and Wellington can be considered for developing the set of differential for the study of variability in the white rust pathotypes in India. At adult plant stage, 2 kinds of pustules were observed on the lower surface of the leaves. One type of pustules formed ring-like structure, while others were of pin head or dot type. Similar kind of difference in pustules phenotype were observed by Gupta and Saharan (2002). Both ring and dot types of pustules were present on most of varieties of *B. juncea*, whereas only dot-type pustules were

*Short note

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Table 1 Reaction of different varieties against white rust infection

Variety	Crop	Seedling response		Adult plant response		Remarks
		Host pathogen interaction phenotype	Seedlings infected(%)	Rating on 0–5 scale	Stag head(%)	
'Vardan'	Indian mustard	S	100	3.5	12.73	Moderately resistant as yellow hallow surround pustules
'RN 393'	Indian mustard	S	100	2.3	34.62	Both dot type and ring type pustules
'PCR 7'	Indian mustard	S	100	4.0	18.52	Both dot type and ring type pustules
'PBR 91'	Indian mustard	S	100	3.5	17.95	Both dot type and ring type pustules
'GM 1'	Indian mustard	S	100	2.9	16.13	Both dot type and ring type pustules
'Varuna'	Indian mustard	S	100	4.7	200.00	Both ring type and dot type pustules
'RH 8113'	Indian mustard	S	100	3.7	3.03	Both ring type and dot type pustules
'Bio 902'	Indian mustard	S	100	3.8	20.09	Both ring type and dot type pustules
'JM 1'	Indian mustard	V	73	2.0	10.01	Differential response
'GM2'	Indian mustard	S	100	3.9	12.73	Both ring type and dot type
'Rohini'	Indian mustard	S	100	4.4	15.56	Both types of pustule but predominately ring type
'RH 781'	Indian mustard	S	100	4.4	22.41	
'RH30'	Indian mustard	S	100	3.8	20.71	
'RH 819'	Indian mustard	S	100	2.3	23.81	
'Sej 2'	Indian mustard	S	100	3.4	6.76	
'Kranti'	Indian mustard	S	100	3.7	12.90	Both ring and dot type pustules
'RLM1359'	Indian mustard	S	100	3.8	21.21	Both ring and dot type pustules
'RH 8812'	Indian mustard	S	100	3.7	40.5	Both ring and dot type pustules
'CS 52'	Indian mustard	S	100	4.4	13.21	Both ring and dot type pustules
'Pusa Bold'	Indian mustard	S	100	4.4	12.96	Both ring and dot type pustules
'Basanti'	Indian mustard		100	2.2	34.78	Both ring type and dot type pustules
'PT 303'	Toria	V	84	1.0	5.1	Very small dot type pustules
'TH 68'	Toria	S	100	2.0	10.21	Very small dot type pustules
'PBT 37'	Toria	R	0	1.0	2.5	Very small dot type pustules
'Pusa Gold'	Yellow sarson	V	53	1.5	5.6	Very small dot type pustules
'Jhumka'	Yellow sarson	V	72	1.9	2.1	Very small dot type pustules
'Sheetal'	Gobhi sarson	R	0	0	0	
'GSL 1'	Gobhi sarson	R	0	0	0	
'Hyola 401'	Gobhi sarson	R	0	0	2.0	
'PC 5	Ethiopian mustard	R	0	0	0	
'Kiran'	Ethiopian mustard	R	0	0	0	

present on *B. campestris* group. Among the different varieties, 'Varuna', the most predominating varieties of Indian mustard in India was highly susceptible with maximum number of stag-head formations. The variety 'JM 1' showed the variable response with most of plants showing susceptible reaction and few were free from disease at adult stage also. Thirteen identified donors for white-rust resistance under All-India Co-ordinated Programme were tested for white-rust resistance at Bharatpur and Wellington (Table 2). Out of these, 'PBR 181', 'EC 399-301', 'EC 399-299' and 'EC 414-303' and 'EC 414-288' were found resistant against the prevailing racial flora of *Albugo candida* at Bharatpur and Wellington. 'PYSR 14', 'PBR 181' and 'EC 399-299', though were not completely free from white-rust infection, the resistant mechanism operating against white rust was visible in the form of yellow hallow surrounding the very small and dot type of pustules. Utilization of such sources will not only provide the protection against the losses caused by white rust but also slow down the racial evolution. None of the varieties of Ethiopian mustard (*B. carinata*) and gobhi sarson (*B.napus*) developed pustules of white rust and therefore, all of these can be used as sources of resistance against white rust. 'Varuna', 'PCR 7', 'RH 819' and 'Kranti' (released varieties of Indian mustard) were crossed with 'GSL 1', 'Hyola 401' (released varieties of gobhi sarson) and 'PC 5'(released variety of Ethiopian mustard) and 'BPKR 13' (advance strain of Ethiopian mustard). The F_1s were evaluated for resistance at seedling stage and adult plant at Bharatpur. The resistance of F_1s was further confirmed in the off-season nursery at Wellington (Tamil Nadu). Since, F_1s of all crosses were immune against white rust at both the locations, it is clear that the resistance available in *B.napus* and *B.carinata* against the prevalent pathotypes of white rust is dominant. It can therefore, be concluded that keeping in view the acreage

Table 2 Status of white rust-resistant sources identified under All-India Programme at Bharatpur and Wellington

Entry	White rust score on 0–5 scale at Bharatpur	White rust score (0–5 Scale) at Wellington (TN)	Staghead	Remarks
'BEC 107'	2	3	P	Pustule size small and dot type
'EC 399-288'	2	2	A	Pustule size small and dot type
'PHR 1'	3	3	P	Tall plants with pigmented leaves. Both dot type and ring type pustules present
'PYSR 1'	Differential response	2	A	Small and dot type pustules
'PYSR 2'	3	2	P	Both types of pustules
'PYSR 14'	1	2	A	Dot type pustules surrounded by yellow hallow
'RC 781'	3	3	A	Mainly ring type pustules. Plants tall and very late with pigmented leaves.
'YRT 3'	3	3	P	Both type of pustules present.
'PBR 181'	0	1	A	
'EC 399*299'	1	1	A	Dot type very small pustules surrounded by yellow hallow
'EC 399-301'	0	1	A	Succulent stem with leaves generally free from pustules
'EC 414-303'	0	0	A	*B. campestris* entry
'EC 414-288'	0	0	A	*B.campestris*

P, present ; A, absent

under Indian mustard among the rapeseed–mustard and almost non-existing diversity for resistance among the cultivated varieties of Indian mustard against white rust, the donors like 'PBR 181', 'EC 399-301', 'EC 399-299' (all *B. juncea*) should be used in the breeding programme. White-rust resistance sources like 'EC 414-303' and 'EC 414-288' (*B. campestris*), 'Hyola 401' (*B. napus*) and 'PC 5' (*B. carinata*) can prove useful to diversify the base for resistance in Indian mustard against white rust.

SUMMARY

Twenty-one released varieties of Indian mustard [*Brassica juncea*(L.) Czernj. & Cosson], 3 of toria [*B. campestris* L. ssp *oleifera* (Metzger) Sinsk. var toria; syn *B. rapa* (L.) Thell. emend. Metzger var *napus* L.], 2 of yellow sarson [*B. campestris* L. ssp *oleifera* (Metzger) Sinsk. var yellow sarson; syn. *B. rapa* (L.) Thell. emend. Metzger var *glauca* (Roxb.) Schulz.], 3 of gobhi sarson (*B.napus* L. ssp *oleifera* DC. var *annua* L.) and 2 varieties of Ethiopian mustard (*B.carinata* Braun.) were tested against white -rust [*Albugo candida* (Pers ex. Lev.) Kuntze] infection both at seedling stage and adult plant stage. All of the released varieties of *B. juncea*, including 'JM 1' were susceptible to white rust at the seedling stage. However, 'JM 1' and some of the varieties of yellow sarson and toria showed variable reaction against white-rust infection. The varieties of *B. carinata* and *B. napus* were uniformly resistant. The observation on the adult plants under field conditions gave similar results. Among the large number of resistant sources identified under All-India Co-ordinated Research Project on Rapeseed-Mustard, 'EC 399-299', 'EC 399-301', 'EC 414-303', 'EC 414-288' and 'PBR 181' were found resistant against white rust both at Bharatpur (Rajasthan) and Wellington (Tamil Nadu). *B.carinata* and *B.napus*, which were also found immune against white rust, were used as donor for developing white rust-resistant Indian mustard.

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Evaluation of common rust (*Puccinia sorghi*) resistance in maize (*Zea mays*) inbred lines

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The average national grain yield of winter (*rabi*) maize (*Zea mays* L.) is 2.7 tonnes/ha compared to 1.75 tonnes/ha obtained during rainy (*kharif*) season. The productivity of 6–8 tonnes/ha is usually attained at the farmers fields (DMR, New Delhi 2002). Hence, it can be adopted as a viable alternative to wheat (*Triticum aestivum* L.emend. Fiori & Paol.) for crop diversification leading to sustainable agriculture. The crop is inflicted by a number of diseases, of which common rust caused by *Puccinia sorghi* Schw. takes a heavy toll of this crop. Under epidemic conditions losses ranging from 6.32 to 36.0% have been reported (Sharma 1983), and in India most of the cultivated varieties are susceptible (DMR, New Delhi 2002). The disease can be managed by application of fungitoxicants (Sharma *et al.* 1993), but the resource-starved farmers cannot afford to apply costly biocides. The cultivation of resistant varieties is an eco-friendly viable, practically feasible and cost-effective method to manage this disease. Identification of resistant inbred lines is a pre-requisite for any hybrid or composite breeding programme aimed at evolving resistant varieties. Keeping this in view, 400 inbred lines were evaluated against the disease at Dhaulakuan, a hot spot of national importance and the resistant lines are reported in this paper.

Four hundred inbred lines were procured from the Punjab Agricultural University, Ludhiana, Directorate of Maize Research, New Delhi and those developed at Dhaulakuan. The lines were planted in 2 rows plot of 5 m length in the last week of October following recommended package of practices (PAU, Ludhiana 2002). Rust epiphytotics were created by periodically spraying the uredosporic suspension of locally available isolates of *Puccinia sorghi* starting from first week of February. The plants were arbitrarily divided into lower, middle and upper parts and the data were recorded for rust severity, using modified cobb's scale. The first observation was recorded in the first week of March, followed by 5 subsequent observations at 12-day intervals. Based on average rust severity for each date, area under disease progress curve (AUDPC) was worked out using the formulae of Shanner and Finney (1977).

$$\text{AUDPC} = \sum_{1=1}^{n} (yi + 1) + y_i)/2\ [x_i + 1 - x]$$

where yi, disease severity (%) at ith observations;

xi, time day at ith observations; n, total number of observations.

The data were also recorded on disease reaction based on 0–5 scale (Gupta 1983).

The inbred lines, viz, 'A670 FRVa26 J54-2-4-2-1-1-2-1-2-2-3-5-1-2- # - #-6-1-06', '(MSP1-SSP-5-3-1-1-2-1-1-1-1)-FS_1- # - #-1-FS_1 -1-1-7', '($BSUL_2$-8-1-1-2-2-2-1) -02-FS_1-#-5-1', 'Pool 22 Ht Res (TIYD) *Turcicum* # - 1-1-2-2-1-# - 1-1-1-1-1', 'Pop 845 - CS#, 'Pop 920. C3 × b', 'H104-15-----× MSP_1-21----) -6-1-4-1-2-# -5-6', 'Pop 28TSR (S_2)-13-# - #- 6F - # - # - 1-3-1- # -1- # - # - FS[1]', 'CML295-2-2' and 'JH 6820 1-1-1 ⊗ bulk' were found free from rust during 1997–98 and 1998–99. Disease reaction, terminal disease severity and area under disease progress curve of some resistant and prominent inbred lines are given in Table 1. Four inbred lines, viz 'Pop 960-C_3 × ⊗ b-2---1', 'Pool 22 Ht Res (TIYD)', '*Turcicum* - # - 3-1-2-3-1-1-1-1- # × b -10', '1 109' and 'JH 6629 1-1-1 ⊗ bulk' showed disease reaction 1–2. Terminal disease severity and area under disease progress curve in these lines varied from 1.7 to 5.0% and 8.91 to 82.52% respectively. These lines were highly resistant. Inbred line 'LM 9' and 'JH 6608' ⊗ bulk' showing disease reaction of 2 and 2.5, respectively, developed terminal disease severity of 8.33 and 10.03% and area under disease progress curve of 173.3 and 175.8, respectively, and were resistant. Inbred lines 'CM 400' 'CM 120', 'Pratap × J 1027 - # - # - 1 - 1- 3-1-2-1-1-#-1-1-2-#', '370565' and 'DKI 9337' showing disease reaction '3' recorded terminal disease severity 11.67 – 20.0% and area under disease progress curve 212.3–486.5. Disease reaction in 5 lines, viz 'Expt. 10-5-7-3-2- # -2-1-1-

*Short note

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Table 1 Disease reaction, terminal disease severity and area under disease progress curve (AUDPC) against common rust (*Puccinia sorghi*) in maize inbred lines

Inbred line	Origin	Terminal disease spread (%)	Disease reaction (0–5)	AUDPC
'Pop 960-C_3 ⊗ bulk b 2---1'	PAU, Ludhiana	1.7	1	8.9
'Pool 22 HT Res. (TIYD) *Turcicum* # - 3-1-2-3-1-1-1-1-1- # × 6-10'	PAU, Ludhiana	5.0	2	71.9
'I 109*'		5.0	2	82.5
'LM 9'	PAU, Ludhiana	8.3	2	173.3
'JH 6608'	PAU, Ludhiana	10.0	2.5	175.7
'CM 400'	DMR, New Delhi	11.7	3	212.3
'CM 120'	DMR, New Delhi	15.0	3	231.1
'JH 6629'	PAU, Ludhiana	4.03	1	22.6
'Partap × J1027- # - # - 1-13-1-2-1-1- # -1-1-1-2- #'	PAU, Ludhiana	13.4	3	265.4
'370565*'	PAU, Ludhiana	13.3	3	353.4
'DKI 9337'	RRS, Dhaulakuan	15.0	3	486.6
'CM 400'	DMR, New Delhi	26.7	3.5	450.3
'Expt-10-5-7-3-2 × H 3191) - # - 2-1-1-3-1-1-1-2-1-#-#'	PAU, Ludhiana	30.0	4	575.7
'SE 513'	PAU, Ludhiana	23.3	3.5	653.5
'Farraka 8328'	RRS, Bajaura	20.0	3.5	727.3
'EC 383394-1-2'	PAU, Ludhiana	30.0	4.0	878.9
($BSUL_2$-8-1-1-2-2-2-1)-$2FS_1$#, -1 ⊗ b'	PAU, Ludhiana	50.0	4.5	993.9
'DKI 9564'	RRS, Dhaulakuan	50.0	4.5	1 385.7
'CM 113'	DMR, New Delhi	28.3	4.5	1 469.4
'CM 111', 'CM 12', 'CM 125', 'CM 126', 'CM 211', 'CM 501'	DMR, New Delhi	53.7–76.7	5.0	1 861.9–2 463.5
'LM 5', 'LM 6'	PAU, Ludhiana	43.3–80.00	5.0	2 282.00

*Pedigree not known ; PAU, Punjab Agricultural University; DMR, Directorate of Maize Research; RRS Regional Research Station,

3-1-1-1-1-2-1 - #-1-1- # - #', 'SE 513', 'Farraka 8328', 'EC 38394-1-2' and '$BSUL_2$-8-1-2-2-2-1)-2 FS1#1-1 ⊗ bulk b' varied from 3.5 to 4.5, whereas the terminal disease severity and area under disease progress curve varied between 20.0 and 50.0% and 575.7-7 and 1 469.41 respectively. The susceptible lines showed disease reaction of '5' and the terminal disease severity and area under disease progress in these lines varied between 43.33 and 80.00% and 1 861.94 and 2 463.52 respectively. It is evident from the data that the lines with same disease reaction varied considerably in terminal disease severity and disease development. Inbred lines showing resistance to rust have been identified (Gupta 1983, Sharma 1983, Sharma *et al.* 1993). Payak *et al.* (1974) identified 29 entries containing single dominant gene for resistant to *P. sorghi,* whereas Sharma and Payak (1979) reported that resistant against *P. sorghi* in maize was controlled by polygenes. Inbred lines 'GE 440', 'CM 104' and 'CM 105' were the best general combiners for resistance. Sharma (1983) reported that yellow-grain varieties with inbred lines 'CM 104', 'CM 105', 'CM 500' in their parents and 'Ganga 5' were resistant to *P. sorghi.*

Agronomically desirable, inbred lines with high degree of resistance may be directly utilized in the development of rust-resistant maize varieties. Inbred lines 'LM 9' (MS Pool-C_2IC_2-11---- and 'LM 10' (Pop 28-13---) have already been utilized in development of hybrid 'Sheetal', which has been released for winter season cultivation in Punjab. In the present study a number of inbred lines showed less disease development as has been advocated by Berry (1963), such entries can be utilized for the development of resistant commercial hybrids.

SUMMARY

An experiment was conducted during 1997–98 and 1998–99 to evaluate common rust (*Puccinia sorghi* Schw.) resistance in maize (*Zea mays* L.) inbred lines. Eleven inbred lines were found free from rust during both the years. The lines with same disease reaction varied considerably in terminal disease soverity and disease development. Inbred lines 'GE 440', 'CM 104' and 'CM 105' were found to be the best general combiner for resistance.

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Evaluation of insecticides against apple root-borer (*Dorysthenes hugelii*) (Cerambycidae:Coleoptera)

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Insect-pests play an important role in low productivity of apple (*Malus ×domestica* Borkh; syn *M. Pumila* Mill.) orchards in India especially Himachal Pradesh and Jammu and Kashmir. The major insect-pests associated with apple are leaf mites, *Panonychus ulmi* (Koch) and *Tetranychus urticae* (Koch), san jose scale (*Quadraspidiotus perniciosus* Comstock), woolly apple aphid (*Eriosoma lanigerum* Hausman) and apple root-borer (*Dorysthenes hugelii* Redtenbacher).

Among these, apple root-borer (*Dorysthenes hugelii*) is the pest threatening in large area. It mainly damages the orchards having sandy soil and orchards, which are located in sunny sites (Butani 1979). The grubs of this beetle occasionally infest roots of apricot (*Prunus armeniaca* L.), cherry [*Prunus avium* (L.) L.], peach [*Prunus persica* (L.) Batsch.], pear (*Pyrus communis* L.), walnut (*Juglans regia* L.) and a number of forest trees. The grubs feed on apple roots, as a result of which small as well as major roots are severed from the base. The trees, if young (1–5 years old) die immediately, whereas the older ones become weak having smaller size of leaves and fruits. Such old trees fall down eventually, due to the action of strong winds (Butani 1979). Verma *et al.* (1986) recorded 13.57 larvae/tree in Rohru region of Shimla district, 10.86 larvae/tree in Brua in the Kinnaur district and 6.75 larvae/tree in Bajaura in the Kullu district. The infestation ranged from 2 to 16 larvae/tree. There are a few references regarding its chemical control. Keeping this in view, a study was undertaken to evaluate the different insecticides against this pest.

The present investigation was carried out at Temperate Horticultural Research Station, Kotkhai, Shimla (Himachal Pradesh) during 1998–2000. The orchard selected was having sandy soil and sunny location. The plants selected were shaky and stunted, as the plants having root-borer infestation become shaky and stunted.

Different concentrations of 7 insecticides, viz triazophos (Hostathion 40 EC), chlorpyriphos (Durmet 20 EC), chlorpyriphos (Massban 20 EC), lindane (Kanodane 20 EC), lindane (Kanodane 6 G) and phorate (Thimet 10 G), were evaluated for efficacy against the apple root-borer. The trees selected were treated twice, ie October and April. every year. Treatment was done in October as it was ideal time because adults of apple root-borer emerge at the advent of monsoon and lay eggs in July–August, which hatch after 1 month (Atwal 1986). After that winter starts in November onwards and activity of the grubs slows down and again the grubs speed up their activity after hibernation in April (Atwal 1986). Therefore the second application was given in April. October treatment was given to 10 trees of each concentration, whereas for April treatment half of the trees of October treatment were treated with each concentration or dose. The liquid formulations were applied to the basins of the trees in the form of drenching, whereas for dust and granule applications broadcasting was done on the basins of the trees into 5 cm layer of the soil. The insecticides were applied around a radius of 30–91 cm depending on the age of the tree, as maximum population of the borer is present there (Sharma 1999).

Observations for treatment given in October were recorded in November. Roots of the trees were exposed and observed for preserved any live grub or fresh infestation. If live grub or fresh infestation was not found, then it was considered as an effective treatment, otherwise as an ineffective treatment. For the April treatment, observations were recorded in May. These trials were repeated in 1999 and 2000. The data were analysed as randomized block design.

Triazophos showed 100% mortality of the root-borer at 0.08% concentration, when applied twice, ie October and April. Single application at 0.08% concentration in October recorded 90% control. At 0.04% concentration, 2 applications

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Table 1 Evaluation of different insecticides against apple root-borer, (*Dorysthenes hugelii*)

Insecticide	Concentration (%) or dose (g/tree)	Control after	
		Single application (%)	2 applications (%)
Triazophos	0.02	60.0 (50.83)	80.0 (68.04)
(Hostathion 40 EC)	0.04	80.0 (63.90)	80.0 (64.9)
	0.08	90.0 (74.97)	100.0 (89.96)
Chlorpyriphos	0.02	60.0 (50.83)	80.0 (68.04)
(Durmet 20 EC)	0.04	80.0 (63.90)	100.0 (89.96)
Chlorpyriphos	0.02	70.0 (56.77)	80.0 (68.04)
(Massban 20 EC)	0.04	70.0 (57.68)	80.0 (63.91)
Lindane	0.02	50.0 (44.98)	60.0 (50.75)
(Kanodane 20 EC)	0.04	60.0 (50.83)	80.0 (68.04)
	0.06	80.0 (63.90)	100.0 (89.96)
Lindane	25	30.0 (32.99)	40.0 (38.84)
(Kanodane 1.3 D)	50	40.0 (39.13)	60.0 (50.75)
	75	60.0 (50.75)	80.0 (68.04)
Lindane	25	40.0 (39.13)	60.0 (51.12)
(Kanodane 6 G)	50	40.0 (39.22)	60.0 (50.74)
	75	60.0 (50.92)	80.0 (68.04)
Phorate	25	40.0 (39.13)	40.0 (38.84)
(Thimet 10 G)	50	40.0 (39.22)	60.0 (50.75)
	75	60.0 (50.75)	80.0 (68.04)
Control	Water application	0.0 (0.0)	0.0 (0.0)
CD (P=0.05)		(11.08)	(21.70)
CV (%)		(13.97)	(21.71)

*Observations are average of 3-year data from 1998-2000; **figures in parentheses are angular transformed values

of this insecticide showed 80% mortality of the grub. Chlorpyriphos (Durmet 20 EC) at 0.04% concentration recorded 100% mortality of the pest, when applied twice. At 0.04% concentration Massban 20 EC showed only 80% control of the grub, when used twice. Lindane at 0.06% concentration was 100% effective when applied twice. Single application was only 80% effective. At 0.04% concentration, 80% mortality of the grub was recorded with 2 applications. Chlorpyriphos at 0.04% concentration has been recommended for the control of apple root-borer (YSPUHF, Nauni 1995). Atwal (1986) reported triazophos and lindane good soil insecticides against many soil-inhabiting insects.

In the present investigations, dust and granule applications of lindane and phorate were also tried. Lindane dust (Kanodane 1.3 D) when broadcast @ 75 g/tree twice proved 80% effective. Single application of the same dose disclosed only 60% control. At the rate of 50 g/tree application of this dust when used twice revealed only 60% mortality of the grub. Granules of the lindane (Kanodane 6 G) and phorate (Thimet 10 G) were 80% effective in reducing the population of this grub, when used twice @ 75 g/tree. Other dose, @ 50 g/tree in 2 applications, recorded only 60% control of both the granule insecticides, whereas single application @ 75 g/tree resulted in 60% mortality of the borer. Granule application of phorate (Thimet 10 G) has been recommended against woolly apple aphid infestation of apple orchards (YSPUHF Nauni 1995).

Thus 0.08% triazophos, 0.04% chlorpyriphos and 0.06% lindane are effective (100% control) against apple root-borer infestation, when applied twice, ie October and April. Chlorpyriphos at 0.04% concentration proved 80% effective in reducing borer population. Lindane 1.3 D, lindane 6 G and phorate 10 G are effective to some extent when applied twice @75 g/tee.

SUMMARY

An experiment was conducted during 1998–2000 to study the effect of 7 insecticides in controlling apple root-borer (*Dorysthenes hugelii* Redtenbacher) (Cerambycidae: Coleoptera) on apple (*M.* ×*domestica* Borkh; syn *M. pumila* Mill.) at Temperate Horticultural Research Station, Kotkhai, Shimla (Himachal Pradesh). Triazophos (Hostathion 40 EC) gave 100% control at 0.08% concentration, when applied twice, ie October and April. Single application of the same concentration during October showed only 90% control. At 0.04% concentration, 80% mortality of the grub was observed for both 1 and 2 applications. Chlorpyriphos (Durmet 20 EC) at 0.04 % concentration revealed 80 and 100% mortality for 1 and 2 times application respectively. However, chlorpyriphos (Massban 20 EC) at 0.04% showed only 70 and 80 % mortality of the grub for 1 and 2 applications respectively. Lindane (Kanodane 20 EC) proved quite effective at 0.06% concentration, where it recorded 80 and 100% mortality for 1 and 2 applications respectively. Lindane (Kanodane 1.3 D), lindane (Kanodane 6 G) and phorate (Thimet 10 G) were 80 % effective in controlling this pest when applied @ 75 g/tree twice, ie October and April.

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