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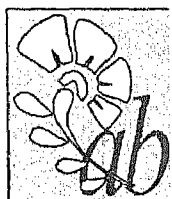
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Comparable studies of rainfed upland winter rice (*Oryza sativa*) cultivars for drought tolerance

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ABSTRACT

An experiment was conducted during 1995-96 to compare ten upland winter season (*rabi*) rice (*Oryza sativa* L.) cultivars amongst themselves for drought tolerance based on some physiological parameters. The seeds were first subjected to moisture stress to study the effect of drought on seed germination. Five levels of moisture stress (0, -3.0, -5.0, -7.5 and -10.0 bar) treatment were given with 'PEG 6000'. The per cent germination decreased with increase in intensity of stress in all the cultivars. Amongst the cultivars 'Iharsal Ahu' and 'Maibee II' recorded better germination under stress. Though relative leaf water content, leaf area, root and shoot dry weight decreased significantly under stress, cultivars 'Iharsal Ahu' and 'Maibee II' performed better under stress. The cultivars also differed significantly in respect of leaf chlorophyll, proline, nitrate reductase activity and nitrogen, phosphorus and potassium content under stress and non-stress condition. 'Iharsal Ahu' and 'Maibee II' showed better results under stress indicating their tolerance to moisture stress.

Key words : moisture-stress, drought tolerance, rainfed, rice

Rice (*Oryza sativa* L.) is the most important and widely grown cereal in India and grown under different situations. The rainfed upland rice in Assam is locally known as *ahu* rice and water-stress is one of the limiting factors for higher yield. The rainfed rice faces 2 major problems, the intensity and duration of stress (Rowsurya Prakash and Venkateswarlu 1983). Although the local rice cultivars of Assam possess many desirable characters but their tolerability to drought have not been studied so far. If the genotypes with better tolerance to drought can be identified then the physiological traits (better germination, proline content, potassium content, etc under stress) may be incorporated in the breeding programmes.

So the present investigation is carried out to make a comparable study amongst the cultivars under stress and thereby to screen the cultivars for drought tolerance.

MATERIALS AND METHODS

The experiment was conducted at the Department of Crop Physiology of the University, Jorhat in the winter season (*rabi*). Ten local rice cultivars, viz 'Naga Ahu', 'Garem', 'Poroma Ahu', 'AS-190', 'Meghi Ahu', 'Hasakumra', 'Iharsal Ahu', 'Maibee II', 'Bala' and 'Chilarai' were selected for the experiment. Four osmoticum solution of -3.0, -5.0, -7.5 and -10.0 bar were prepared with 'PEG 6000' along with control

(0 bar) following the method of Hadas (1976). Twenty surface sterilized seeds were shown on moisten filter paper on petri-dishes and subjected to above mentioned solutions. The petri-dishes were kept in laboratory at room temperature. Seed germination was recorded and average values were subjected to arcsin transformation for analysis of variance. The seeds were taken to be germinated with 2 mm radicle.

Further, the cultivars were grown under 2 moisture regimes; non-stress (irrigated) and stress (unirrigated) in plastic pot in net house. Sixty pots (30 cm × 25 cm) were arranged in a factorial completely randomized design replicating thrice. Each pot was filled with 5 kg of soil collected from rice field and recommended doses of fertilizers were added. Fifty sprouted seeds were sown in each pot. Treatments were given after seedling establishment (7 days after sowing) and continued until the wilting of the seedling. Root and shoot dry weight (mean of 10 samples) were determined in an electronic balance; leaf area was determined in a leaf area meter (LICOR LI 3000 USA) and relative leaf water content was determined by using formula of Matin *et al.* (1989). Leaf chlorophyll and proline were estimated by the method of Anderson and Boardman (1964) and Bates *et al.* (1973) respectively. Nitrate reductase activity in leaf and total soluble protein in shoot were determined by the method of Kleeper *et al.* (1971) and Lowry *et al.* (1951) respectively. Nitrogen, phosphorus and potassium in the shoot were determined by the method of Jackson (1973).

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Table 1 Germination percentage of rice cultivars at different external water potential treatments

Treatments	Variety										Mean
	'Naga Ahu'	'Garem'	'Poroma Ahu'	'AS-190'	'Meghi Ahu'	'Hasakumra'	'Iharsal Ahu'	'Bala'	'Maibee II'	'Chilarai'	
0 bar	86 (68.32)	83 (65.75)	81 (64.24)	81 (53.96)	85 (67.37)	81 (64.37)	90 (71.39)	84 (66.47)	88 (70.25)	91 (73.12)	67
-3.0 bar	74 (59.34)	71 (57.68)	63 (52.33)	63 (52.57)	74 (59.38)	72 (57.86)	73 (58.94)	72 (58.15)	79 (62.53)	80 (63.40)	58
-5.0 bar	40 (39.29)	39 (38.84)	36 (36.67)	47 (43.07)	46 (42.70)	49 (44.62)	64 (52.35)	62 (52.00)	65 (53.73)	70 (57.02)	46
-7.5 bar	24 (29.55)	29 (32.57)	29 (32.57)	34 (35.46)	30 (32.96)	39 (38.84)	45 (42.14)	40 (39.23)	44 (41.74)	44 (41.74)	36
-10.0 bar	0 (6.42)	0 (6.42)	0 (6.42)	0 (6.42)	10 (18.42)	10 (18.42)	15 (22.45)	0 (6.42)	16 (23.57)	0 (6.42)	12
Mean	40.58	40.25	38.25	40.30	44.82	44.76	49.65	44.45	52.36	48.35	
	SED ($\pm$)		CD ($P=0.05$)								
Variety (V)	0.867		1.719								
Treatment (T)	0.613		1.215								
V $\times$ T	1.938		3.843								

Angular values are in parenthesis

RESULTS AND DISCUSSION

All the tested cultivars showed significant reduction in per cent germination with increase in intensity of stress (Table 1). In extreme water stress (-10.0 bar), cultivars 'Iharsal Ahu' and 'Maibee II' recorded higher per cent germination compared to other cultivars. The reason for decrease in germination

with increased level of stress may be that the water potential and osmotic potential as mediated by solutes, develop the additive effect on the inhibition of seed germination. Reduction of seed germination of different crops under moisture stress have also been reported (Hadas 1976, Winter *et al.* 1989, Goswami and Baruah 1994a). The cultivars differed

Table 2 Physiological responses of rice cultivars under stress and non-stress conditions

Cultivars	Relative leaf water content (%)		Root dry weight/ seedling (g)		Shoot dry weight/ seedling (g)		Leaf area/ seedling (cm ²)	
	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress
'Naga Ahu'	91.30	81.20	0.018	0.013	0.063	0.039	29.7	24.3
'Garem'	91.20	79.40	0.029	0.017	0.069	0.042	27.2	21.9
'Poroma Ahu'	92.10	79.50	0.021	0.015	0.070	0.045	22.7	18.1
'CAS-190'	90.10	80.90	0.018	0.013	0.068	0.039	18.5	16.5
'Meghi ahu'	92.30	80.30	0.021	0.016	0.056	0.035	21.3	18.2
'Hasakumra'	91.70	83.10	0.027	0.025	0.108	0.082	29.5	26.8
'Iharsal ahu'								
'Bala'	88.80	81.30	0.021	0.016	0.073	0.035	26.4	20.0
'Maibee II'	91.40	81.80	0.029	0.024	0.093	0.075	29.0	26.1
'Chilarai'	90.00	78.50	0.026	0.020	0.092	0.066	30.4	26.0
Mean	90.93	80.60	0.023	0.018	0.077	0.051	25.8	21.1
Variety (V)								
SED ($\pm$)	0.752		0.001		0.004		0.086	
CD ($P=0.05$)	1.5197		0.003		0.008		0.779	
Moisture								
SED ($\pm$)	0.0336		0.0006		0.0002		0.173	
CD ($P=0.05$)	0.679		0.001		0.0034		0.349	
Variety $\times$ moisture								
MSED ($\pm$)	1.064		0.002		0.005		0.546	
CD ($P=0.05$)	2.150		NS		0.011		1.103	

Table 3 Effect of moisture stress on leaf chlorophyll, leaf proline, total soluble protein and leaf nitrate reductase activity of rice seedling

Cultivars	Leaf chlorophyll (mg/g fresh weight)		Leaf proline (μ g/g fresh weight)		Protein content in shoot (mg/g fresh weight)		NR activity in leaf (n mol NO ₂ /g fresh weight/hr)	
	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress
'Naga Ahu'	2.38	1.39	621	993	0.175	0.123	1175	918
'Garem'	2.03	1.49	645	898	0.178	0.125	1152	880
'Poroma Ahu'	2.37	1.49	597	818	0.185	0.134	1238	918
'AS-190'	2.11	1.51	613	828	0.197	0.131	1191	856
'Meghi Ahu'	2.46	1.56	659	871	0.194	0.128	1269	903
'Hasakumra'	2.20	1.04	654	963	0.201	0.139	1152	794
'Iharsal Ahu'	2.52	1.58	747	1212	0.202	0.156	1394	1214
'Bala'	2.29	1.33	631	1077	0.198	0.135	1113	716
'Maibee II'	2.43	1.44	731	1196	0.201	0.151	1339	996
'Chilarai'	2.40	1.53	718	1145	0.200	0.139	1222	989
Mean	2.32	1.44	651.6	1000.1	0.193	0.136	1224.5	918.4
Variety								
SED ($\pm$)	0.075		23.961		0.0019		29.336	
CD ($P=0.05$)	0.151		48.426		0.0037		59.288	
Moisture								
SED ($\pm$)	0.033		10.716		0.0008		13.119	
CD ($P=0.05$)	0.068		21.657		0.0017		26.515	
Variety $\times$ Moisture								
SED ($\pm$)	0.106		33.886		0.0026		41.488	
CD ($P=0.05$)	0.214		68.484		0.0053		83.847	

significantly in respect of root and shoot dry weight under stress and non-stress conditions (Table 2). Though there was significant reduction in root and shoot dry weight under stress, but cultivars 'Iharsal Ahu' and 'Maibee II' showed lower reduction under stress compared to other cultivars. All the tested cultivars showed significant reduction in leaf area/seedling under stress (Table 2). However, cultivars 'Iharsal Ahu' and 'Maibee II' recorded higher leaf area under stress. Again though, all the cultivars showed significant reduction in relative leaf water content under drought, varieties 'Iharsal Ahu' and 'Maibee II' maintained higher relative leaf water content under stress. Better dry-matter accumulation in 'Iharsal Ahu' and 'Maibee II' may be due to more active photosynthetic area (leaf area) that causes more expansion of root and shoot (results were not presented) which is an indication of good seedling vigour. Finding of Goswami and Baruah (1994a) and Chauhan *et al.* (1996) on reduction of root and shoot dry weight due to reduction of root and shoot expansion (length) under drought in upland *ahu* rice supports the finding of our study. Greater expansion of root of these 2 cultivars may contribute to better tissue water status in shoot as evident from the data of relative leaf water content.

Leaf chlorophyll and nitrate reductase activity decreased significantly under stress in all the cultivars (Table 3). Cultivars 'Iharsal Ahu' and 'Maibee II' recorded higher leaf chlorophyll content under stress. Likewise the highest nitrate reductase activity was recorded in 'Iharsal Ahu' followed by 'Maibee II' at stress and non-stress condition. Lower nitrate reductase

activity in leaf tissue of rice seedling grown at moisture level below saturation has been reported as an indication of poor efficiency of stressed seedlings for nitrogen assimilation (Goswami and Baruah 1994b). Imposed moisture stress has adversely affected the nitrate reductase activity in the leaf of rice seedlings (Table 3). Similar results of decrease in nitrate reductase activity at drought in rice was reported by Saxena *et al.* (1996). In this study, the decrease in nitrate reductase activity in leaves of cultivars 'Iharsal Ahu' and 'Maibee II' was relatively less in comparison to other cultivars under water-stress. Higher nitrate reductase activity in leaves of these 2 cultivars under stress were also associated with higher relative leaf water content. Stable nitrogen metabolism as indicated from nitrate reductase activity of 'Iharsal Ahu' and 'Maibee II' might be associated with drought tolerance. Significant decrease in total soluble protein in leaves under stress was recorded in all the cultivars (Table 3). Minimum reduction in total soluble protein was recorded in 'Iharsal Ahu' and 'Maibee II' at stress over non-stress condition. Water deficit induced decrease in shoot protein has been reported by Macauley *et al.* (1992) and reduction in protein content is clearly correlated with sensitivity of the cultivars to drought and thus supports the result of the study. A significant increase in free proline content under stress condition was recorded in all the cultivars (Table 3). Amongst the cultivars, 'Iharsal Ahu' and 'Maibee II' recorded higher proline accumulation in leaf under stress. Hence, these two cultivars may be considered suitable for growing at moisture

Table 4 Effect of moisture stress on nitrogen, phosphorus and potassium content in shoot

Cultivars	Nitrogen (% dry weight)		Phosphorus (% dry weight)		Potassium (% dry weight)	
	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress
'Naga Ahu'	0.51	0.37	0.43	0.37	1.68	1.29
'Garem'	0.57	0.45	0.43	0.31	1.70	1.39
'Poroma Ahu'	0.60	0.40	0.44	0.25	1.71	1.42
'AS-190'	0.49	0.35	0.37	0.32	1.68	1.33
'Meghi Ahu'	0.63	0.48	0.39	0.30	1.68	1.34
'Hasakumra'	0.60	0.44	0.43	0.34	1.70	1.45
'Iharsal Ahu'	0.75	0.53	0.50	0.39	1.79	1.59
'Bala'	0.68	0.34	0.39	0.32	1.63	1.44
'Maibee II'	0.73	0.51	0.43	0.36	1.73	1.56
'Chilarai'	0.68	0.53	0.45	0.31	1.69	1.25
Mean	0.62	0.44	0.43	0.33	1.71	1.41
Variety						
SED ($\pm$)	0.012		0.0009		0.021	
CD ($P=0.05$)	0.024		0.017		0.043	
Moisture						
SED ($\pm$)	0.005		0.004		0.009	
CD ($P=0.05$)	0.011		0.008		0.019	
Variety $\times$ moisture						
SED ($\pm$)	0.017		0.012		0.030	
CD ($P=0.05$)	0.034		0.024		0.060	

stress condition. Though the precise role of proline accumulation during moisture-stress has not been clearly understood; yet many have proposed that accumulated proline acts as an osmoticum (Joshi *et al.* 1992).

There was significant reduction in nitrogen, phosphorus and potassium content in shoot under moisture stress condition (Table 4). Under stress varieties 'Iharsal Ahu' and 'Maibee II' accumulated higher potassium in shoot. Potassium influences the water economy and crop growth through its effect on water uptake, root growth, maintenance of turgour and stomatal regulation. Potassium application was reported to help in maintaining the adverse effect of drought via retaining more tissue water in sorghum (Umar *et al.* 1993).

Better germination and seedling vigour with better growth of 'Iharsal Ahu' and 'Maibee II' at seedling stage indicate their suitability to grow at moisture stress condition. Since seedling can give a reasonable estimate of the relative response of mature plants to drought (Matin *et al.* 1989); therefore, it is expected that mature plants of 'Iharsal Ahu' and 'Maibee II' may show some degree of tolerability to moisture stress compared to the other cultivars tested. However, further investigation under field conditions is needed.

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Response of two rice (*Oryza sativa*) hybrids to graded levels of nitrogen

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ABSTRACT

A field experiment was conducted during wet season of 1993 and 1994 to study the effect of 5 nitrogen levels (0, 50, 100, 150 and 200 kg/ha) and 2 rice (*Oryza sativa*) hybrids 'PHB 71' and 'PMS2A/IR31802'. The results revealed that the hybrid 'PHB 71' seedlings were more vigorous than the 'PMS2A/IR31802' in terms of dry weight, shoot length and vigour index. There was a significant increase in grain yield with each additional application of nitrogen from 0 - 200 kg/ha during 1993 while in 1994 the increase in N dose from 150 - 200 kg/ha could not register significant increase. Hybrid 'PHB 71' gave 0.75 and 0.95 tonnes/ha higher yield than 'PMS2A/IR31802' in 1993 and 1994 respectively. The highest level of yield 9.25 and 8.24 tonnes/ha was recorded by 'PHB 71' at 200 kg N/ha during the respective year. Yield attributes showed improvement with the increase in N level.

Key words: rice hybrids, nitrogen, 'PHB 71', 'PMS2A/IR31802', transplanting

After the successful performance of hybrid rice in China, few hybrids in India have been developed and released to enhance the yield in the context of plateauing trend in yield. The grain yield obtained by rice hybrids are about 20 % higher than the best pure line cultures. Nitrogen plays a pivotal role in realising full yield potential of a genotype. Seed vigour facilitates the production of robust seedlings in nursery, resulting into the differential response of hybrids to the applied inputs. Measurements of seedling vigour at the nursery stage may prove beneficial in the advanced screening of hybrids.

MATERIALS AND METHODS

A field investigation was carried out during the wet season of 1993 and 1994 at the Rice Research Station at the University

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, Kaul (Kaithal) inviting 5 nitrogen levels (0, 50, 100, 150 and 200 kg/ha) in main plots and 2 hybrid genotypes, 'PHB 71' and 'PMS2A/IR31802' in sub plots. The soil was clay-loam in texture with 8.1 pH, 0.31% organic carbon, 0.26 mmhos/cm EC and 99.6, 26.0 and 389.7 kg/ha available N, P and K respectively. Nursery was sown as per the treatment 1 month before transplanting to get 30 days seedlings at planting.

The experiment was transplanted on 29 June 1993 and 28 June 1994 with a spacing of 20 cm × 15 cm keeping 2 seedlings/hill in split plot design with 4 replications. At final puddling, 26 kg P and 25 kg ZnSO₄/ha were broadcasted uniformly. Nitrogen was applied in 3 equal splits at 4 days after transplanting, active tillering and panicle initiation stage. Growth observations in nursery were recorded 1-day before uprooting the seedlings for transplanting in the main field. The vigour index of the seedling was calculated by the formula mentioned by Raju *et al.* (1989):

Table 1 Effect of hybrids on seedling growth at the time of transplanting

Growth parameters of hybrids	'PHB 71'		'PMS2A/IR31802'	
	1993	1994	1993	1994
Shoot length (cm)	30.6	31.6	26.4	25.8
Root length (cm)	7.00	6.80	6.89	6.32
Tillers/seedling	1.68	1.70	1.83	2.05
Dry weight (g/m ²)	1 020	980	947	876
Seedling density/m ²	1 660	1 610	1 962	1 600
Dry weight of seedling (g)	0.61	0.59	0.56	0.55
Vigour index	3 534	3 496	3 129	2 955

Table 2 Interaction of grain yield (tonnes/ha) between nitrogen level and rice hybrids

N level (kg/ha)/ hybrid	'PHB 71'		'PMS2A/IR31802'		Mean	
	1993	1994	1993	1994	1993	1994
0	3.70	5.00	3.72	3.39	3.71	4.20
50	6.03	6.84	5.40	5.44	5.71	6.14
100	7.75	7.62	6.85	6.86	7.30	7.24
150	8.60	8.06	7.60	7.60	8.10	7.83
200	9.25	8.24	8.00	7.71	8.63	7.97
Mean	7.07	7.15	6.32	6.20		

CD (P=0.05) 1993 N=0.27 Hybrid=0.11 N × Hybrid=0.32
 1994 N=0.23 Hybrid=0.16 N × Hybrid=0.35

Vigour index = (Shoot length + Root length) × Germination (%)

RESULTS AND DISCUSSION

Seedling vigour of the hybrids in the nursery

The seedlings of hybrid 'PHB 71' were taller and more vigorous with higher dry matter / seedling, shoot length and vigour index than hybrid 'PMS2A/IR31802' (Table 1).

Effect on yield and yield attributes

There was a significant increase in grain yield with the subsequent increase in nitrogen application from 0 - 200 kg / ha except in 1994 where the differences were not significant between 150 and 200 kg N/ha (Table 2). The magnitude of increase in grain yield was 53.9, 96.8, 118.3 and 132.6; and 46.2, 72.4, 86.4 and 89.8 % with the application of 50, 100, 150 and 200 kg N/ha over control in 1993 and 1994 respectively. An increase in grain yield with the successive increase in N dose in hybrid rice have been reported by Om (1995).

The hybrid 'PHB 71' gave 0.75 and 0.95 tonne/ha higher grain yield than 'PMS2A/IR31802' during 1993 and 1994 respectively (Table 2). This might be due to increased seedling

vigour in 'PHB 71' over 'PMS2A/IR31802' (Table 1). The superiority of hybrid 'PHB 71' over 'PMS2A/IR31802' and other hybrids in grain yield has been reported by Singh and Panwar (1994) and Om (1995). The grain yield was found significant up to 200 kg in 1993 and 150 kg/ha in 1994 in both the hybrids. The potential productivity was higher in 1993 than in 1994 which might be attributed to the availability of 48% more sunshine hours during tillering and grand growth phases of the crop (July and August) in 1993 than in 1994 resulting in more panicles/m². Higher response of N to grain yield during the year of greater sunshine has also been reported by Watanabe and Takeichi (1991).

Each additional application of N from 0 to 200 kg/ha brought about a corresponding increase in panicles/m², grains/panicle and 1000-grain weight (Table 3). These findings are in confirmation with those of Balasubramanian and Palaniappan (1989) and Shukla *et al.* (1993) in pure line culture.

From the present investigation, it can be concluded that rice hybrid 'PHB 71' is superior which produces more vigorous seedlings and productivity and is more responsive to nitrogen application than the other hybrid 'PMS2A/IR31802'.

Table 3 Effect of nitrogen levels and rice hybrids on yield attributing characters

Treatment	Grains/panicle		Panicles/m ²		1 000-grain weight (g)	
	1993	1994	1993	1994	1993	1994
<i>Nitrogen levels (kg/ha)</i>						
0	107	126	196	179	21.0	21.7
50	112	135	238	234	22.3	22.4
100	128	143	276	259	22.9	22.7
150	136	147	284	266	23.6	23.0
200	145	151	297	280	23.8	23.2
CD (P=0.05)	4	6	14	13	0.2	0.2
<i>Rice hybrids</i>						
'PHB 71'	130	146	253	242	23.0	23.0
'PMS2A/IR31802'	120	135	263	245	22.5	22.2
CD (P=0.05)	3	4	ns	ns	0.1	0.2

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Biomass partitioning and yield components of individual tillers of rice (*Oryza sativa*) at different nitrogen levels

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ABSTRACT

An experiment was conducted during winter season (*rabi*) 1995–96 with rice (*Oryza sativa* L.) to investigate the distribution pattern of biomass among different tillers. The productive potential of individual tillers of 2 cultivars ('IR36' medium tall and 'Swarnaprabha' tall) at 4 different nitrogen levels (N_0 , N_{30} , N_{60} and N_{90}) were studied in terms of biomass partitioning, harvest index and proportion of high density grains. Vegetative phase partitioning of biomass in the mother shoot of 'Swarnaprabha' was more in the order of culm > leaf sheath > and leaf blade. But in 'IR 36' higher proportion was in leaf sheath followed by culm and leaf blade. High levels of nitrogen application resulted in more partitioning to leaf sheath than to culm. In general, mother shoot and primary tillers had high number of filled grains, harvest index and yield in both varieties. Increasing levels of nitrogen application resulted in more secondary tillers which contributed little to grain yield resulting in low harvest index.

Key words : biomass partitioning, N application, rice, tillering, yield

Rice (*Oryza sativa* L.) productivity depends not only on the accumulation of total amount of biomass, but its partitioning to grain yield (Muralidharan *et al.* 1996). Without proper partitioning of biomass, mere increase in biomass would only end up with higher proportion of structural components rather than the grain yield (Venkateswarlu *et al.* 1982). The grain yield can be enhanced by increasing the number and size of spikelets (Venkateswarlu *et al.* 1981), increasing grain weight, the proportion of high density grain (Padmaja Rao *et al.* 1985) and by increasing carbon assimilation of rice plant under nitrogen application (Ying *et al.* 1998). Rice cultivars differ in their yield potential; even within a hill, the productive potentials of tillers are found differing (Padmaja Rao 1987). Information is, however, lacking on the distribution pattern of biomass among different tillers and within the component of tillers of rice varieties at different levels of nitrogen (Ying *et al.* 1998). Hence an investigation was conducted on the productive potential of individual tillers of 2 cultivars at 4 different levels of nitrogen in terms of biomass partitioning, harvest index and proportion of high density grains.

MATERIALS AND METHODS

The experiment was conducted during the dry season of 1995 and 1996 with 'IR 36' and 'Swarnaprabha' at the

Institute, Cuttack in a deltaic alluvial sandy loam soil (Haplaquept). Seedlings of 21-day-old were transplanted on 15 July 1995 and 1996 (for 2 consecutive years) with 4 levels of nitrogen. Nitrogen in the form of urea at 0, 30, 60 and 90 kg N/ha, (N_0 , N_{30} , N_{60} and N_{90}) was applied in 3 equal splits, at basal, active tillering and panicle initiation stages. Normal doses of phosphorous (11 kg P/ha) and potash (21 kg K/ha) were applied. The experiment was laid out in randomised block design with 4 replications. Emergence of primary, secondary and tertiary tillers was recorded by carefully tagging the tillers in chronological order. At maturity, observations were made on partitioning of biomass, harvest index and economic yield among individual tillers. Biomass distributed to the culm, leaf sheath and leaf blade was recorded separately. The proportion of high density grain was determined by using salt solution (NaCl at 1.20 specific gravity) as described by Padmaja Rao (1987). The data for 2 consecutive years were pooled and analyzed.

RESULTS AND DISCUSSION

The data recorded on bio-mass and harvest index indicate that the main shoot in general showed higher values than either primary or secondary tillers (Tables 1). In 'Swarnaprabha', the distribution of biomass in the mother shoot was more in the following order : culm, leaf sheath and leaf blade. While in 'IR 36' higher proportion of biomass was recorded in leaf sheath followed by culm and leaf blade.

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Table 1 Distribution of biomass, grain yield, high density grain, harvest index and yield components among different tillers in 'IR 36' and 'Swarnaprabha' 'IR 36'

Tillers		Total biomass (g/tiller)	Per cent distribution			Panicle	Grain yield (g)	Tiller height (cm)	Grain number	High density grain number	High density grain index	Harvest Index of grain	1 000 grain weight (g)
			Culm	Leaf sheath	Leaf blade								
'IR 36'													
Mother	N ₀	3.891	11.1	16.4	14.1	58.4	2.134	74.3	99	82	62.3	54.8	17.9
	N ₃₀	4.123	11.5	15.3	12.5	60.7	2.432	77.3	116	105	65.2	59.3	18.3
	N ₆₀	4.267	13.1	14.9	10.8	61.2	2.581	78.0	127	117	66.1	60.5	18.3
	N ₉₀	4.389	14.0	14.0	9.5	61.6	2.763	78.5	136	120	67.3	61.5	18.5
Primary	N ₀	2.557	12.9	15.1	15.3	56.7	1.266	74.5	88	56	53.7	49.5	17.7
	N ₃₀	2.795	13.2	15.3	14.1	57.3	1.473	75.1	98	69	57.6	52.6	18.2
	N ₆₀	3.275	13.8	15.9	12.5	57.8	1.764	76.7	107	73	58.25	3.81	8.2
	N ₉₀	3.895	14.4	16.4	9.85	9.4	1.919	77.1	112	84	59.45	4.29	18.3
Secondary	N ₀	2.317	14.4	17.9	17.1	50.7	1.178	70.3	74	44	42.7	50.84	17.9
	N ₃₀	2.556	14.8	17.8	17.0	50.3	1.245	70.6	87	53	44.9	48.51	17.9
	N ₆₀	2.856	16.7	18.0	16.3	49.0	1.304	72.7	95	58	46.1	45.66	18.1
	N ₉₀	3.532	17.5	18.2	15.7	48.6	1.589	74.3	106	67	48.4	44.99	18.2
Tertiary	N ₀												
	N ₃₀	2.132	16.5	23.0	17.3	43.1	0.946	64.7	68	36	30.6	44.09	17.5
	N ₆₀	2.563	17.8	23.7	17.5	41.1	1.088	65.6	71	39	32.4	42.45	17.7
	N ₉₀	2.857	18.1	24.5	17.8	39.6	1.121	66.1	74	43	34.1	39.21	17.8
CD (<i>P</i> =0.05) (N*V)		0.185	0.19	0.21	0.13	1.11	0.07	0.62	4.7	2.8	0.79	0.35	NS
'Swarnaprabha'													
Mother	N ₀	4.853	15.9	8.4	8.3	67.4	2.874	90.4	108	85	57.45	59.2	24.1
	N ₃₀	5.128	16.2	9.9	7.9	66.0	3.077	92.1	120	108	69.0	60.3	24.5
	N ₆₀	5.579	16.4	11.8	6.5	65.5	3.416	95.8	136	117	69.4	61.2	24.7
	N ₉₀	5.632	16.6	12.5	5.4	65.4	3.477	100.5	140	126	69.6	61.73	24.9
Primary	N ₀	3.227	15.1	11.7	12.1	61.1	1.662	90.1	78	54	56.4	51.5	24.1
	N ₃₀	3.478	14.9	12.1	11.1	61.9	1.812	90.4	84	67	58.6	52.12	24.0
	N ₆₀	4.788	14.8	14.3	9.9	62.0	2.681	94.7	117	89	59.25	5.92	24.3
	N ₉₀	4.835	14.8	14.9	7.5	62.7	2.723	96.3	125	100	60.3	56.32	24.6
Secondary	N ₀												
	N ₃₀	2.275	15.6	12.5	11.4	60.5	1.033	86.6	76	56	53.54	45.43	23.7
	N ₆₀	3.784	15.5	15.4	10.7	58.4	1.621	88.8	85	67	55.5	42.8	24.2
	N ₉₀	3.951	15.4	16.3	10.3	58.01	1.660	90.2	105	83	56.4	42.02	24.2
CD (<i>P</i> =0.05) (N*V)		0.155	0.2	0.17	0.29	0.19	0.18	4.18	2.8	1.5	0.43	0.62	NS

However, the ratio of panicle weight to plant weight was recorded high in 'Swarnaprabha' (62.63%) compared with 'IR 36' (53.03%). Nitrogen application increased grain yield in secondary and tertiary tillers. In 'IR 36' at N₉₀ the per cent distribution of panicle to total biomass in primary and secondary was 48.6 and 39.6% respectively.

In 'Swarnaprabha', the secondary tiller panicle distribution to total biomass at N₉₀ decreased to 58% inspite

of not having any tertiary tillers. The distribution of biomass in the mother shoot in 'Swarnaprabha' was found to be higher in leaf sheath while it was to leaf blade in 'IR 36'. In both the varieties the pattern of distribution among primary and secondary tillers was similar to mother shoot. Out of all the tillers the mother shoot followed by primary tillers showed higher biomass than the rest of the tillers. Nitrogen application in general resulted in higher biomass in all the tillers. The

pattern of distribution was such that irrespective of the variety it was higher in leaf sheath. The distribution pattern of spikelets, filled grains and high density grains among various tillers showed that higher numbers of spikelets were recorded in main shoot as well as primary tillers (almost in equal quantities) but the values declined with the secondary tillers. The high-density index (ratio of high-density grain to the total number of spikelets produced) showed similar trend among the two varieties. High nitrogen level resulted in higher number of high-density grain number in the panicles.

Grain yield recorded in various tillers indicated higher values with the main shoot and primary tillers. The yield declined with the tillers gave at later dates in both the varieties. Application of nitrogen resulted in improved grain yield in the primary (47% at N_{90}) and secondary tillers (57% at N_{90}) but without significant variation in mother shoot. However, the harvest index recorded with the mother shoot was also higher than the late generated, primary and secondary tillers in that order among 2 varieties. With higher N, harvest index of secondary and tertiary tillers decreased. In other words, with declining trend of harvest index among the late generated tillers, the per cent of biomass appeared more. In the present tested varieties, the effective partitioning pattern along with increased yield is observed only with mother shoot and the primary tillers. This would indicate that proper balancing of both foundation (biomass) and super structure (harvest index) is necessary for an effective output in the modern plant type.

Results from the experiments showed that emergence of tertiary tillers and late primary and secondary tillers by virtue of varietal character or by N application are undesirable. These tillers contribute little to grain yield and actually have a negative effect on productivity. Hence it is suggested that selection of breeding lines and nutrient management practices which encourage low tiller number would be beneficial in enhancing yield potential of rice in future.

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Evaluation of maize (*Zea mays*) cultivars for their suitability for babycorn under mid-hills of north-western Himalayas

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ABSTRACT

Out of 30 cultivars of maize (*Zea mays* L.) evaluated for babycorn production at 2 locations (Bajaura and Sundernagar) during 1995–97, the hybrid 'VL 42' gave significantly highest marketable babycorn yield followed by hybrids 'MEH 133' and 'MEH 114'. All these hybrids remaining statistically at par with each other, had significantly higher cobs/plant than composite 'Early Composite'. Per cent husk and barrenness were less in hybrids than composite, whereas fodder yield was more in 'Early Composite' than hybrids. Removal of tassel just after its emergence gave 18% higher marketable babycorn yield than no de-tasseling.

Key words : *Zea mays*, babycorn, cultivars, tassel

Selection of a suitable cultivar is the most critical issue in babycorn (*Zea mays* L.) cultivation. An early maturing cultivar with short stature, uniform in flowering and prolific is more suitable. Hybrids are more uniform in flowering and require less harvesting time than an open pollinated cultivar which flowers for longer period and thus needs harvesting for a longer duration. A cultivar which flowers early can give 2 or 3 crops in a year. Short stature is a desirable trait in babycorn. Planting at a high population density of 120–180 thousand plants/ha is required to obtain higher yield/unit area and at this high density, a short plant type cultivar will not suffer from competition for light and other inputs and thus lodging is reduced.

Farmers of Himachal Pradesh are growing maize for babycorn purpose in areas near to processing units. The produce is procured by the fruit processing units of the State Department of Horticulture and Himachal Pradesh Fruit Processing and Marketing Corporation and canned babycorn is marketed in Delhi and Mumbai markets. Due to lack of knowledge about suitable cultivars, the farmers are growing the cultivars suitable for grain maize for babycorn purpose. Keeping these in view, maize hybrids and composites were evaluated for their suitability for babycorn purpose.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of

the Regional Research Station of the Vishvavidyalaya, Bajaura (1 090 m amsl) and Research Sub-Station, Sundernagar (874 m amsl) during wet season of 1995–97. The soil was sandy loam in texture with near neutral pH (6.8). The available N (270 kg/ha), P (18.4 kg/ha) were medium while available K (290 kg/ha) was high in this soil. In all 30 hybrid/composite cultivars of maize were evaluated and data pertaining to 4 best cultivars have been presented in this paper. The experiment was conducted in a randomized complete block design with 3 replications. Two treatment comprising tassel removal just after its emergence and without tassel removal were also superimposed in the same experiment during 1995–97 at Bajaura to find out the effect of tassel removal on babycorn yield.

The crop was sown in the first fortnight of June each season with a spacing of 40 cm from row to row and 20 cm from plant to plant under irrigated condition with 2–3 irrigation each season at Bajaura and under rainfed condition at Sundernagar. Bajaura receives 952 mm annual rainfall out of which only 44% is received during rainy season (June to September) in 42 days and the total annual rainfall of Sundernagar is 1472 mm out of which 70% is received during rainy season. Fertilizers were applied @ 150 kg N, 26 kg P and 33 kg K/ha. Half dose of N and whole P and K were applied as basal and remaining half N was side dressed at knee high stage (25 days after sowing). Young cobs were hand picked during August in 7–8 pickings and picking was done every third day when the silk had emerged about 2–3 cm long out of cob husk. The criteria for marketable babycorn were 4.5–10 cm length and 717 mm diameter of dehusked cobs having regular row arrangement (Bar-Zur and Saadi 1990).

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Table 1 Performance of maize cultivars grown for babycorn purpose over years at two locations of Himachal Pradesh

Cultivar	Marketable babycorn yield (tonnes/ha)						Mean of 2 locations over years
	Bajaura			Sundernagar			
	1995	1996	1997	1995	1996	1997	
'V142'	1.88	1.92	1.71	2.06	1.51	1.86	1.82
'Early Composite'	1.13	1.44	1.27	1.04		0.85	1.14
'MEH 114'	1.56	1.66	1.50	1.39	1.00	1.05	1.36
'MEH 113'	1.73	1.67	1.41	2.04	1.11	1.48	1.57
CD(P=0.05)	0.59	0.42	0.14	0.64		0.37	

RESULTS AND DISCUSSION

Marketable babycorn yield

The hybrid 'VL 42' gave significantly highest marketable babycorn yield during all the years at both the locations followed by hybrids 'MEH 133' and 'MEH 114', however, during 1995-96, the latter both were statistically at par with former at Bajaura location (Table 1). 'MEH 133' was statistically at par with 'VL 42' during 1995 at Sundernagar also. The higher marketable babycorn yield of hybrid particularly of 'VL 42' may be ascribed to higher cobs/plant and lower husk (%) and Barrenness (%) (Table 2). The eleventh Thai National Corn and Sorghum Reporting Programme (Anonymous 1979) has also reported that baby ear production varied greatly among varieties.

Agronomic characteristics and fodder yield

Composite cultivar 'Early Composite' gave significantly higher fodder yield than hybrids due to its significant higher plant height (Table 2). All the hybrids remaining statistically at par with each other had significantly higher cobs/plant than composite 'Early Composite'. Percentage of husk and barrenness were less in hybrids than composite. Because of early and uniform flowering hybrids in general and 'VL 42' in particular took less duration of harvest compared to composite. Data in Table 2 reveal that hybrid 'VL 42' has all the desirable

characteristics for babycorn cultivation, i.e. early and uniform flowering, short plant stature and prolificacy. Further, size of young cob with out husk from this cultivar was of proper length and diameter which is a desirable character for canning (Bar-Zur and Saadi 1990).

Effect of tassel removal

Average yield data over three crop seasons showed that tassel removal just after its emergence gave significantly higher marketable babycorn yield (1.480 tonnes/ha) than without tassel removal (1.255 tonnes/ha) because former resulted in significantly higher cob yield with husk and number of cobs/plant and less discarded babycorn and barrenness (Table 3). De-tasseling did not affect the fodder yield significantly. Prasanna *et al.* (1995) have also advocated that the regular and careful de-tasseling of maize plants leads to avoid fertilization of ears for higher babycorn production.

Thus, it is concluded that hybrid 'VL 42' of maize has almost all the desirable characters required for high babycorn yield and should be preferred for babycorn cultivation. However, in case of non-availability of seed of this cultivar, other cultivars, viz 'MEH 133', 'MEH 114' and 'Early Composite' may also be grown for babycorn purpose as next order of preference under irrigated as well as rainfed mid-hill conditions of north-western Himalayas. Tassel removal just after

Table 2 Agronomic characteristics of four selected maize cultivars for babycorn production at Bajaura (mean of 1995-97)

Cultivar	Cob yield with husk (tonnes/ha)	Discarded dehusked babycorn (tonnes/ha)	Fodder yield (tonnes/ha)	Size of dehusked young cob (cm)		Cobs/plant	Plant height (cm)	Days to harvest	Period of harvest	Husk (%)	Barren- ness (%)
				Length	Diameter						
'VL 42'	7.98	0.135	24.6	8.1	1.18	2.68	165	48	18	76.1	3.68
'Early Composite'	7.44	0.126	38.9	9.4	1.23	1.76	204	58	21	82.8	7.48
'MEH 133'	8.64	0.185	30.2	8.6	1.16	2.29	178	55	20	81.8	4.28
'MEH 114'	8.20	0.145	31.6	8.4	1.18	2.30	182	54	22	79.9	5.08
CD(P=0.05)	0.20	0.03	2.4	NS	NS	0.36	16	2.28	NS	2.54	1.26

Table 3 Effect of tassel removal on babycorn yield (mean data of 1995–97)

Treatment	Cob yield (tonnes/ha)			Fodder yield (tonnes/ha)	Cobs/plant	Barrenness(%)
	With husk	Without husk				
		Marketable	Discarded			
Without tassel*	8.86	1.48	0.10	33.0	2.14	5.27
With tassel	7.59	1.26	0.16	32.6	1.95	7.81
CD (P=0.05)	0.29	0.07	0.01	NS	0.18	0.73

*Tassel was removed just after its emergence from the leaf sheath

its emergence increase the babycorn yield considerably.

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Evapo-transpiration, water and radiation-utilization of clusterbean (*Cyamopsis tetragonoloba*)

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ABSTRACT

The evapotranspiration rate of unstressed 'Maruguar' clusterbean (*Cyamopsis tetragonoloba* (L.) Taubert) in an arid region at Jodhpur was 2.4–3.9 mm/day during early growth, 6.3–9.3 mm/day at peak vegetative stage, 5.3–5.8 mm/day at flowering/pod formation stage and 1.2–4.2 mm/day at maturity stage. The crop coefficient (ratio of actual to potential evapotranspiration) was 0.42–0.58 at early growth stage, 0.62–1.17 at peak vegetative stage, 0.70–1.05 flowering and pod formation stages and declined to 0.43–0.60 at maturity. Irrigation enhanced seed yield of clusterbean by 123% at 50% rate and 180% at 100% rate of water application from that of rainfed crop. The water-use efficiency of the crop varied from 1.47 to 4.10 kg/ha/mm and the radiation-use efficiency for unit dry matter production of intercepted photosynthetically active radiation was 0.57–1.21 g/MJ under rainfed to 1.42–2.31 g/MJ under irrigated condition. Advection enhanced evapotranspiration of clusterbean by 50–78%.

Key words: clusterbean, evapotranspiration, irrigation, water-use efficiency, radiation-use efficiency, advection, arid region

Clusterbean (*Cyamopsis tetragonoloba* (L.) Taubert) is a drought-hardy crop grown mainly in arid and semi-arid regions of Africa and South-east Asia. In India, the crop is grown in 2.64 million ha in regions experiencing an annual rainfall of 200–600 mm and air temperatures 18.0–42.0°C achieving seed yield of 247–625 kg/ha (Arora *et al.* 1988). A polysaccharide gum (galactomannan) in the endosperm finds use in various industrial applications and hence the area under clusterbean cultivation in the region grew by 5% per annum during 1965–86 (Arora *et al.* 1988, Saini and Paroda 1990).

Like other legumes clusterbean fixes atmospheric nitrogen through its nodules and application of 20 kg N/ha+17.2 kg P/ha keeping seed rate of 30 kg/ha gave the highest yield of 1850 kg/ha compared to 1470 kg/ha without fertilization (Baboo and Rana 1995). The crop performs well under low rainfall but water supply during flowering, pod setting and seed developmental stages influenced the crop yield (Singh 1983). The moisture-use efficiency of 4 grain legumes at Jodhpur showed that 'Sona' clusterbean had highest water-use efficiency compared to 'S 12' greengram (*Phaseolus radiatus* L.), 'H 10' blackgram (*Phaseolus mungo* L.) and

'C 152' cowpea [*Vigna unguiculata* (L.) Walp.] (Singh and Ramakrishna 1976). Besides the reduction in yield due to water deficit, the crops have specific limits for radiation-use efficiency even under adequate water and nutrient supply (Gallagher and Biscoe 1978, Kiniry *et al.* 1989 and Monteith 1994) and therefore, the present study was made to investigate the production, potential, water and energy-use aspects of clusterbean.

MATERIALS AND METHODS

A field experiment on 'Maruguar' clusterbean was conducted at the Institute, Jodhpur (26°18' N; 73°01' E and 224 m above msl during 1993–95. The area experience an average rainfall of 310 mm and air temperatures between 24° and 40°C during the cropping season. The soil of the area is at 1 m depth and classified as coarse loamy, mixed hyperthermic Haplocambids. The organic matter content according to Walkley and Black's method was 0.4%, the available P using Olsen's method was 17 kg/ha and the available K with ammonium acetate method was 190 kg/ha.

With the onset of monsoon, the crop was sown on 14 July in 1993 (late sown crop), 7 July in 1994 (normal sown crop) and on 22 July in 1995 (late sown crop) maintaining with inter- and intra-row spacing of 45 and 10 cm respectively in about 1 ha field from which separate plots were ear marked for different treatments. The crop was harvested on 20 October 1993, 7 November in 1994 and 27 October in 1995. In 1993, there was a break in monsoon rain from 8–52 days after

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Table 1 Yield and yield attributes of clusterbean

	1993				1994				1995			
	Rainfed	Irrigated		SE _m	Rainfed	Irrigated		SE _m	Rainfed	Irrigated		SE _m
		50%	100% ET			50%	100% ET			50%	100% ET	
Plant height (cm)	69	117	147	4.6	124	129	150	4.2	79	86	87	4.2
leaves/plant												
Mainstream	14	22	24	1.3	21	21	22	0.5	20	20	20	0.6
Branch	24	81	89	7.1	56	63	64	7.3	47	53	63	7.6
Total	38	103	113	8.4	77	84	86	7.8	67	73	83	8.2
Branches/plant	6	8	9	0.6	10	12	13	0.9	9	9	9	1.1
Pods/plant												
Mainstream	21	23	27	5.9	16	17	19	2.5	24	26	29	4.1
Branch	16	38	45	6.2	14	18	20	2.4	8	12	58	10.1
Total	37	61	72	9.1	30	35	39	4.9	32	38	87	14.2
Leaf area index (m ² /m ²)	1.61	5.02	7.33	1.40	1.25	2.91	5.09	0.20	0.63	0.84	1.00	0.27
Seed yield (kg/ha)	710	1 580	2 000	11.9	957	987	1 255	4.3	690	970	1 740	14.8
Straw yield (kg/ha)	2 904	7 371	12 583	139.9	6 542	7 000	7 555	14.3	5 764	5 972	6 875	15.3

SE_m, Standard error for mean; ET, evapotranspiration

emergence. In 1994, the rainfall was well distributed, whereas in 1995, the rainfall receded after 56 days after emergence.

Daily evapo-transpiration was recorded using 3 gravimetric lysimeters consisting of a sensitive type of weighing machines of 2-tonnes capacity (Anonymous 1979). These lysimeters were surrounded by 5 m × 15 m plot of crop with similar irrigation treatment to act as buffer. Separate field plots of size 5 m × 15 m was maintained under rainfed, 50 and 100% evapo-transpiration and monitored the growth and phenology from 7 tagged plants in each of 3 treatments, while the dry matter was sampled at 15-day-intervals. The tip of the leaf appearance was recorded on every alternate day to relate to the growing degree days. Fertilizer @ 20 kg N/ha and 17.2 kg P/ha was applied.

Daily irrigation at 100% evapotranspiration rate was given to the crop after 20 days after emergence based on the evapotranspiration during the previous day and irrigation at 50% rate was given once in 4 days. The irrigation time and quantity applied were the same both in the field plots as well as in the lysimeters. The weekly average evapotranspiration for the 3 cropping seasons for 100% rate of irrigated crop was used for working out the crop coefficients (ratio of actual to potential evapo-transpiration). The potential evapo-transpiration was calculated based on a modified Penman formula (Doorenbos and Pruitt 1975). The weather parameters were recorded using an automatic weather station. The day time energy balance was calculated using the following equation :

$$R_n = LE + H + G$$

Net radiation (R_n), and soil heat flux (G) at different growth stages at hourly interval between 0600 and 1800 hr IST on all

plots were recorded. The latent heat of vapourization (LE) in MJ was indirectly calculated from the hourly evapotranspiration (mm) measured from the lysimeters. Leaf transpiration was monitored using a steady state porometer (LI-1600). Water-use-efficiency (kg/ha/mm) was worked out as a ratio of grain yield produced per unit of evapotranspiration used by the crop.

The radiation-use efficiency of clusterbean was calculated as a ratio of dry biomass to the intercepted PAR radiation. The integral of fractional daily foliar PAR radiation interception was calculated from the formula :

$$I_a = I_i (1 - e^{-kL})$$

where I_a is absorbed PAR, I_i is PAR above canopy, k is extinction coefficient and L is leaf area index (Kiniry *et al.* 1989). The PAR above the canopy was calculated by multiplying incoming solar radiation with 0.45 (Rosenthal and Gerik 1991).

The growing degree days (°CD) were calculated as the accumulated temperature above a base temperature of 8°C (Ong and Montieth 1985) from the date of emergence to harvest.

RESULTS AND DISCUSSION

Yield and yield attributes

Clusterbean sown on normal dates of onset of rainfall in 1994 performed better than the crop sown under delayed rainfall conditions in 1993 and 1995 as evidenced from observations on plant height, number of branches, pods/plant, seed and straw yield (Table 1). Irrigation at 50% evapotranspiration enhanced seed yield by 123% in 1993, 3 % in 1994 and 40% in 1995. Irrigation at 100%

evapotranspiration water supply increased seed yield by 180% in 1993 and 152% in 1995. However, in 1994 the increase due to irrigation was only 31% due to shedding or flowers from frequent rains.

The irrigated clusterbean gave 0–3 more branches/plant and 9–55 pods/plant contributing to higher seed yield than the rainfed crop. Leaf area of the mainstem and branches

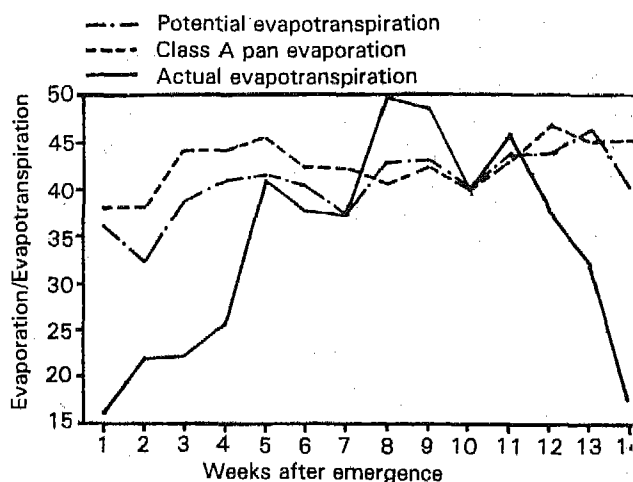


Fig 1 Daily class A pan evaporation, potential and actual evapotranspiration of clusterbean

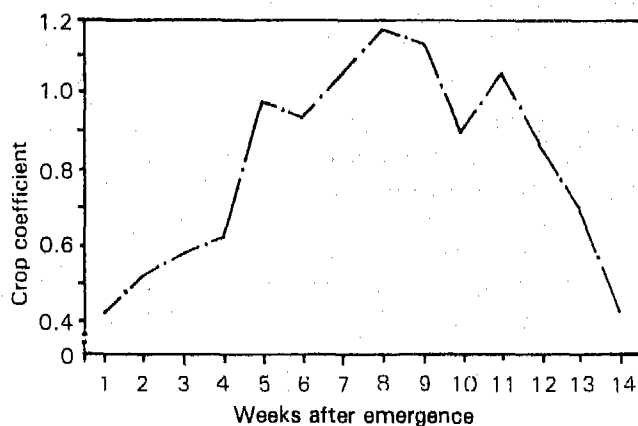


Fig 2 Crop coefficient of clusterbean.

increased by 226 at 50% and by 340% at 100% evapotranspiration moisture regimes. The initiation of branches was delayed by 3–5 days under rainfed condition compared to irrigated clusterbean. The maximum root density was confined between 10–45 cm depth. The relative contribution of seed to biomass (Harvest index) varied between 12 and 25% by weight depending upon the moisture and other weather conditions.

Evapotranspiration and crop coefficients

The evapo-transpiration of clusterbean grown at 100% evapotranspiration was 2.4–3.9 mm/day during early growth, 6–9.3 mm/day during peak vegetative stage, 5.3–5.8 mm/day during flowering and pod formation and 1.2–4.2 mm/day during maturity stage (Fig 1). The class A pan evaporation was consistently higher than the potential evapotranspiration estimates made using Penman.

The crop coefficients (ratio of actual to potential evapotranspiration estimated using modified Penman formula) were 0.42–0.58 at the early growth, 0.62–1.17 during the peak vegetative stage, 0.70–1.05 during flowering and pod formation stages and 0.43–0.60 during maturity stage. Water- and radiation-use efficiency.

The seasonal evapo-transpiration of clusterbean was 332 mm, 447 mm and 654 mm under rainfed, 50% and 100% evapotranspiration irrigated conditions (Table 2). With the increased moisture availability, the water-use efficiency of the crop decreased from 4.10 to 2.73 kg/ha/mm during 1993, whereas it increased from 1.47 to 2.17 kg/ha/mm in 1995 under delayed sown conditions.

The radiation-use efficiency of clusterbean was 0.57–1.21 g/MJ for rainfed crop, 1.21–1.41 g/MJ for 50% rate and 1.41–2.31 g/MJ for 100% irrigated crop.

Leaf transpiration

In 1993, the leaf transpiration rate of clusterbean at vegetative stage (1200 hr ISI) was 57–113 $\mu\text{g}/\text{cm}^2/\text{s}$ under rainfed crop, 66–160 $\mu\text{g}/\text{cm}^2/\text{s}$ under 50% evapotranspiration and 205–350 $\mu\text{g}/\text{cm}^2/\text{s}$ under 100%

Table 2 Evapotranspiration and water-use efficiency of clusterbean

Variable	1993	1994	1995	Mean
Seasonal rainfall (mm)	182	487	302	324
Number of rainy days (rainfall 2.5 mm)	9	28	14	17
Seasonal evapotranspiration (mm)				
Rainfed	173	354	469	332
50% evapotranspiration	416	375	549	447
100% evapotranspiration	733	425	803	654
Water-use efficiency (kg/ha/mm)				
Rainfed	4.10	2.70	1.47	2.76
50% evapotranspiration	3.79	2.63	1.77	2.73
100% evapotranspiration	2.73	2.95	2.17	2.62
SE _m	0.05	1.45	0.95	

Table 3 Cumulative growing degree day requirement for leaf ppearance of clusterbean

Leaf number	Growing degree days		
	Rainfed	Irrigated	
		50% rate	100% rate
1	98	211	232
2	183	255	284
3	268	310	337
5	440	420	443
10	867	695	708
15	1 295	970	972
20	1 722	1 255	1 236

emergence to flowering of clusterbean was 947 °Cd for rainfed crop, 1026 °Cd for 50% and 1134 °Cd for 100% evapotranspiration crop and for physiological maturity, the crop required 2039 °Cd under rainfed condition, 2158 °Cd at 50% evapotranspiration and 2259 °Cd at 100% evapotranspiration crop.

Energy balance and advection

The day time energy balance over the clusterbean showed that 2.7–17.3 MJ/m² of energy was utilized for evapotranspiration process by the rainfed crop and 6.8–22.6 MJ/m² by irrigated crop during 1995 crop season (Table 4) under rainfed condition. The advection occurred at 40 days after emergence following a rainfall of 67 mm. Under irrigated condition, the advection was 78% at 40 days after emergence and 50% at 55 days after

Table 4 Day time (0600 to 1800 hr ISI) energy balance (MJ/m²) over rainfed clusterbean at Jodhpur, 1995

Days after emergence	R _s	Rainfed					100% ET level irrigated				
		R _n	LE	G	H	A	R _s	LE	G	H	A
40	22.5	15.9	17.3	2.5	-3.9	24	14.2	22.6	2.7	-11.1	78
55	22.6	14.8	13.6	2.1	-0.9	6	14.1	20.8	0.4	-7.1	50
75	20.8	11.3	2.7	1.4	+7.2	0	11.0	6.8	0.6	+3.6	0

R_s, Solar radiation, R_n, net radiation, LE, latent heat of vapourization G, soil heat flux, H, sensible heat flux, A, advection (%), ET, evapotranspiration

evapotranspiration. In 1994, the rainfall was high throughout the season and therefore, the transpiration was 130–345 µg/cm²/s for rainfed crop, 132–355 µg/cm²/s for 50% and 190–390 µg/cm²/s for 100% evapotranspiration crop.

Growing degree days

Linear type of relationship are found between the growing degree days (X) and the leaf appearance (Y) as follows:

$$Y_1 = 0.0117 X_1 - 0.1468 (R^2 = 0.99)$$

$$Y_2 = 0.0182 X_2 - 2.6497 (R^2 = 0.98)$$

$$Y_3 = 0.0189 X_3 - 3.3779 (R^2 = 0.98)$$

where Y₁, Y₂ and Y₃ are the number of leaves appeared and X₁, X₂ and X₃ are the corresponding growing degree days for rainfed, 50% and 100% potential evapotranspiration rate of irrigated crops. The appearance of leaves was slow up to the 3rd leaf, but afterwards it was faster in the irrigated crop than the rainfed (Table 3).

The initiation of first branch was early in the 100% evapotranspiration crop with a growing degree days requirement of 500° Cd compared to 568° Cd for 50% evapotranspiration and 634° Cd for rainfed crops. By the appearance of 9th branch, the growing degree days requirement increased from 984° Cd for 100% evapotranspiration crop to 1283° Cd for rainfed crop.

The cumulative growing degree days (°Cd) from

emergence which gradually reduced to 0% by maturity period.

Thus though clusterbean is grown as a rainfed crop, the crop responded to irrigated for higher seed yield up to 100% level of evapotranspiration. The water- and radiation-use efficiency of the crop are also increased at higher moisture regimes. The evapotranspiration of irrigated clusterbean was considerably influenced by advection in the arid region.

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Evaluation of diverse germplasm lines/cultivars for yield and yield components in blackgram (*Phaseolus mungo*)

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ABSTRACT

A study was conducted during 1993-95 on the extent of variability in 87 and 30 lines/cultivars in the blackgram (*Phaseolus mungo* L.). Based on the performance in 1993, 5 superior lines for each character as well as for yield /plant were selected for the evaluation in 1995. Large extent of variability was observed for all the characters in both the years except for days to maturity. Some of the lines/cultivars were superior to the check (s) for different character (s). Whereas 'HPU 4' was better than the best check, ie 'Pant U 19' in the replicated yield trial. Thirty lines/cultivars were represented by 4 distinct morphological groups

Key words : blackgram, *Phaseolus mungo*, germplasm

Any improvement in a crop species depends on the existence of variability. The knowledge of variability in germplasm guides the breeders in chalking out the right strategies of their breeding programme. Limited efforts have been made to explore the variability available in blackgram (*Phaseolus mungo* L.). The study was aimed on the extent of variability for yield and its components and to test the performance of these lines in relation to check varieties. An attempt is also made to represent the variability through metroglyph and index score analysis.

MATERIALS AND METHODS

Eighty seven lines/cultivars including 3 checks; 'Type 9', 'Pant U 19' and 'Pant U 35' of blackgram were grown in wet season (*kharif*) of 1993 in a single row plot of 3 m length with a row distance of 30 cm and plant-to-plant distance of 10 cm. Observations were recorded on 5 randomly selected plants for 8 characters, namely days to maturity, plant height (cm), clusters/plant, pods/plant, pods/cluster, seeds/pod, 100-seed weight (g) and yield/plant (g). On the basis of these observations 5 best lines for each of the 8 characters were selected. Some of the lines were superior for more than one character, therefore, the total number of lines thus selected were 30 including the three checks. These 30 lines were reevaluated in *kharif* 1995 in a randomized block design with 3 replications in a single row plot of 3 m length with a row distance of 30 cm and plant-to-plant distance of 10 cm. The

observations were recorded on 5 randomly selected plants from each plot for the same characters as in 1993. The data of 3 replications were pooled to estimate the mean values and for further analysis. The data from 30 lines, were also represented as metroglyph and index-score analysis (Anderson 1957). Each genotype was represented as a glyph bearing its serial number. All the characters except yield/plant were represented as rays at different positions on the glyph. A scatter diagram has been presented taking yield/plant as the abscissa and pods/plant as ordinate. The range of variation in each character is represented by different length of rays (Fig 1). The index values and class internals for the character are given in Table 3.

RESULTS AND DISCUSSION

The estimates of mean, range and coefficient of variation for 8 agronomic characteristics studied in both the years are presented in Table 1. All the characters except days to maturity showed large extent of variability in both the years, highest being for pods/cluster followed by clusters/plant in 1993 and for yield/plant followed by pods/plant in 1995. Acharya *et al.* (1993) have also reported high variability for pods/plant and yield/plant in local genotypes of blackgram while Kasundra *et al.* (1995) observed high variability for yield and yield related traits in their study of 42 diverse genotypes of blackgram.

Extent of variability for all the characters except for yield/plant and pods/plant decreased in 1995, when only selected lines were evaluated. An increase in the variability for yield/plant and pods/plant could be due to the larger influence of environment on the expression of these characters. In general, similar trends for variability were observed in both the years.

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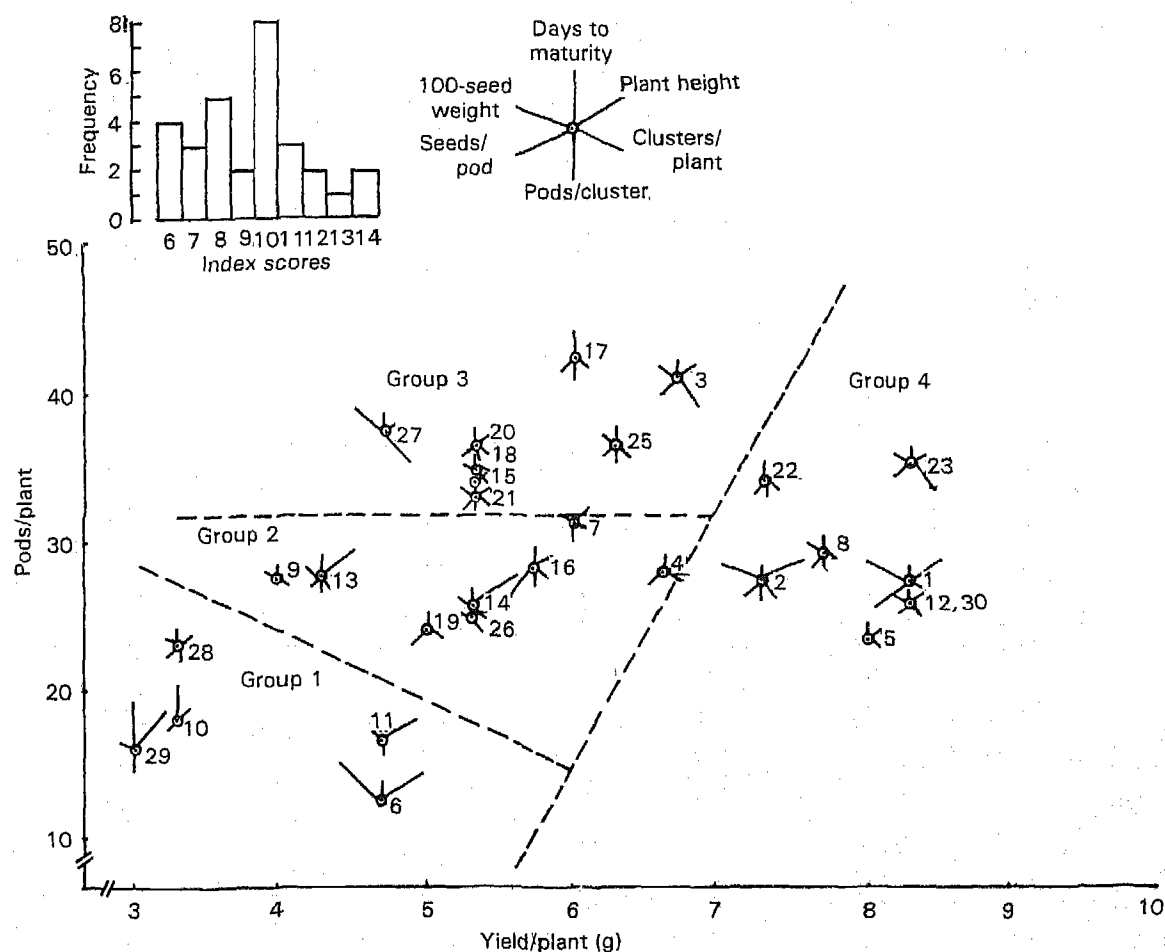


Fig 1 Metroglyph analysis in blackgram

As a result of selection of superior lines, a change in mean values in 1995 in the desired direction was observed for days to maturity, pods/plant, 100-seed weight and yield/plant while the mean plant height had increased, i.e. a change in mean in negative direction which could be due to the fact that the superior lines for other character(s) also had higher plant

height. For remaining characters the mean values in two different years did not change.

To assess the status of germplasm lines, performance of these lines was compared for each of the 8 characters with best performing check for the corresponding character (Table 2). Six lines were superior for 3 or more yield components

Table 1 Mean, range and coefficient of variation for different characters in blackgram in 1993 and 1995

Character	1993			1995		
	Mean $\pm$ SE	Range	CV	Mean $\pm$ SE	Range	CV
Days to maturity	91.7 $\pm$ 0.28	83.0 - 99.0	2.9	81.7 $\pm$ 0.12	80.0 - 83.0	0.8
Plant height (cm)	71.2 $\pm$ 2.32	44.4 - 151.0	30.6	95.9 $\pm$ 3.20	67.3 - 124.6	18.6
Pods/plant	27.5 $\pm$ 0.70	8.8 - 46.0	26.7	30.0 $\pm$ 0.16	12.5 - 45.9	29.0
Clusters/plant	14.9 $\pm$ 0.62	4.0 - 30.4	38.9	14.1 $\pm$ 0.69	6.0 - 23.7	27.3
Pods/cluster	2.1 $\pm$ 0.09	1.1 - 6.2	44.1	2.2 $\pm$ 0.07	1.5 - 3.3	18.6
Seeds/pod	6.2 $\pm$ 0.11	3.0 - 8.1	16.5	6.1 $\pm$ 0.14	4.7 - 8.2	13.4
100-seed weight (g)	3.3 $\pm$ 0.06	1.6 - 5.3	17.6	3.4 $\pm$ 0.05	2.8 - 4.0	8.7
Yield/plant (g)	3.6 $\pm$ 0.07	1.7 - 5.6	17.7	5.9 $\pm$ 0.31	3.0 - 9.3	29.4

Table 2 Performance of 30 lines/cultivars of blackgram for 8 characters in 1995

Genotypes	Days to maturity	Plant height (cm)	Pods/plant	Clusters/plant	Pods/cluster	Seeds/pod	100-seed weight(g)	Yield/plant (g)
'HPU 23'	81	109.4	27.4	13.4	2.6	8.2*	3.8*	8.3
'PLU 825'	81	121.4	27.5	13.5	2.1	6.0	4.0*	7.3
'HPU 156'	82	87.5*	41.1*	21.3*	2.0	7.0*	3.2	6.7
'HPU 170'	82	79.6*	28.0	15.5	1.9	5.9	3.1	6.7
'K 560-49'	82	97.3	23.5	12.4	1.8	5.6	3.1	8.0
'PLU 483'	82	121.5	12.5	8.5	1.5	5.4	3.7*	4.7
'HPU 148'	80*	89.98	31.5*	14.9	2.3	4.8	3.3	6.0
'HPU 105'	82	78.3*	29.6	13.0	2.2	6.6*	3.5	7.7
'PLU 280'	81	73.8*	27.7	13.7	2.0	5.8	3.5	4.0
'PDU 31'	83	96.1	18.8	11.0	1.8	6.3	3.0	3.3
'PDU 1'	80*	109.0	16.1	6.0	2.5	4.9	3.5	4.7
'PLU 429'	82	98.5	26.7	15.3	1.7	6.3	3.4	8.3
'PLU 533'	82	112.7	27.9	12.2	2.4	6.2	3.3	4.3
'PLU 839'	81	118.9	25.5	13.8	2.0	4.9	3.6	5.3
'PLU 551'	82	118.1	28.8	11.4	2.8	4.9	3.4	5.3
'PLU 782'	81	89.1*	28.8	13.1	2.3	7.2*	3.0	5.7
'MS 13'	82	67.3*	42.1*	16.4	2.3*	6.5	2.9	6.0
'Ledjhalat'	82	77.1*	35.2*	16.3	3.3*	4.7	3.2	5.3
'IC 10703'	82	82.0*	24.2	13.2	1.9	6.5	3.0	5.0
'Pant U 1146'	82	70.3*	35.9*	13.7	2.6	6.2	2.8	5.3
'PLU 119'	81	97.6	33.3*	15.4	2.2	6.7*	3.6	5.3
'HPU 9'	82	71.0*	34.1*	14.0	2.4	6.8*	3.1	7.3
'PLU 1079'	82	87.0*	35.7*	23.2*	1.7	6.9	3.2	8.3
'HPU 4'	82	88.5*	45.9*	23.7*	2.8	6.8	3.1	9.3*
'PLU 98-313'	82	79.3*	36.7*	14.8	2.7	6.3	3.6	6.3
'PLU 646'	82	105.0	25.8	14.6	1.8	5.7	3.6	5.3
'PLU 468'	82	88.1*	37.5*	17.9*	2.0	5.7	3.7*	4.7
'Type-9' (ch)	81	105.3	23.4	10.5	2.7	6.2	3.2	3.3
'Pant U 35 (ch)	83	124.6	16.2	7.5	2.1	4.9	3.6	3.0
'Pant U 19 (ch)	82	98.5	26.7	15.3	1.7	6.3	3.4	8.3
CD (P=0.05)	0.25	6.52	3.18	1.41	0.15	0.30	0.11	0.63

Table 3 Class intervals in index values for 9 characters in blackgram

Character	Range of mean	Score-1 Values less than	Score-2 Values less than	Score-3 Values more than
Days to maturity	80.0-83.0	81.0	81.0-82.0	82.0
Plant height (cm)	67.3-124.6	86.4	86.4-105.5	105.5
Pods/plant	12.5-45.9	23.6	23.6-34.8	34.8
Clusters/plant	6.0-23.7	11.9	11.9-17.8	17.8
Pods/cluster	1.5-3.3	2.1	2.1-2.7	2.7
Seeds/pod	4.7-8.2	5.9	5.9-7.0	7.0
100-seed weight (g)	2.8-4.0	3.2	3.2-3.6	3.6
Yield/plant (g)	3.0-9.3	5.1	5.1-7.2	7.2

to the best performing check for corresponding trait. Only one line 'HPU 4' could produce more yield than the best check, 'Pant U 19'. 'HPU 156' and 'PLU 1079' showed low plant height, more pods/plant, clusters/plant and seeds/pod but less pods/cluster and low 100-seed weight and resulted in low yield. 'Ledjhalat' another line though had more number

of pods/plant and pods/cluster, it had low plant height but due to fewer seeds/pod it could not yield more than the check.

Line 'HPU 9' had more pods/plant and less seeds/pod with low plant height yielded less than check due to low 100-seed weight. Similarly, the lines 'HPU 4' and 'PLU 468' were superior for 4 component characters but had less 100-seed weight and

less seeds/pod, respectively, and resulted in low yield.

This comparison clearly indicates that though several superior lines/cultivars are available in germplasm for each of the traits, however, they need to be improved as only one line could produce more yield than the best check in 1995. It was because a line superior for one trait was not good for the other traits, resulting in low yield. Hybridization followed by selection seems to be the right strategy to improve these lines to evolve the high-yielding cultivars.

The scatter diagram (Fig 1) revealed that in blackgram 4 groups could be distinguished on the basis of morphological variation. The first group was represented by the genotypes with lower values of yield/plant and pods/plant. The values for other characters of this group were low to average except for plant height and 100-seed weight which had average to high values. The second group was characterized by the genotypes with average yield/plant and pods/plant, however, two lines were low yielders. The values for clusters/plant, pods/cluster and 100-seed weight were of low to average magnitude and the values for plant height and seeds/pod were low/average/high. The third group was represented by average yield/plant and high pods/plant with low to average

plant height, pods/cluster, seeds/pod and the values for clusters/plant and 100-seed weight were low/average/high. The fourth group was depicted by the genotypes with high yield and average pods/plant with average to high values for clusters/plant and low/average/high values for the remaining characters.

The range of index score was from 6 to 14 with maximum frequency around an index score of 10. Approximately equal distribution of genotypes was observed in 4 groups. The lines within a group varied for different characters. These observations suggested a scope of improvement of these lines through hybridization.

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Path coefficient and stability analysis studies in andigena potato

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ABSTRACT

The relationship between yield and some measures of growth and yield was examined during 1995-97 for andigena potatoes (*Solanum tuberosum*) grown in 3 different nutritional environments, viz 120 kg N: 35.2 kg P : 83.0 kg K/ha; 150 kg N: 44.0 kg P: 103.7 kg K/ha and 180 kg N: 52.8 kg P: 124.4 kg K/ha. Consistent association of characters across 3 environments were considered for drawing conclusions. Tuber yield was positively and significantly correlated with haulm weight, leaf area index and mean tuber weight. Leaf area index was positively correlated with mean tuber weight, tuber number and tuber yield. Tuber number was negatively correlated to mean tuber weight. Mean tuber weight proved to be the most important determinant of tuber yield. Mean tuber weight and number of tuber had significant and positive direct effect on tuber yield. The number of tuber, however, had significant and negative indirect effect on tuber yield via mean tuber weight. Leaf area index had significant and positive indirect effect on tuber yield via mean tuber weight. Out of the 30 genotypes evaluated for tuber yield at 90 days harvest, genotypes 'JEX/A 30', 'JEX/A 199', 'JEX/A 318', 'JEX/A 459', 'JEX/A 541', 'JEX/A 715', 'JEX/A 717', 'JEX/A 764', 'JEX/A 1102', 'JEX/A 1152' and 'JEX/B 998' was found to be highly stable for tuber yield. These genotypes can be gainfully used in andigena breeding programme.

Key words : andigena potato, correlation, path analysis, stability, tuber yield

Andigena potato [*Solanum tuberosum* ssp *andigena* (Juz. et. Buk.) Hawkes], an ancestral subspecies of tuberosum potato (*Solanum tuberosum* ssp *tuberosum*) has wide variability. The short day adapted andigena could be useful in improvement of potato in India where about 4/5 of potato production is under short day condition. Use of andigena in the improvement of tuberosum potato requires its genetic enhancement or prebreeding. Studies on character association and stability for tuber yield can be useful to the breeders to identify suitable genotypes for utilization in andigena breeding programme.

Separating the correlation coefficient of yield components into direct and indirect effects can be used to understand the exact association. Consistency over a number of environments is also a valuable asset. Hence an investigation was undertaken to estimate correlations between characters and their direct and indirect effects on yield and to evaluate tuber yield and phenotypic stability for yield in some andigena genotypes.

MATERIALS AND METHODS

The experimental material comprised 30 andigena genotypes. The genotypes were planted in 3 replications over 4 nutritional environments in randomized block design.

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Fertilizer dose of 120 kg N, 35.2 kg P and 83.0 kg K/ha in 1995-96 crop season constituted environment first (E_1). The second (E_2), third (E_3) and fourth (E_4) environment in 1996-97 crop season were created by applying different amounts of N, P, K, namely E_2 , 120 kg N, 35.2 kg P, 83.0 kg K/ha; E_3 , 150 kg N, 44.0 kg P, and 103.7 kg K/ha; E_4 , 180 kg N, 52.8 kg P and 124.4 kg K/ha. The andigena genotypes included was 'JEX/A 7', 'JEX/A 30', 'JEX/A 44', 'JEX/A 95', 'JEX/A 199', 'JEX/A 318', 'JEX/A 430', 'JEX/A 459', 'JEX/A 514', 'JEX/A 516', 'JEX/A 522', 'JEX/A 541', 'JEX/A 681', 'JEX/A 715', 'JEX/A 717', 'JEX/A 764', 'JEX/A 798', 'JEX/A 805', 'JEX/A 855', 'JEX/A 874', 'JEX/A 875', 'JEX/A 934', 'JEX/A 1048', 'JEX/A 1102', 'JEX/A 1152', 'JEX/A 1205', 'JEX/A 1209', 'JEX/B 998', 'JEX/B 2814', and 'EX/A 680-16'. The plot size for each genotype in each environment consisted of a single row of 12 tubers with 60 cm spacing between row to row and 20 cm spacing between plants. Dehaulming was done 90 days after planting. Data were taken on total tuber yield/plot in all the 4 environments. Data on plant height, number of shoots, number of leaves, haulm (top) weight, leaf area index and number of tubers were recorded at 90 days after planting in 3 environments, namely E_2 , E_3 , and E_4 . Data from these 3 environment were used to estimate phenotypic correlation coefficients and their direct and indirect effects (Dewey and Lu 1959). Pooled and stability analyses were done as suggested by Eberhart and Russel (1966) and Perkins and Jinks (1968). Both the models used in analysis are

Table 1 Correlation coefficients amongs eight characters in Andigena potato

Characters	Environment	No. of leaves	Haulm weight (g)	No. of shoots	Leaf area index	Mean tuber weight (g)	No. of tubers	Tuber yield (g)
Plant height (cm)	E ₁	0.0510	0.1818	0.03654**	0.0124	0.0937	0.0094	0.0785
	E ₂	0.0166	0.2803**	0.2719**	-0.1469	-0.0369	-0.1104	-0.1127
	E ₃	0.0500	0.2506*	0.1914	0.0100	0.0075	-0.0701	0.0493
No. of leaves	E ₁		0.0269**	0.1839	0.4004**	-0.0872	0.4002**	0.1497
	E ₂		0.3114**	0.3906**	0.1973	0.0615	0.3427**	0.2201*
	E ₃		0.2835**	0.5818**	0.1552	-0.0159	0.3997**	0.1788
Haulm weight (g)	E ₁			0.3131**	0.5045**	0.4289**	0.3076**	0.7024**
	E ₂			0.3701**	0.4215**	-0.0185	0.5042**	0.3166**
	E ₃			0.3077**	0.4767**	-0.0719	0.5170**	0.2981
No. of shoots	E ₁				-0.0717	-0.0934	0.4781**	0.2341*
	E ₂				-0.0546	-0.1314	0.3572**	0.1543
	E ₃				0.0000	-0.0647	0.3430**	0.2376*
Leaf area index	E ₁					0.4578**	0.3242**	0.6656**
	E ₂					0.5406**	0.2679**	0.7496**
	E ₃					0.5115**	0.3419**	0.7688**
Mean tuber weight (g)	E ₁						-0.3330**	0.7919**
	E ₂						-0.3667**	0.8066**
	E ₃						-0.4069**	0.7823**
No. of tubers	E ₁							0.2258*
	E ₂							0.1249
	E ₃							0.1902

*Significant at $P=0.05$, ** significant at $P=0.01$

associated with each other so that mean and squared deviation from regression (Sd_1^2) are identical and the regression coefficient (B_1) of the Perkins-Jinks model is equivalent to $b_1 - 1/b_1$, b_1 being the regression coefficient of Eberhart -Russel model. Consequently the ranking pattern of the genotypes under Perkins-Jinks model will be similar to the pattern obtained with Eberhart - Russel model.

RESULTS AND DISCUSSION

Correlation and path analysis

Genotypic differences were highly significant for all the characters indicating there was high degree of diversity in material for various characters. The more reliable character association is one which is consistent across environments. Hence, only those character associations which were consistent across 3 environments were considered for drawing conclusions. The estimate of correlation coefficient among 8 characters are given in Table 1. Association analysis indicated that haulm weight was significantly and positively correlated with number of shoots, number of leaves, leaf area index, number of tubers and tuber yield. There are reports of positive correlation of haulm weight with tuber number (Sharma 1990, Singh and Singh 1987) and tuber yield (Sharma 1990). The leaf area index had significant and positive relationship with mean tuber weight, number of tubers and tuber yield. Previous investigators also reported increase in tuber number (Lemage and Caesar 1990, Kumar *et al.* 1991) and tuber yield (Singh and Singh 1987, Lemage and Caesar 1990, Kumar *et al.* 1991)

with increase in leaf area in tuberosum potatoes. Lemage and Caesar (1990), however, reported the significant and negative correlation of leaf area with mean tuber weight. Mean tuber weight had significant and positive relationship with tuber yield and significant and negative correlation with number of tubers. This is in agreement with the findings of several workers including Lemage and Caesar (1990). Correlation coefficients shows that number of tuber was positively related to number of leaves, haulm weight, leaf area index and negatively to mean tuber weight. A large number of leaves/plant and increased haulm weight led to increase in number of tubers plant. Number of tubers was not significantly correlated with tuber yield in andigena potato. This is in contrast to the earlier findings in tuberosum potatoes (Sidhu and Pandita 1979, Sidhu *et al.* 1980, Singh and Singh 1987, Sharma 1990, Lemage and Caesar 1990, Kumar *et al.* 1991). This disagreement, among other factors, could be attributed to genotypic differences. Tuber yield was significantly correlated with haulm weight, leaf area index and mean tuber weight. Results showed that mean tuber weight is more important yield determinant than number of tubers in andigena potato. Birhman and Verma (1986) and Birhman and Kang (1993) also found mean tuber weight to be more important than number of tubers in determining yield in tuberosum potato. However, some investigators had reported tuber number to be more strong yield determinant than mean tuber weight in tuberosum potato (Sidhu and Pandita 1979, Sidhu *et al.* 1980, Lemage and Caesar 1990. Maris (1988) and Lynch and Kozub (1991) observed that

Table 2 Direct and indirect effects in *Andigena* potato

Character	Environment	Plant height (cm)	No. of leaves leaves	Haulm weight (g)	No. of shoots	Leaf area index	Mean tuber weight (g)	No. of tubers
Plant height (cm)	E ₁	-0.0792	-0.0028	0.0333	0.0493	0.0017	0.0730	0.0032
	E ₂	-0.0806	-0.0014	0.0181	0.0477	-0.0206	-0.0337	-0.0423
	E ₃	0.0283	-0.0067	0.0011	0.0445	0.0025	0.0061	-0.0264
No. of leaves	E ₁	-0.0040	-0.0554	0.0600	0.0248	0.0553	-0.0680	0.1370
	E ₂	-0.0013	-0.0821	0.0201	0.0685	0.0227	0.0561	0.1312
	E ₃	0.0014	-0.1348	0.0012	0.1353	0.0381	-0.0128	0.1504
Haulm weight (g)	E ₁	-0.0144	-0.0181	0.1834	0.0422	0.0697	0.3342**	0.1053
	E ₂	-0.0226	-0.0256	0.0646	0.0649	0.0591	-0.0168	0.1930
	E ₃	0.0710	-0.0382	0.0042	0.0716	0.1171	-0.0581	0.1945
No. of shoots	E ₁	-0.0290	-0.0102	0.0574	0.1348	-0.0099	-0.0728	0.1637
	E ₂	-0.0219	-0.0321	0.0239	0.1753	-0.0077	-0.1199	0.1367
	E ₃	0.0054	-0.0784	0.0013	0.2326*	0.000	-0.0523	0.1290
Leaf area index	E ₁	-0.0010	-0.0222	0.0925	-0.0097	0.1382	0.3567**	0.1110
	E ₂	0.0118	-0.0162	0.0272	-0.0096	0.1403	0.4934**	0.1025
	E ₃	0.0003	-0.0209	0.0020	0.000	0.2457*	0.4131**	0.1286
Mean tuber weight (g)	E ₁	-0.0074	0.0048	0.0787	-0.0126	0.0633	0.7792**	-0.1140
	E ₂	0.0030	-0.0050	-0.0012	-0.0230	0.0759	0.9127**	-0.1557
	E ₃	0.0002	0.0021	-0.0003	-0.0151	0.1257	0.8076**	-0.1380
No. of tubers	E ₁	-0.0007	-0.0222	0.0564	0.0644	0.0448	-0.2595*	0.3425**
	E ₂	0.0089	-0.0282	0.0326	0.0626	0.0376	-0.3714**	0.3827**
	E ₃	-0.0020	-0.0539	0.0022	0.0798	0.0840	-0.2961**	0.3762**

Residual (E₁)=0.0677, residual (E₂)=0.0740, residual (E₃)=0.0723*Significant at $P=0.05$, ** significant at $P=0.01$

while tuber number was more important for determining tuber yield in some of the progenies and environments, it was the mean tuber weight that was more important for tuber yield determination in other genotypes and environments. Plant height, number of leaves and number of shoots were also found to have no clear relationship with tuber yield.

Knowledge of correlation alone does not reveal the real picture of dependence of one character on other. Sidhu and Pandita (1979), Singh (1987), Singh and Singh (1987), Maris (1988), Lemaire and Caesar (1990), Kumar *et al.* (1991), Dhal and Acharya (1992) and Bihman and Kang (1993) studied correlation between yield and its components in potato. However, limited information on their direct and indirect effects on yield is available (Sidhu *et al.* 1980, Bihman and Verma 1986, Sharma 1990). Direct and indirect effects of different characters on tuber yield are presented in Table 2. Mean tuber weight had highest positive and significant effect on yield. The other character having direct positive and significant effect was number of tubers. The usefulness of these two characters in selection for tuber yield in tuberosum potato has also been reported by Sidhu *et al.* 1980. The number of tubers, however, had significant and negative indirect effect on tuber yield via mean tuber weight. This indirect negative effect is largely responsible for nonsignificant correlation of tuber number with tuber yield. Leaf area index was having significant and positive indirect effect on tuber yield via mean tuber weight. With increase in leaf area index, it is expected that there will be

more assimilate available and bigger will be the size of tubers resulting in increased mean tuber weight and tuber yield. The low value of residual factors indicate that most of the yield components has been taken into consideration.

From the total correlation it appears that haulm weight, leaf area index and mean tuber weight influences tuber yield. However, path analysis showed the importance of number of tubers and mean tuber weight which had significant direct effect and leaf area index which showed high indirect effect via mean tuber weight. The apparent conflict between two analyses arises largely from the fact that two methods measures different things (Dewey and Lu 1959). While correlation simply measure mutual association without regard to causation, path analysis specifies the causes and measures their relative importances. Consistency of associations across environments varying in fertility levels add to their reliability. It can be concluded that mean tuber weight, number of tubers and leaf area index are the most important tuber yield contributing characters in *andigena* potatoes.

Stability analysis

The results of analysis of variance over 4 environments showed that the genotypes and environment were significantly different among themselves. Genotype $\times$ environment interaction was significant. Genotype $\times$ environment interaction for tuber yield in tuberosum potato has been reported to be significant by a number of workers

Table 3 Stability parameters of andigena genotypes

Genotype	Mean	b_i	B_i	Sd_i^2
'JEX/A 7'	87.3±11.2	0.60	0.40	—37.83
'JEX/A 30'	341.4±29.3	1.54	0.54	510.04
'JEX/A 44'	363.4±35.4	1.76*	0.76*	1 541.38**
'JEX/A 95'	177.7±20.2	1.05	0.05	263.84
'JEX/A 199'	276.3±26.2	1.36	0.36	525.11
'JEX/A 318'	240.0±14.9	0.80	—0.20	11.23
'JEX/A 430'	58.2±14.9	0.78	—0.22	89.49
'JEX/A 459'	217.3±14.3	0.65	—0.35	317.19
'JEX/A 514'	95.2±16.5	0.87	—0.13	92.04
'JEX/A 516'	80.2±12.8	0.57	—0.43	246.33
'JEX/A 522'	109.1±18.2	0.95	—0.05	172.35
'JEX/A 541'	418.3±12.9	0.68	—0.32	25.02
'JEX/A 681'	132.9±15.6	0.72	—0.28	356.38
'JEX/A 715'	215.1±20.2	1.01	0.01	425.39
'JEX/A 717'	213.5±27.4	1.49	0.49	190.02
'JEX/A 764'	246.7±17.5	0.94	—0.06	43.07
'JEX/A 798'	292.2±29.1	0.96	—0.04	3 244.28**
'JEX/A 805'	283.2±26.4	1.18	0.18	1 409.64**
'JEX/A 855'	314.3±20.9	0.76	—0.24	1 424.62**
'JEX/A 874'	172.9±13.2	0.72	—0.28	—40.37
'JEX/A 875'	101.6±10.9	0.58	—0.42	—32.07
'JEX/A 934'	176.8±17.6	0.93	—0.07	112.17
'JEX/A 1048'	197.5±13.8	0.74	—0.26	—13.09
'JEX/A 1102'	224.6±18.3	1.00	0.00	1.10
'JEX/A 1152'	207.1±13.0	0.70	—0.30	—29.94
'JEX/A 1205'	285.6±31.2	1.49	0.49	1543.19**
'JEX/A 1209'	239.3±37.5	2.04**	1.04**	422.42
'JEX/B 998'	528.7±18.0	0.98	—0.02	33.55
'JEX/B 2814'	128.2±22.6	1.05	0.05	854.12*
'EX/A 680-16'	188.2±19.7	1.11	0.11	—90.68
(P=0.05) 37.9				

*Significant at $P=0.05$, **Significant at $P=0.01$,

(Pandita and Sidhu 1979, Kang and Birhman 1990, Singh *et al.* 1994). Both linear and nonlinear components contributed towards genotype $\times$ environment interaction. Estimates of stability parameters, namely deviation mean square (Sd_i^2), regression coefficient (b_i and B_i) and mean (M) are given in Table 3. The deviation from regression was significant for 6 genotypes, namely, 'JEX/A 44', 'JEX/A 798', 'JEX/A 805', 'JEX/A 855', 'JEX/A 1205' and 'JEX/B 2814'. The regression coefficients (b_i) were significantly more than unity for 2 genotypes, namely 'JEX/A 44' and 'JEX/A 1209'. Genotype with high mean performance, regression coefficient approaching one and low deviation mean square was considered a stable genotype which could be expected to perform uniformly well over variable environments. The maximum stability for tuber yield was exhibited by the genotype 'JEX/B 998' followed by 'JEX/A 541', 'JEX/A 199', 'JEX/A 764', 'JEX/A 318', 'JEX/A 1102', 'JEX/A 459', 'JEX/A 715', 'JEX/A 717' and 'JEX/A 1152' respectively.

These 11 genotypes hold considerable promise for

evolving high yielding andigena genotypes. These genotypes may perform well in their crosses with tuberosum genotypes in potato breeding programme. Rest of the genotypes were however, either above average responsive ($b_i > 1$), not associated with least deviation from regression coefficient ($Sd_i^2 \neq 0$) or poor yielder.

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Economical management of loose smut of wheat with propiconazole

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ABSTRACT

A study was conducted during 1994-95 and 1995-96 to work out a cheaper seed treatment for the control of loose smut of wheat with triazole fungicides, viz tebuconazole (Raxil), difenoconazole (Score and Dividend) and propiconazole (Tilt). Of these the wet treatment with Tilt by dipping the seed in 0.01% solution for 6 hr and dry seed treatment with Raxil (0.1%) were most effective. The former proved quite economic, costing just Rs 15.00/100 kg of seed as compared to Rs 188.00 with carboxin (Vitavax).

Key words : loose smut, wheat, propiconazole

Loose smut caused by an internally seed borne fungus *Ustilago tritici* (Pers.) Rostr. is one of the major diseases of wheat in the northern hill zone, north-western plain zone and north-eastern plain zone of the country causing 2-3 % annual losses in yield every year (Joshi *et al.* 1984). Up to 45.7% incidence of this disease in some remote areas of Kullu valley in Himachal Pradesh has been reported (Sood 1988). Since most of the recommended wheat cultivars are susceptible, the disease can be effectively controlled by chemical seed treatment. However, the higher cost of seed treatment with the presently recommended fungicides (Basant Ram and Arora 1986) is the limiting factor for their adoption by the poor farmers of the hilly region. The study reports a much cheaper seed treatment for effective management of loose smut.

MATERIALS AND METHODS

Four triazole fungicides, viz tebuconazole (Raxil 2DS), difenoconazole (Dividend 30 WS and Score 10 WP) and propiconazole (Tilt 25 EC) were evaluated in comparison to carboxin (Vitavax 75 WP) as seed treatments by using loose smut infected seed of wheat cultivars 'WL 711' and 'HD 2285'. This seed was developed by artificial inoculation using the Go go method (Joshi *et al.* 1982). Field trials consisting of 5 rows of 1.5 m length in a randomized block design with 3 replications were conducted during winter (*rabi*) 1994-95 and 1995-96. On farm trials with selected effective concentrations for further validating the findings were conducted during *rabi* 1996-97. The test fungicides Raxil (0.025, 0.05 and 0.1%),

Dividend (0.025, 0.05, 0.075 and 0.1%) and Score (0.1, 0.2, 0.3 and 0.4%) were applied as dry seed treatments, whereas Tilt (0.0025, 0.005 and 0.01%) was used as wet seed treatment by dipping infected seed for 6 hrs. Dividend (0.075%) and Score

Table 1 Comparative efficacy of triazole fungicides in controlling loose smut of wheat

Treatment	Concentration (%)	Per cent loose smut*		
		1994-95 'WL 711'	1995-96 'WL 711'	'HD 2285'
Raxil (D)	0.025	0.09(1.20)	0.76(4.97)	0.76(4.92)
	0.050	0.23(2.32)	0.80(5.10)	0.09(1.16)
	0.100	0.08(1.14)	0.19(1.63)	0.00(0.29)
Score(D)	0.100	1.89(7.80)	2.43(8.92)	0.55(3.39)
	0.200	0.51(4.07)	2.32(8.57)	0.47(3.76)
	0.300	0.41(3.65)	0.97(5.41)	0.26(2.45)
Score(S)	0.400	0.35(2.14)	1.29(6.29)	0.18(1.58)
	0.200	0.37(3.48)	0.33(2.09)	0.26(2.49)
Dividend(D)	0.025	0.22(1.76)	2.09(8.24)	0.73(4.87)
	0.050	0.43(3.18)	2.19(8.38)	0.67(3.83)
	0.075	0.31(2.59)	1.46(6.94)	0.11(1.27)
Dividend(S)	0.100	0.00(0.29)	1.33(6.62)	0.08(1.14)
	0.075	0.13(1.37)	0.61(3.51)	0.00(0.29)
Tilt(W)	0.0025	2.09(8.22)	3.64(10.98)	1.32(6.32)
	0.0050	0.97(5.53)	1.14(6.05)	0.26(2.48)
	0.0100	0.34(2.74)	0.45(3.24)	0.05(1.47)
Vitavax (D)	0.250	1.23(6.22)	0.64(4.52)	0.18(1.58)
Control	Dry	6.11(14.28)	14.56(22.43)	5.75(13.82)
	Wet	6.16(14.29)	13.40(21.47)	6.21(14.36)
SE		1.41	1.39	1.54
CD (P=0.05)		2.86	2.82	3.13

* Mean of three replications

Figures in parentheses are angular transformed values
D, Dry; W, wet; S, slurry

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Table 2 Efficacy of triazole fungicides in controlling loose smut of wheat in the on-farm trials

Treatment	Concentration (%)	Per cent loose smut*	
		'WL 711'	'HD 2285'
Raxil (D)	0.05	0.10(1.43)	0.31(2.39)
Dividend (D)	0.10	1.40(6.62)	1.45(5.96)
Tilt (W)	0.01	0.00(0.29)	0.00(0.29)
Vitavax (D)	0.25	2.78(9.55)	0.96(3.84)
Control	Dry	42.28(40.55)	33.28(35.12)
	Wet	35.25(36.40)	33.76(35.48)
SE		1.47	2.27
CD (P=0.05)		3.13	4.83

* Mean of three replications

Figures in parentheses are angular transformed values

D, Dry; W, wet

(0.2%) were also applied as slurry treatments. The untreated loose smut infected dry seed and seed dipped in plain water for 6 hr served as control. In case of wet seed treatment, the seed was shade-dried before sowing. Loose smut percentage in each treatment was worked out after flowering by counting the smutted and healthy spikes/plot.

RESULTS AND DISCUSSION

During 1994–95, when seed infection in cultivar 'WL 711' was low (6.11 and 6.16%), all the fungicidal treatments except Score (0.1%) were superior to Vitavax (0.25%) in controlling loose smut (Table 1). Raxil and Dividend (0.1%) were most effective giving almost complete control. Slurry treatment with Score (0.2%) and Dividend (0.075%) gave better control than their dry seed treatment at the same application rates. During *rabi* 1995–96, in 'WL 711' where control showed relatively higher loose smut infection (14.56 and 13.40%), Raxil (0.1%), Tilt (0.01%) and slurry treatments with Dividend (0.075%) and Score (0.2%) gave better control of the disease than Vitavax. However, in 'HD 2285' where seed infection was relatively less, Raxil (0.05 and 0.1%), Dividend (0.075 and 0.1%), Tilt (0.01%) and Dividend slurry (0.075%) proved superior to Vitavax (0.25%).

During 1996–97, when seed infection was very high in the on-farm trials both with cultivars 'WL 711' and 'HD 2285', Tilt (0.01%) proved to be the most effective treatment (Table 2) giving a complete control of the disease followed by Raxil (0.05%) and Dividend (0.1%).

Thus all the triazole formulations gave better control of loose smut as compared to carboxin. Propiconazole (Tilt 25 EC) @ 0.01%, applied as wet seed treatment, proved more effective over the previously recommended fungicide Vitavax in disease control. Moreover, this seed treatment was quite cheaper, costing about Rs 15/100 kg of seed, than the earlier recommended treatment of Vitavax costing about Rs 188/100 kg of seed. Tebuconazole (Raxil) @ 0.05% was next to propiconazole in efficacy and has recently been found quite promising over previously recommended fungicides (Aggarwal *et al.* 1993, Sinha and Singh 1996).

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Yield loss due to leaf spot and pod blight disease complex in rainfed blackgram (*Phaseolus mungo*) dominated by *Cercospora cruenta* relative to meteorological parameters

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ABSTRACT

A field experiment conducted during 5 wet seasons during 1993-97 over 6 environments each year to investigate the yield loss relationship of leaf spot and pod blight disease complex with mean weekly weather parameter at pre-flowering and post-flowering revealed that leaf spot and pod blight disease complex dominated by *Cercospora cruenta* Sacc. The 1 July sown gave highest grain yield of 'PDU 1' blackgram both in protected (624 kg/ha) and unprotected (393 kg/ha) plots. The interaction effect of sowing dates and plant protection was not significant. The relationship of this interaction at pre-flowering with maximum temperature (30.25°C) was negative and significant (-0.982*) indicating that rise in temperature would result in decrease in yield. Contrarily, maximum relative humidity of 90.70% (+0.931**) and rain frequency of 2.95 days/week (+0.786**) had significant positive correlation. Interestingly, all the parameters were significantly and negatively correlated at post-flowering crop period indicating that a small degree of rise or fall in these parameters would significantly reduce the yield both under protected and unprotected disease management. Reduced rainfall and its frequency at post-flowering seemed to contribute to low yield of blackgram with delayed sowing.

Key words : leaf spot, pod blight disease, *Cercospora cruenta*, blackgram, *Phaseolus mungo*

Leaf spot and pod blight disease complex in blackgram (*Phaseolus mungo* L.) dominated by *Cercospora cruenta* Sacc. comprises major constraint in stabilizing high yield (Bhardwaj and Thakur 1991). Environment during the crop season and eventuality of occurrence of pests are well known to destabilize the yield of different crops to varying degree in an agroclimate. A perusal of literature revealed that the information on the yield loss due to leaf spot and pod blight disease complex influenced by occurrence of *Cercospora cruenta* Sacc., *C. canescens* Ellis and Mart., *Colletotrichum dematium* (Pers.) ex. Fr.) Grove f. sp. *truncatum* and *Ascochyta phaseolorum* Sacc. in relation to prevailing weather parameters and the adoption of plant protection against dominant pathogens is lacking. Therefore, an attempt was made to assess the yield loss relationship of leaf spot and pod blight disease complex in rainfed blackgram with environmental factors and plant protection over different environments.

MATERIALS AND METHODS

A field experiment was conducted in randomized complete block design with 3 replications for 5 rainy seasons (*kharif*) 1993-97 at the research farm, Bajaura (1 090 m above MSL).

'PDU 1' blackgram was raised at a low spacing of 30 cm and plant spacing of 10 cm under 6 environments at weekly interval from mid-June (17 June onwards) comprising protected and unprotected plots. Recommended dose of fertilizers (15 kg N and 27 kg P/ha) was applied. Protected plots were sprayed with mancozeb 75 WP (Dithane M-45 @ 2.5 g/litre) at 15 day interval starting sprays from 45th day of sowing (ie at onset of flowering). Data were recorded on grain yield after harvest of the crop under each sown date at appropriate stage. The data on the effect of sowing dates and plant protection on yield were statistically analysed by performing Duncan's Multiple Range Test. Data on meteorological parameters was obtained from meteorological observatory installed at approximately 10 m away from the field of experiment. The relationship of mean weekly weather parameters, viz maximum temperature, minimum temperature, maximum relative humidity, rainfall and rainy days at pre-flowering (6 weeks after germination of the crop) and post-flowering (5 weeks subsequent to 6 weeks at pre-flowering stage) and grain yield over interaction of sown dates × plant protection was calculated by adopting standard procedures.

RESULTS AND DISCUSSION

Effect of sowing date and plant protection on yield

Data of sowing dates at weekly interval showed that delay

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Table 1 Yield loss assessment under different sowing dates and plant protection against leaf spot and pod blight disease complex in rainfed blackgram dominated by *Cercospora cruenta*

Environment at weekly interval	Yield (kg/ha)* under disease(s) protection		Dates mean	Yield loss	
	Protected	Unprotected		(kg/ha)	(%)
17 June	529 b	348 ab	439 b	181**	52.01
24 June	515 b	372 a	443 b	143**	38.44
1 July	624 a	393 a	509 a	231**	58.78
8 July	443 c	258 c	351 c	185**	71.70
15 July	478 bc	371 z	424 b	107**	28.84
22 July	432 c	303 bc	367 c	130**	42.90
P mean	504 a	341 b	422	163	48.78

**Significant at $P=0.01$

*Mean yield of blackgram over 5 years (1993–97)

Dates $\times$ plant protection interaction, non-significantIn a column, means followed by a common letter are not significantly different at $P=0.05$ by DMRT.

in sowing beyond 1 July reduced grain yield significantly. Scheduled plant protection with mancozeb 75 WP significantly stabilized high yield to the extent of 22.38–41.76% under different sowing dates. The 1 July sown gave highest yield (624 kg/ha) in protected as well as in unprotected (393 kg/ha) plots among 6 sowing dates over 5 years (Table 1). No significant relationship between sowing dates and plant protection was observed indicating that these 2 factors independently influenced the grain yield to a greater extent. Highest yield losses were recorded in 1 July (58.78%) followed by 8 July (71.11%) sown date. It indicated that pre- and post-flowering weather parameters during these 2 dates were congenial for disease of leaf spot and pod blight dominated by *Cercospora cruenta*. This confirms that the pathogen is predominant in early crop season and favoured relatively by higher maximum temperature ranging up to 35°C (Sood *et al.* 1981). It is also evident from comparatively higher level of disease control in delayed sowing beyond 20 July. However, plant protection stabilized higher yield in all environments indicating that protection also afforded management of other pathogens associated with leaf spot and pod blight disease complex of which *Colletotrichum dematium* f sp *truncatum* was observed during early sown dates dominated by *Cercospora cruenta* and *Cercospora canescens* dominated by *Ascochyta phaseolorum* in delayed sowing beyond 8 July.

Relationship of sowing dates and plant protection with weather factors

The relationship of interaction of dates $\times$ plant protection with yield and weekly weather parameters prevailing at pre- and post-flowering stages was negative and significant, whereas maximum relative humidity (+0.93%**), and rainy days (+0.786**) had significant positive correlation (Table 2). This indicated that increase in maximum temperature at pre-flowering stage would amount to reduced yield, whereas high maximum relative humidity and frequency of rains will favour blackgram yield both in protected and unprotected conditions. During the period, the mean weekly maximum temperature of 30.25°C, maximum relative humidity of 90.70% and 2.95 rainy days prevailed. This indicated that temperature below 30.25°C coupled with relative humidity above 90.70%, rainfall above 30.01 mm and rain frequency of above 2.95 days/ week would be congenial for higher production.

The maximum temperature (–0.621*), minimum temperature (–0.973**), maximum relative humidity (–0.604*), rainfall (–0.949**) and rainy days (–0.893**) had significant and negative correlation at post-flowering. It indicated that a slight rise or fall in the weather parameters under study with delay in planting period influence the blackgram yield to a greater extent both with and without management of leaf spot and pod blight disease complex. The maximum temperature of

Table 2 Relationship of dates $\times$ plant protection with yield and mean weekly environmental factors at pre- and post-flowering stages of blackgram over 5 wet seasons (1993–97)

Crop stage	Yield	Maximum temperature (°C)	Minimum temperature (°C)	Maximum relative humidity (°C)	Rainfall (mm)	Rainy days
Pre-flowering	–0.282	–0.982** (30.25)	–0.268 (20.76)	+0.931** (90.70)	–0.496 (31.01)	+0.786** (1.95)
Post-flowering	–0.282	–0.621* (29.34)	–0.973** (17.66)	–0.604* (90.50)	–0.949** (13.91)	–0.893** (2.88)

29.34°C, minimum temperature of 17.66°C, maximum relative humidity of 90.50%, rainfall (13.91 mm) and rainy days to the extent of 2.88 days/week prevailed at post-flowering (Table 2). The prevalence of above parameters revealed that reduction in level of atleast 3 parameters, viz minimum temperature, rainfall and its frequency, were responsible for decreased yield and pressure of leaf spots and pod blights disease complex dominated by *Cercospora cruenta* in blackgram. These 3 factors were also strongly correlative at higher value of relationship than maximum temperature and maximum relative humidity. It appeared that frequency of rainfall influences the grain yield since it brings changes in all other parameters during crop season. Since highest yield losses were recorded in 8 July, the occurrence of maximum temperature of 29.42 °C, minimum temperature of 17.46°C, maximum relative humidity of 90.27%, rainfall of 13.40 mm and 1.85 rainy days at post-flowering crop season seemed to be congenial for the development of leaf spot and pod blight disease complex dominated by *C. cruenta*.

It is concluded that 1 July is the optimum sowing date for obtaining higher yield of blackgram both with and without under management of leaf spot and pod blight disease complex dominated by *C. cruenta*. Comparatively higher rainfall above 13.40 mm/week and its frequency of more than 1.85 rainy days at post-flowering period coupled with higher temperature above 17.46°C would help in increasing yield of blackgram as well as avoidance of losses expected to be caused by leaf spot and pod blight disease complex.

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Effect of honeybee (*Apis cerana indica*) pollination on seedset and yield of buckwheat (*Fagopyrum esculentum*)

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ABSTRACT

An experiment was conducted during 1993–95 to investigate the effect of honeybee (*Apis cerana indica*) on seed set and yield of buckwheat (*Fagopyrum esculentum* L.). Buckwheat spike/plant, seeds/spike, percentage of filled seed and weight of grain were found to be higher in bee pollinated treatments over open and self pollination. There was significant difference in yield in bee pollinated treatment over open and without bee pollinated treatments. The foraging activity of *A. indica* showed maximum number was recorded during 15.00 to 16.00 pm having 0.8 foragers on the crop.

Key words : buckwheat, *Apis cerana indica*, pollination effect

Buckwheat (*Fagopyrum esculentum* L.) is one of the important cereal crops belonging to the family polygonaceae and is indigenous to Asia. It is grown in several states of India particularly in the drought areas. The crop is also grown in Assam and is getting momentum both in acreage and production. Grain of this crop is important source of high quality protein and carbohydrates for which it is mixed with wheat flour and used for gluten free diets. Mostly flowers attract bees for their nectar source and thereby enhances pollination. As a cross pollinated crop, the effect of insect foragers more particularly honeybees have not so far been exclusively studied in India. Hence, an attempt has been made to evaluate the effect of *Apis cerana indica* in the pollination, seed set and yield of buckwheat. In Russia, buckwheat has been considered as main source of honey supply (Kushnir 1976) and works on biological characterization of bees and their role on pollination of buckwheat were made.

MATERIALS AND METHODS

The experiment was conducted in the experimental apiary of the University, Jorhat for successive 2 years, ie 1993–94 and 1994–95. 'Local' buckwheat variety was grown as per package of practices of the University. The floral biology, particular floral taxonomy was studied. The foraging activity of different insect foragers was recorded at an hour interval from 7.00 to 16.00 hr of the day at weekly interval during flowering season of the crop. For determining the effect of *A. cerana indica*

pollination on seed set and yield of buckwheat, the treatments like bee pollination, open pollination and without bee pollination were taken and the treatments were replicated thrice. In the bee pollination treatment 1000 young *A. cerana indica* worker bees containing in the nucleus bee hive was placed in the treated plots and was covered by the nylon cage at 25% flowering of the crop. At the initiation of flowering, the without bee pollination plot was covered by nylon cage without allowing any insect foragers. Open pollination plot was left open for insect pollination. Ten plants from each treatment were randomly selected and the number of spike/plant was recorded similarly 10 spikes/plant were randomly selected from each treatment and number of seeds/spike were counted. The percentage of filled seeds in the spikes was worked out on the basis of matured and chaffy seeds contained in the spike. At harvest, weight of 1000 seeds and yield/plant were taken from each treatment and converted in to hectare.

RESULTS AND DISCUSSION

Floral biology

Buckwheat plant has numerous florets which bear spike inflorescence. Flowers are bisexual, regular, hypognathous, cyclic, staminate with 508 stamens, gynoeceum syncarpous, ovary unilocular with 2–3 styles, sepals, 5, gamosepalous and zygomorphic. Petals–5, polypetalous. The dehiscence occurs in the morning hours. Anthers are small, pink in colour, stigma furcated with 45 lobes. Fruit is a triangular nut, greyish to black in colour and is called achene.

Foraging activity

Foraging activity of *A. cerana indica* on buckwheat was

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Table 1 Foraging activity of *A. cerana indica* on buckwheat

Time of observation	Foragers/m ² /min	Returning m ² /min	Time spent/floret m ² /min	Florets visited/min
7.00–8.00 AM	4.6	2.8	1.8	20.6
8.00–9.00 AM	6.2	3.2	2.4	21.6
9.00–10.00 AM	9.22	6.2	3.2	22.8
10.00–11.00 AM	4.2	4.2	2.6	25.0
11.00–12.00 AM	2.4	2.8	2.6	23.4
12.00–13.00 PM	2.2	2.2	2.2	17.8
13.00–14.00 PM	1.6	1.8	1.8	14.8
14.00–15.00 PM	1.8	2.6	1.6	15.4
15.00–16.00 PM	0.8	2.8	1.0	9.4

Data are mean of 10 observations

Table 2 Effect of bee pollination on seed set and yield of buckwheat

Treatment	Spike plant	Seeds/spike	Filled seed (%)	Weight of 1000-seeds (g)	Yield (tonnes/ha)	Increase over without bee pollination (%)	Increase over open pollination (%)
Bee pollination	414.2	15.4	60.2	21.931	1.42	221.94	153.1
Open pollination	362.2	11.1	55.2	19.024	0.93	145.21	
Without bee pollination	300.0	9.4	43.6	19.036	0.64		
'F' test					38.28*		
CD (P=0.05)					1.69		

recorded for different hours from 7.00 to 16.00 hrs of the day during peak flowering. Table 1 showed that maximum number of 9.2 foragers at 15.00–16.00 hr. Maximum returning foragers (6.2/m²/min) and time spent (3.2 sec/floret) were also found in the same period indicating best time of foraging on the crop. The data revealed that foraging activity declined gradually during the evening hours of the day attaining minimum of 0.8 at 4.00 pm.

Foraging activity on buckwheat was reported by Rahman (1990) and Fesenko (1976). Roubic (1995) also included buckwheat as predominantly foraged by *Apis* spp.

Effect of bee pollination on seed set and yield

Bee pollinated plots showed better seed set and yield over open pollination and without bee pollination (Table 2). In bee pollination, the number of spikes/plant was 414.2 against 362.2 and 300.0 in open and without bee pollination. Similarly, number of seeds/spike was 15.4 against 11.1 and 9.4 in open and without bee pollination. The percentage of filled seeds was 60.2 in bee pollination with higher seed weight over open and without bee pollination.

The yield obtained from bee pollination treatment was found to have significant difference over without bee and open pollination. The per cent increase in yield of bee pollination and open pollination was 221.94 and 145.21 over without bee pollination. Bee pollination treatment also showed 153.1% increased yield over open pollination. Kushnir (1976) reported the significant increase of buckwheat yield due to honeybee pollination.

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Fertilizer requirement of wheat (*Triticum aestivum*) for pre-set yield targets in an Inceptisol of mid-western plain zone of Uttar Pradesh*

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Key words : fertilizer, wheat, Inceptisol

Soil testing as a tool for judicious fertilizer use is a well recognized practice all over the world which takes care of too little, too much or disproportionate application of nutrients. Fertilizer recommendation for pre-set yield target is refined technique particularly applicable under conditions of fertilizer resource constraint for most efficient use of fertilizer and soil nutrients (Ramamoorthy and Velayutham 1971). In this technique, the fertilizers are recommended separately for different fields separately on the basis of soil-test and are pre-set uniform yield targets depending upon the availability of fertilizer input. The efficiency of applied fertilizer nutrient and the nutrient already present in the soil is very much location-specific and calibrations are needed for every set of crop-soil-climate complex under optimum agronomic practices. Lack of information in respect of wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crop in an Inceptisol of Uttar Pradesh prompted the present investigation to be undertaken.

To calibrate the fertilizer prescription equations for pre-set yield target of wheat, an experiment was conducted at the research center of the University in Bijnore district of Uttar Pradesh. The soil was to the order Inceptisol and has been classified to be Typic Dystrochrept (Sharma 1993).

The experiment was conducted in 2 phases. In the first phase, the whole experimental plot (52 m × 48.5 m) was divided in 4 equal strips, soil fertility gradients were created by applying graded levels of fertilizers (N, P and K) and growing 'Rio' fodder sorghum (*Sorghum bicolor* C. Moench). A wide range of soil test values in respect of available nitrogen, phosphorus and potassium was created.

In the second phase, each of these 4 strips were subdivided into 28 plots and composite soil sample (0–0.15 m depth) from each plot was collected, dried, ground and passed through 2 mm sieve and analyzed for organic carbon (Walkley and Black 1954), available phosphorus (Olsen *et al.* 1954) and available potassium (Hanway and Heidal 1952). The yield and

nitrogen, phosphorus and potassium uptake response of 'Raj 3077' wheat to selected combinations of 5 levels of fertilizer nitrogen (0, 50, 100, 150 and 200 kg N/ha) 4 levels of fertilizer phosphorus (0, 22.0, 44.0 and 67.0 kg P/ha) and 3 levels of fertilizer potassium (0, 1.5 and 83.0 kg K/ha) with simultaneous variations in initial available soil nitrogen, phosphorus and potassium were studied. At harvest, plot-wise grain and straw yield were recorded. Samples of grain and straw were collected on the basis of maximum yield of treated and control plots. All the grain and straw samples (from treated and control) were analyzed using standard procedures.

The fertilizer prescription equation were worked out in conjunction with the yield levels, soil test values and fertilizer doses in the following manner.

$$F(\text{nutrient}) = [(YT \times A) - (STV \times B)] 100/C \dots \text{eqn 1}$$

where F(nutrient), fertilizer nutrient requirement (kg/ha); YT, grain yield target (tonnes/ha); A, total nutrient uptake (grain + straw to give 100 kg of wheat grain (kg); STV, soil test value; organic carbon; kg P₂O₅/ha+ and kg K₂O/ha; B, factor for contribution of nutrient from the soil (%) and C, fertilizer-use efficiency

$$B = \frac{\text{Total uptake of nutrient in control plot}}{\text{Soil test value of that nutrient in control plot}} \times 100$$

$$C = \frac{\text{Total uptake of nutrient in treated plot} - [STV \times B/100]}{\text{Fertilizer dose}} \times 100$$

With the help of soil and plant analysis and yield data, the basic data for targeted yield of wheat are given in Table 1. The data indicate that 2.28, 0.45 and 2.57 for N, P₂O₅ and K₂O respectively are required to produce 100 kg of wheat. The utilization efficiency of soil tests for N (organic carbon %), Olsen P₂O₅ and ammonium acetate extractable K₂O, were 32.58, 11.03 and 8.5 % respectively. The fertilizer-use efficiency was 72.34, 21.90 and 145.50 % for N, P₂O₅ and K₂O respectively.

*Short note

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Table 1 Basic data for calculating fertilizer doses for targeted yield of wheat

Particulars	Nitrogen	Phosphorus	Potassium
Nutrient required (kg) for the production of 100 kg of grain (NR)	2.28	0.45	2.57
Contribution from soil as percentage of its available nutrient (CS)*	32.58	11.03	8.50
Contribution from fertilizers as percentage of its available nutrient (CF)	72.34	21.90	145.50

*Soil test values : Organic carbon (Walkley and Black 1954), available phosphorus (Olsen *et al.* 1954) and available potassium (Hanway and Heidal 1952)

Table 2 Results of the verification trials with wheat at farmers fields

Location	Soil test values			Yield target (kg/ha)	Fertilizer nutrient added (kg/ha)			Actual mean grain yield obtained (kg/ha)	Yield deviation (%)
	Organic Carbon (%)	Average phosphorus (kg P ₂ O ₅ /ha)	Average potassium (kg K ₂ O/ha)		N	P ₂ O ₅	K ₂ O		
I	0.3	20	175	3000	81.0	51.5	42.6	2850	-5.0
				4000	112.5	72.0	60.3	3600	-10.0
				5000	144.6	92.5	70.0	4600	-8.0
II	0.5	30	225	3000	72.6	46.5	39.6	2750	-8.3
				4000	103.5	67.0	57.3	3700	-7.5
				5000	135.0	87.5	75.0	4500	-10.0
III	0.4	30	250	3000	76.5	46.5	38.1	2750	-8.3
				4000	108.0	67.0	55.8	3860	-5.0
				5000	139.5	87.5	73.5	4700	-6.0
IV	0.5	40	250	3000	72.0	41.5	38.1	2700	-10.0
				4000	103.5	62.0	55.8	3860	-5.0
				5000	135.0	82.5	73.5	4800	-4.0

The value of more than hundred for potassium is due to interaction effect of N and P and priming effect of K in the treated plots. Using these basic data (Table 1), the following simple fertilizer requirement equations for targeted yields of wheat were worked out.

$$\text{Fertilizer nitrogen (kg N/ha)} = 3.15YT - 45.04 \times (\text{O.C.}\%) \quad (\dots \text{eq 2})$$

$$\text{Fertilizer phosphorus (kg P}_2\text{O}_5\text{/ha)} = 2.05YT - 0.5 \times (\text{kg P}_2\text{O}_5\text{/ha}) \quad (\dots \text{eq 3})$$

$$\text{Fertilizer potassium (kg K}_2\text{O/ha)} = 1.77YT - 0.06 \times (\text{kg K}_2\text{O/ha}) \quad (\dots \text{eq 4})$$

The range of soil test values utilized was 0.3–0.7% organic carbon, 16.6–58.4 kg P₂O₅/ha and 188.3–278.4 kg K₂O/ha. These equations, therefore will be applicable normally only within these limits of soil test values and yield in mid-western plains of Uttar Pradesh.

The results of follow-up study in the succeeding year are given in Table 2. These multi-locational experiments were conducted to test the applicability of these equations at various places of mid-western plain area. The soils of various sites

were pre-tested and fertilizer doses computed from the eqn 2, 3 and 4 for different yield target and soil test values.

The actual yield levels obtained were within $\pm 10\%$ of the targeted yield levels. Therefore these equations could be used for making fertilizer recommendations for targeted yields of 'Raj 3077' wheat in an Inceptisol of Uttar Pradesh. The concept may prove useful in many other wheat growing areas in India.

ACKNOWLEDGMENT

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Irrigation scheduling in acid lime (*Citrus aurantifolia*) as affected by different soil moisture regimes*

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Key words : acid lime, evapotranspiration, irrigation scheduling, soil moisture distribution, water balance method

Acid lime (*Citrus aurantifolia* Swingle) is one of the important citrus fruit grown in over an area of 93 000 ha with average production of 7.46 lakh tonnes. Low productivity in citrus is largely due to neglect to irrigation scheduling. Although acid lime is hardy plant, it requires adequate soil-moisture during its critical growth stages. The acid lime orchards are not irrigated and scheduled as per the requirement adequately by the growers. The water requirement of citrus has been estimated at 40–45 inches/year under Florida conditions (Reitz 1968). The water requirement of grapefruit (Leyden *et al.* 1977), Shomouti orange (Moreshet *et al.* 1986) and Valencia orange (Smajstrla *et al.* 1986, Plessis 1988) were also studied under different location for improving the growth and fruit quality. The water requirement of young, mid-age and mature citrus trees under Nagpur conditions was 651.9, 849.0 and 997.3 mm/yr respectively (Ghadekhar *et al.* 1989). Kinnow mandarin of 6-years-age required 63.67–121.6 cm of water for the growth (Makhija *et al.* 1986). The highest biomass/plant was obtained when irrigation was scheduled at -0.05 MPa soil water potential.

The water requirement of 4-year-old young lemon plants required 7 400 m³/ha annually under Central Tajikistan condition. The effect of different levels of water-stress on yield and fruit quality of lemon tree indicated a high percentage of drop after the resumption of irrigation in the most stressed treatment (Barbera *et al.* 1988). The Verna lemon yield was higher in drip irrigated treatment (141–275 kg/tree/year) in comparison to flood irrigations, whereas the total soluble solids, acidity, sugars and juice percentage decreased in the treatments that used more water (Sanchez Blanco *et al.* 1989). Therefore it is essential to irrigate the acid lime trees with utmost care to the quantum and frequency of the irrigation. Hence, a study was to find out irrigation scheduling, soil-moisture distribution and evapo-

transpiration of acid lime under central Indian conditions. The field experiment was conducted during 1996–97 in a 0.52 ha acid lime plot located in the research farm of the Centre, Nagpur (21°09' N latitude, 79°22' E longitude, 311 m above mean sea level). The site is in sub-tropical climate with no summer rains. The average precipitation (June–Oct) in this area is about 900 mm. The acid lime plants were planted in August 1993 in the plot of 72 m × 72 m with 5 m × 5 m spacing. The soil is medium deep with an average depth of 55 cm underlain by parent material. The field capacity and permanent wilting point were 30.53 and 14.00 % respectively. The bulk density and available water content of the field under study were 1.19 g/cm³ and 16.53 % respectively.

The drip irrigation system was installed in early January 1994, and irrigation treatments were initiated in December 1996. The treatments consisted of irrigation at 6 % available water content (T₁), irrigation at 12 % available water content (T₂), irrigation at 25 % available water content (T₃), irrigation at 50 % available water content (T₄), irrigation equivalent to 0.6 Epan (on alternate days) (T₅) and irrigation equivalent to 0.6 CPE once in 3 days (T₆) with four replications in a randomized block design. The number of plants per unit was seven. The drip irrigation system was laid out in the field as per the statistical design and water-meters with control was installed for maintaining the flow of irrigation water to each treatment. The aluminum access tubes (50 mm dia) were also installed and the soil-moisture status was recorded continuously. The rainfall and evaporation was recorded from the agrometeorology division located in the research farm. The treatments of available soil water content were scheduled as the soil water content at 30 cm depth inside the rootzone reached to 34.8, 33.7, 31.1 and 26.3 % with 7.02, 14.04, 29.2 and 58.5 mm depth of irrigation respectively.

The treatments based on pan evaporation were scheduled at 0.6 CPE of 2 and 3 days. The quantity of irrigation water was worked out by considering the tree spread (150 cm during 1996) and irrigation was given accordingly. Soil water content in the

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Table 1 Treatmentwise depth of irrigation and quantity of irrigation

Treat- ment	Dec 96	Jan 97	Feb	Mar	Apr	May	June	Depth (mm) and irrigation quantity (litres)
T ₁	63.2* (9)	84.2 (12)	112.3(14)	140.4(20)	133.4(19)	140.4(20)	133.4(19)	807.3 (115) 44850
T ₂	56.2 (4)	98.3 (7)	140.4(10)	210.6(15)	196.5(14)	224.6(16)	196.4(14)	1123.2(80) 62400
T ₃	29.2 (1)	87.6 (3)	146.0 (5)	175.2 (6)	146.0 (5)	262.8 (9)	233.6 (8)	1080.4(37) 64000
T ₄		58.5 (1)	58.5 (1)	58.5 (1)	58.5 (1)	117.0 (2)	58.5 (1)	409.5(7) 22540
T ₅	57.7 (10)	59.8 (15)	100.6 (15)	178.0 (15)	164.8 (15)	196.3(15)	135.4(15)	892.6(100) 44166
T ₆	57.7 (7)	59.8(10)	100.6(10)	178.0(10)	164.8(10)	196.3(10)	135.4(10)	892.6(67) 4166

* Depth of irrigation in mm (no. of irrigations)

plant rootzone was monitored using subsurface Neutron moisture probe (model Troxler 4300, Soil moisture Santa Barbara, Calif). Aluminium access tubes were inserted to the depth of 70 cm within the tree basin and 70 cm apart from the trunk in between the two emitters. Soil-water measurement were taken up daily during December 1996–June 1997. The neutron probe was calibrated against gravimetric sampling for this particular field having the following calibration equation

$$Y = 0.0228x + 0.123 \quad (r = 0.95)$$

where, Y is ratio of actual counts to standard counts and X is soil moisture content (volume basis).

Irrigation scheduling and soil-moisture distribution in acid lime

The irrigation was scheduled when the soil-moisture

depleted to 6, 12, 25 and 50 % of available water content (16.53 %) below field capacity. The depth of irrigation as well as number of irrigation increased from December to June except in April due to seasonal rain (28.6 mm). The total depth of irrigation in 12% available water content irrigated treatment was more (1123.2 mm) followed by 25 % available water content (1080.4 mm) and 6% available water content (807.3 mm) (Table 2). The depth of irrigation was 409.5 mm at 50 % available water content treatment. The total depth of irrigation was 892.6 mm with 2 and 3 day intervals in evaporation based irrigation scheduling. The number of irrigations are more for lower available water content (6% and 12%) irrigation scheduling. The quantity of irrigation was more (64 000 litres from December 1996 to June 97) in 25% available water content irrigated plants, whereas it is only 44850 liters at 6% AWC treatment. The irrigation quantity

Table 2 Changes in soil moisture under different moisture regimes

Treatment	Soil moisture status in 30 cm rootzone (mm)							Total mm
	Dec 96	Jan 97	Feb	Mar	Apr	May	June	
Irrigation at 6% AWC	9.3 (31)*	41.1 (137)	29.7 (99)	64.5 (215)	71.4 (238)	49.2 (164)	47.4 (158)	312.6 (1042)
Irrigation at 12% AWC	6.9 (23)	39.3 (131)	27.3 (91)	39.9 (133)	49.2 (164)	41.1 (137)	43.8 (146)	247.5 (825)
Irrigation at 25% AWC	6.0 (20)	31.5 (105)	25.5 (85)	36.3 (121)	46.5 (155)	33.0 (110)	53.7 (179)	232.5 (775)
Irrigation at 50% AWC	3.0 (10)	27.3 (91)	24.9 (83)	19.2 (64)	44.7 (149)	30.6 (102)	46.2 (154)	195.9 (653)
Irrigation equivalent to 0.6 Epan (alternate day)	3.6 (12)	27.9 (93)	32.1 (107)	51.9 (173)	62.7 (209)	39.6 (132)	75.9 (253)	293.7 (979)
Irrigation equivalent to 0.6 CPE of 3 days	4.5 (15)	33.3 (111)	33.3 (111)	56.1 (187)	63.6 (212)	51.3 (171)	79.2 (264)	321.3 (1071)

*The soil moisture depletion (mm/m) at 30 cm depth

Table 3 Estimating the evapotranspiration (ET) using soil water balance method

Treatments	Depth of irrigation (I), (mm)	Change in soil moisture (ΔW), (mm)	Evapotranspiration (ET), mm
Irrigation at 6% AWC	807.3	312.6	494.7
Irrigation at 12% AWC	1123.3	247.6	875.6
Irrigation at 25% AWC	1080.4	232.5	847.9
Irrigation at 50% AWC	4095.5	195.7	213.6
Irrigation equivalent to 0.6 Epan (alternate day)	892.6	293.7	598.9
Irrigation equivalent to 0.6 CPE of 3 days	892.6	321.3	571.3

AWC, Available water content

at 50% available water content treatment was only 22 540 litres. The irrigation interval ranged from 1 day (irrigation at 6% available water content) to 29 days (irrigation at 50% available water content) in various irrigation scheduling treatments. The details of monthwise depth of irrigation, quantity, depth/irrigation and quantity of irrigation is presented in Table 1. The soil-moisture distribution was more at 6, 12 and 25 % available water content, 0.6 Epan and 0.6 CPE of 3 days than at 50 % available water content and increased from December to June but was low in 50, 25 and 12 % available water content. The soil moisture status was largely consistent in April influenced by unseasonal rains (Table 2).

Evapo-transpiration using soil water balance method

The potential and actual evapotranspiration was estimated with soil water balance method. The equation over a certain period of 7–10 days can be written as the change in water storage ΔW

$$\Delta W = I + P - P_i + G - R - ET \dots (1)$$

where I, irrigation (mm); P, precipitation (mm); P_i , intercepted precipitation (mm); G, upward flow through the bottom (mm); R, percolation through the bottom (mm) and ET, evapotranspiration (mm).

The terms P, P_i are negligible in the study since it pertains to non-rainy period. The component G is nil because of absence of watertable in rootzone depth. The component R is eliminated by watering the plants using drip irrigation system. Ultimately the equation (1) becomes

$$ET = I - \Delta W \dots (2)$$

For estimating the evapotranspiration the quantity of irrigation (mm) is recorded treatmentwise using watermeter and the soil moisture distribution change in the rootzone is measured regularly using Neutron moisture probe. Based on these observations the monthwise depth of irrigation and soil moisture distribution from December 96 to June 1997 were calculated (Table 3).

In available water content based treatments, the evapotransmission of acid lime plants was 213.6 mm which is minimum but seems to be inadequate as the plant growth was stunted and dried twigs. The plants irrigated at 6, 12 and 25% available water content were deep green and the evapotranspiration (ET) was comparatively less in 6% and 25% available water content treatments than the 12% available water content. The acid lime irrigated at more frequent irrigation intervals (6% available water content) used lesser amount of water and more changes in soil moisture distribution ultimately giving 494.7 mm ET. The ET of the plants scheduled at 0.6 Epan (alternate days) was 598.7 mm and 0.6 CPE of 3 days was 571.3 mm. The irrigation scheduling based on available soil water content and pan evaporation affect the quantity of irrigation, interval, soil moisture depletion and distribution and evapo-transpiration in acid lime. The total depth of irrigation from December 96 to June 97 varied from 409.5 mm (irrigation at 50% available water content) to 1123.2 mm (irrigation at 12% available water content) and 892.6 mm in the treatments scheduling based on pan evaporation. The monthly irrigation depth and variation of soil moisture distribution increased from December to June. The number of irrigation's varied from 7 (50% available water content) to 115 (6% available water content) in available water content.

The change in soil-moisture distribution in the rootzone of the acid lime plants varied from 195.9 mm to 321.3 mm with the different irrigation schedules. The evapo-transpiration of the acid lime varied from 213.6 mm to 875.6 mm in different irrigation schedules. Results revealed that frequent irrigation required less amount of irrigation depth and more soil-moisture distribution ultimately giving the evapo-transpiration range from 494.7 mm to 598.9 mm under the agro-climatic condition of Nagpur.

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Use of long-term meteorological data for estimation of irrigation requirement of wheat (*Triticum aestivum*) at different risk levels

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Key words : estimation, irrigation, wheat

There are various methods for assessing irrigation need of a crop in a particular location. The most obvious solution is to measure soil-moisture content periodically but this involves problems of instrumentation, sampling at number of sites, number of years of experimentation and requires time and energy and is not generally favoured. Net irrigation demand which is the water deficit in the root zone of crop during a particular stage depend mostly upon the evaporative demand of atmosphere, rainfall received, crop stage and available soil moisture capacity. A long-term weekly water deficit of spring wheat (*Triticum aestivum* L. emend Fiori & Paol) at sub-Himalayan plains of India (Station : Coochbehar, West Bengal at 26°19' north latitude and 89°23' east longitude) was simulated from water balance of long-term rainfall and potential evapo-transpiration data for 3 different sowing time. Probabilities (expressed as percentage risk) of a particular water deficit/irrigation requirement being exceeded was established for different phases of wheat growth. From such analysis likelihood of a certain level of irrigation need could be established for the weeks ahead and this would be most useful in determining irrigation policy in a large area during dry season (WMO 1975)

In sub-Himalayan plains of West Bengal, wheat is sown in the post-rainy season from mid-November to mid-December depending upon the time of harvesting of winter rice (*Oryza sativa* L.). Three sowing weeks, viz 46th (12-18th November), 48th (26 November-2 December) and 50th (10-16th December) were considered covering this entire period. Available water-holding capacity of the soil was 150 mm/m depth (Khan and Saha 1996). Weekly rainfall data from 1901 to 1980 and long-term average data on potential evapo-transpiration was collected from Indian Meteorological Department. Year-wise available soil-moisture at 3 different sowing periods were simulated by water balance model of Thornthwaite and Mather (1955). In this method profile stored soil-moisture

during any period in a year for a soil with surface vegetation can be estimated by the expression.

$$ESM = AWHC [e_{-(APWL/AWHC)}]$$

where ESM, estimated profile stored soil moisture at any given time during the year; AWHC, available water-holding capacity of soil; APWL, accumulated potential water loss, which is accumulated weekly negative values of precipitation minus potential evapo-transpiration at the time of moisture estimation.

The 50% of the maximum available soil-moisture was considered as readily available water to wheat for healthy and unrestricted growth of this crop (Doorenbos and Pruitt 1977). So, in each year simulated available moisture over 75 mm (ie 50% of 150 mm) at sowing was considered as readily available profile stored moisture for initial growth of wheat. For determination of phasic irrigation requirement the growth period of wheat crop was divided into 4 stages, viz i) sowing (S) to crown root initiation stage (1-3 growing week), (ii) crown root initiation (CRI) to late tillering (4-8 growing week), (iii) late tillering (LT) to flowering (9-13 growing week) and (iv) flowering (F) to maturity (14-17 growing week). The entire growth duration was thus considered to be 17 weeks which is very common in this region for irrigated wheat. For simulating year-wise phasic water deficit / net irrigation requirement (for 80 years) another crop specific water balance model known as FAO (Frere and Popov 1979) was used. For this computerized water balance model to run, a third input parameter, viz crop coefficient is required in addition to rainfall and potential evapotranspiration (PET). Weekly crop coefficient (ratio of actual to potential evapo-transpiration) for different sowing periods were estimated for wheat crop by the methods of Doorenbos and Pruitt (1977) in which crop coefficient data given for initial, crop development and maturity phase for spring wheat have been interpolated graphically to obtain weekly crop coefficient value during growing period of wheat. In this water balance model water requirement is determined by multiplying potential evapotranspiration with crop

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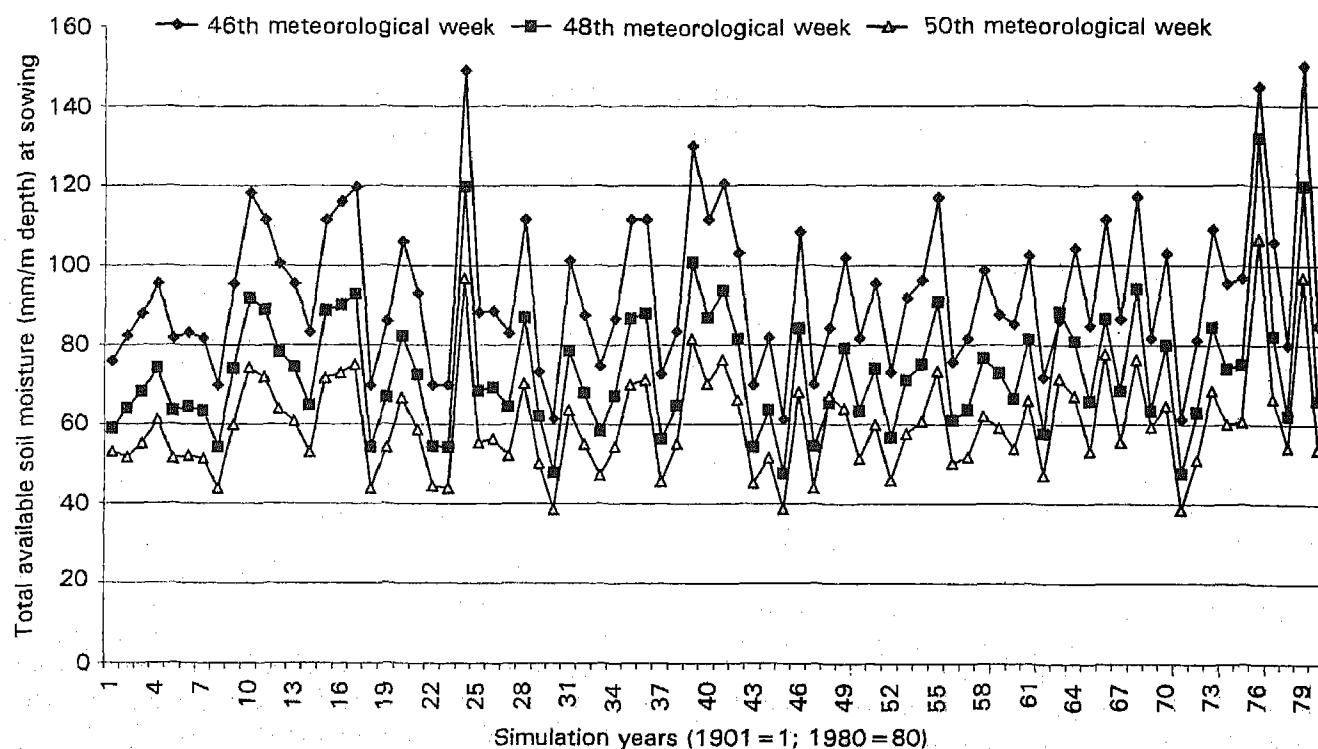


Fig 1 Yearly variation of simulated available soil moisture (mm/m) at different times of sowing of wheat

coefficient during a particular period. Based on the water requirement, rainfall and soil moisture at preceding week weekly deficit/ irrigation requirement (water requirement minus

available soil moisture) were simulated in this method. Year-wise and phenophase-wise irrigation requirement data were then subjected to incomplete gamma distribution (Thom 1958)

Table 1 Weekly water requirement of wheat for different time of sowing estimated from potential evapotranspiration and crop coefficient

Growth stage	Growing week	Sowing at 46th SMW			Sowing at 48th SMW			Sowing at 50th SMW		
		PET(mm)	KCR	WR(mm)	PET (mm)	KCR	WR(mm)	PET (mm)	KCR	WR(mm)
S-CRI	1	19.8	0.30	5.94	16.60	0.35	5.81	14.20	0.35	4.97
	2	18.2	0.30	5.46	15.20	0.35	5.32	13.30	0.35	4.66
	3	16.6	0.40	6.64	14.20	0.44	6.25	12.20	0.45	5.49
	4	15.2	0.62	9.42	13.30	0.64	8.51	12.30	0.65	7.99
CRI-LT	5	14.2	0.82	11.64	12.20	0.84	10.25	12.20	0.84	10.25
	6	13.3	0.98	13.03	12.30	0.98	12.05	12.10	0.98	11.86
	7	12.2	1.05	12.81	12.20	1.05	12.81	12.00	1.05	12.60
	8	12.3	1.05	12.91	12.10	1.05	12.70	13.40	1.05	14.07
LT-F	9	12.2	1.05	12.81	12.00	1.05	12.60	15.50	1.05	16.27
	10	12.1	1.05	12.70	13.40	1.05	14.07	17.00	1.05	17.85
	11	12.0	1.05	12.60	15.50	1.05	16.27	18.50	1.05	19.42
	12	13.4	1.05	14.07	17.00	1.05	17.85	19.40	1.05	20.37
F-M	13	15.5	1.00	15.50	18.50	1.00	18.50	20.80	1.00	20.80
	14	17.0	0.85	14.45	19.40	0.85	16.49	23.00	0.85	19.55
	15	18.5	0.67	12.40	20.80	0.67	13.94	25.30	0.67	16.95
	16	19.4	0.48	9.31	23.00	0.48	11.04	27.60	0.48	13.25
Total	17	20.8	0.28	5.82	25.30	0.28	7.08	30.10	0.28	8.43
		262.7		187.50	273.00		201.60	298.90		224.80

S, Sowing; CRI, crown root initiation; LT, late tillering; F, flowering; M, maturity; PET, potential evapotranspiration; KCR, crop coefficient; WR, water requirement; SMW, standard meteorological week

Table 2 Phenophasewise irrigation requirement (IR) of wheat at a given risk level (AWHC, 150 mm, RAW, 75 mm/m depth)

Percent risk of exceeding value of irrigation requirement	Sowing at 46th SMW					Sowing at 48th SMW					Sowing at 50th SMW				
	A	B	C	D	Growing season total	A	B	C	D	Growing season total	A	B	C	D	Growing season total
10	16	79	90	51	236	26	66	86	54	232	23	77	109	79	288
25	10	61	73	40	184	18	59	77	45	199	18	62	91	54	225
50	4	45	57	30	136	11	50	65	34	160	14	48	73	33	168
75	2	32	43	21	98	6	43	56	25	130	10	36	58	19	123
90	1	23	33	15	72	3	36	47	16	102	7	27	46	10	90
Mean (80 years)	6	48	59	31	144	12	50	65	34	161	14	49	75	39	177

SMW, Standard meteorological week; A, Sowing to crown root initiation (CRI) stage (1st to 3rd growing week); B, CRI to late tillering (LT) stage (4th to 8th growing week); C, LT to flowering (F) stage (9th to 13th growing week) and D, flowering to maturity (M) stage (14th to 17th growing week)

as adopted by Sarkar *et al.* (1988) to determine the percent risk (ie probability) of exceeding a definite irrigation requirement value at different level during different phases of wheat growth. As incomplete gamma distribution of weekly rainfall yields minimum assured rainfall, that of weekly deficit yields minimum assured deficit at a particular percentage probability level and the reverse of which is the percent risk of irrigation requirement.

Profile soil moisture at sowing

To determine irrigation requirement of wheat grown during post-rainy season in the sub-Himalayan plains it was obligatory to estimate the profile moisture at sowing which often contribute substantially towards initial growth of crops for 2–3 weeks. Simulation of soil moisture at different sowing week of wheat (average of 80 years) by Thornthwaite and Mather Soil-water balance method revealed (data not given) that mean available soil-moisture was 93.5, 73.6 and 60.2 mm/m depth at 46th, 47th and 48th standard meteorological week respectively. Standard deviation (80 years) of available soil moisture was 19.2, 16.0 and 12.9 at 46th, 47th and 48th meteorological week, respectively which shows that the effect of variability in the seasonal rainfall on the profile stored moisture gradually smoothes with advance in the sowing time of wheat. However, among 3 different sowing times it is expected that the readily available water, ie moisture above 75 mm of available soil-moisture benefited the crop mostly during first sowing (46th week).

Phasic water requirement of wheat

It is evident from the data presented in Table I that the evaporative demand of the atmosphere during the growth period of wheat increased from 262.7 to 298.9 mm with delaying sowing 46th to 50th standard meteorological week. Accordingly, seasonal water requirement of the crop increased

from 187.5 mm at 46th week to 224.8 mm at 50th week sowing. It is interesting to note that the weekly crop coefficient value from 6th to 17th growing week is same but that from 1st. to 5th growing week was different for three different periods of sowing. This is due to the fact that the crop coefficient value for early growth period as mentioned by Doorenbos and Pruitt (1977), is dependent on the antecedent weather condition at the time of sowing and not on the crop concerned.

Net irrigation requirement of wheat

Mean seasonal irrigation requirement changes from 144 mm at 46th week sowing to 177 mm at 50th week sowing with highest irrigation requirement during late tillering to flowering for all the periods of sowing (Table 2). A comparison of water requirement and mean irrigation requirement for 80 years indicate that percentage of water requirement satisfied either from profile stored moisture or growing season rainfall was 22.9 (43 mm), 20.1 (40.6 mm) and 21.2 (47.8 mm) for wheat crop sown during 46th 48th and 50th standard meteorological week respectively. Irrigation requirement from sowing to crown root initiation stage was very low during 46th week sowing compared with others thereby indicating clearly the beneficial effect of profile stored moisture immediately after cessation of rainy season. Inclusion of per cent risk of exceeding value of irrigation requirement in describing phenophase-wise irrigation requirement helps the farmer or planner exploring/ assessing the irrigation resources ahead of season depending on his risk bearing capacity. Considering readily available water as 50% of total available soil moisture right from sowing to harvest and a large database year (80) makes the estimation more conservative and reliable. When rainfall data are subjected to incomplete gamma distribution, minimum assured rainfall at 75% probability is considered dependable for all crop management decisions (Reddy 1993), which in the estimation of the

probability of deficit corresponds to 25% risk level. That means, for all sowing periods and individual phenophase of wheat growth the value of irrigation requirement corresponds to 25% risk can be considered dependable and resources can be employed accordingly. In a similar way considering three different levels of common consumptive use factor for all crops and six different levels of available water holding capacity of soil throughout the growing period the probability (expressed as percentage risk) of a particular irrigation demand being exceeded was established for weekly periods for different stations of Canada by Coligado *et al.* (1969).

Through this analysis irrigation planning for wheat crop at Coochbehar district can be done on the basis of ability of taking risk at different levels by the farmers or planners. It is expected that seasonal irrigation requirement for wheat will not exceed 184, 199 and 225 mm if sown in 46th, 47th or 48th meteorological week respectively, in 3 out of 4 years, ie at 25% risk level which is an affordable risk. This method of determination of irrigation requirement excludes the possibility of error that stems from determining it from 2–3 years actual field experimentation where the influence of temporal weather variation is not properly accounted for. Following this method an irrigation manual for phasic irrigation requirement at different risk levels can be prepared for different crops and regions.

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Regulation of somatic embryogenesis and plant regeneration in sugarcane (*Saccharum officinarum*)

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Key words : abscisic acid, auxin, desiccation, maltose, plant regeneration, proline, somatic embryogenesis, sucrose, sugarcane

Plants regeneration through somatic embryogenesis in sugarcane (*Saccharum officinarum*) was first reported by Ahloowalia and Maretzki (1983) and has been found to depend on genotype, explant, media composition, auxin concentration, amino acids carbohydrate source and abscisic acid (ABA) and partial desiccation (Taylor *et al.* 1992, Liu 1993, Zimmermann 1993, Brislbe *et al.* 1994). A study was conducted to determine the effect of these factors on somatic embryogenesis and plant regeneration in commercial varieties of sugarcane in Punjab.

Callus Induction and culture conditions

Four sugarcane varieties 'CoJ 64', 'CoJ 83', 'CoJ 84' and 'CoP 84-211' were used. Primary explants derived from apical portions of field grown, spring sown crop were pruned to obtain 5-6 cm long, 1-2 cm diameter spindles which were washed and surface sterilized. Two 5-6 mm long explants from the innermost 4-5 young curled leaves of the spindle were cultured on Murashige and Skoog medium (MS medium) (Murashige and Skoog 1962) supplemented with 4.0 mg/litre 2,4-D, 0.5 mg/litre kinetin, 30.0 g/litre sucrose and 8.0 g/litre agar for callus induction. All the cultures were incubated at 27 ± 2 °C with a 16/8 hr light/dark photo-period cool fluorescent daylight tubes.

Proembryogenic callus was cultured on various media treatments (Table 1) for 45 days to study their effect on induction and maintenance of somatic embryogenesis. The embryogenic calli from each treatment was then transferred to MS medium supplemented with 0.5 mg/litre benzyl amino purine and 0.5 mg/litre kinetin for plantlet formation and observations recorded for normal plants regenerated for 5

replications/treatment in each variety. The data was analysed and assessed at 5% level of significance by Welsch Step-up procedure (Sokal and Rohlf 1995).

Callus proliferation, somatic embryogenesis induction and characteristics

All the varieties showed callus formation in MS medium supplemented with 4.0 mg/litre 2,4-D and 0.5 mg/litre kinetin. The position of the explant with respect to the node of the primary explant influenced callus induction. Guiderdoni and Demarly (1988) reported that nodular calli were produced when explant was derived from bases of young fast growing leaves of sugarcane.

Embryonic callus induction response to different treatments was found similar for all varieties and showed embryogenic callus induction at 4 mg/litre 2,4-D with compact nodular structures. Low auxin concentration resulted in white, somewhat compact and nodular embryogenic callus while control medium the callus further proliferated. The high

Table 1 Variety means and treatments for number of plants regenerated over treatments and media

Variety/ treatment	Number of plants regenerated *	Treatment over control
CoJ 64	54.0 ± 4.6 ^a	
CoJ 84-211	43.6 ± 3.0 ^b	
CoJ 83	35.8 ± 3.1 ^c	
CoJ 84	35.2 ± 2.6 ^c	
ABA (2.0 mg/litre)	43.6 ± 3.6 ^a	3.89
Agar (12.0 g/litre)	35.8 ± 4.4 ^b	3.20
Proline (560.0 mg/litre)	30.6 ± 3.7 ^b	2.73
2,4-D (2.0 mg/litre)	22.8 ± 3.1 ^c	2.04
Maltose (30.0 g/litre)	21.8 ± 4.7 ^c	1.95
Control medium	11.2 ± 2.0 ^d	1.00
2,4-D (6.0 mg/litre)	2.6 ± 1.4 ^c	0.23

* Means with same letter are non-significant at $P = 0.05$ (Welsch Step-up procedure). Control medium : Murashige and Skoog medium supplemented with 4.0 mg/litre 2,4-D, 0.5 mg/litre kinetin, 30.0 g/litre sucrose and 8.0 g/litre agar. In treatments, the rest of the media supplements were same as the control medium except as indicated

*Short note

Based on complete information of M Sc (Plant Breeding) thesis submitted by the first author to the Punjab Agricultural University, Ludhiana, during 1996.

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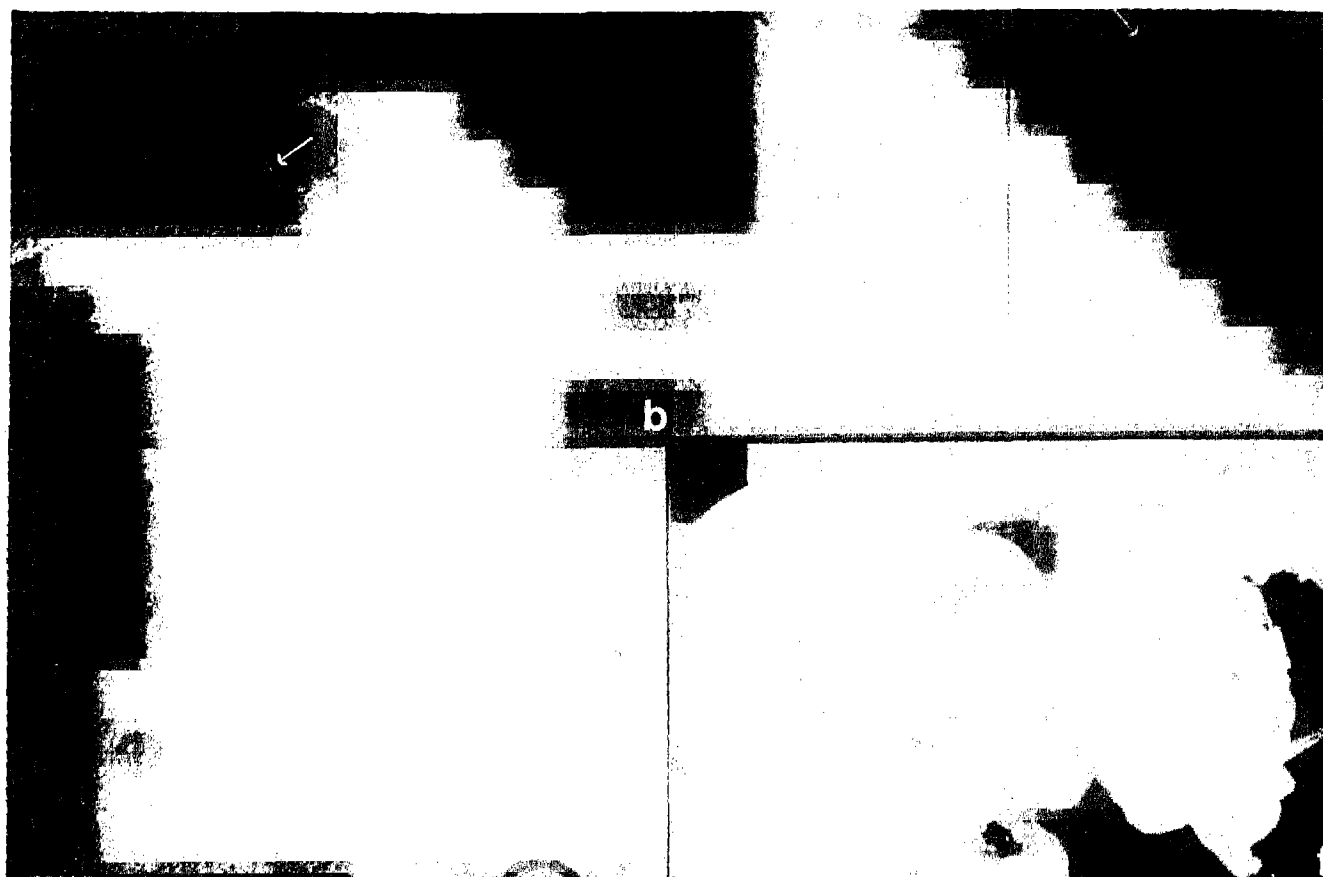


Fig 1 Stages of embryogenesis in embryogenic callus 'CoJ 64' sugarcane. (a-e) various stages of embryogenesis as described by Ho and Vasil (1983). (f) stereo-micrograph of a somatic embryo germinating.

auxin concentration in the medium converted proembryogenic callus into a smooth, watery and non-embryogenic callus. Maltose and proline gave increased mass of embryonic callus which was yellowish, highly embryogenic and compact. ABA and partial desiccation did not increase proembryogenic callus mass but the callus was highly compact, nodular and white. The calli showing nodular and compact structures histologically examined and the results show that the calli identified as embryogenic had typical globular to shoot primordium stages of somatic embryogenesis (Fig 1).

Induction of plant regeneration from somatic embryos

Variety means for number of plants regenerated over media and treatments revealed that 'CoJ 64' sugarcane was the best producer of plants from somatic embryos (Table 1). All treatments except high auxin concentration (6 mg/litre 2,4-D) showed an enhanced plant regeneration response compared to control. The best treatment was ABA (3.89 times over control) followed by partial desiccation and proline supplementation (Table 1). Therefore ABA, partial desiccation and addition of amino acids along with low auxin concentration can be used to enhance plant regeneration from somatic embryos in sugarcane.

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Effect of different mulches on the yield and quality of 'Oso Grande' strawberry (*Fragaria* × *ananassa*)*

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Key words : strawberry, black polythylene, transparent polyethylene, fruit quality

Strawberry (*Fragaria* × *ananassa* Duch.) is one of the important small soft fruit, suitable for cultivation under wide agro-climatic conditions. Because of its remunerative prices the area under this crop is increasing rapidly. Maharashtra is having highest area under commercial cultivation followed by Karnataka. It is also grown in Kashmir, Himachal Pradesh and Punjab recently it is being popularized for commercial cultivation in Haryana. Mulching is one of the essential cultural practices in strawberry cultivation to protect the fruits from soil-fungi. Increase in yield and improvement in quality with black polythene under Himachal Pradesh conditions was reported by Gupta and Acharya (1993). Therefore an experiment was conducted to study the effect of different mulches on the yield and quality of strawberry under Haryana conditions.

The experiment was conducted from October 1997 to April 1998 at King's Orchard, Hisar, Haryana on well drained loamy

sand soil. Planting was done on October 1997 at a spacing of 25 cm × 25 cm on raised beds of 25 cm height, 105 cm width with a distance of 55 cm between the two beds. Each replication consisted of 50 plants and there were 7 replications in a randomized block design. Mulching was done on 1 November 1997 with black polythene (50 gauge), transparent polyethelene (50 guage), 5 cm layer of dry thatches of *sarkanda* (*Saccharum munja*) and unmulched (control). Necessary cultural practices and plant protection measures were taken. Low tunnels were raised on the beds from 5.00 PM to 8.00 AM during December 97, January 98 using transparent polyethylene. Yield (g/plant) was recorded at weekly intervals in different months of harvesting and total yield (g/plant) and yield in (tonnes/ha) was calculated. TSS, acidity and ascorbic acid and of the fruits were assessed as per the AOAC, Washington (1988) methods.

Plants mulched with black polyethylene gave highest weekly yield (g/plant) and total yield followed by transparent polyethylene and *sarkanda*. (Table 1). Minimum yield was obtained in unmulched control. The per cent increase in the yield with black polythene was 43.23 % over the unmulched

*Short note

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Table 1 Effect of different mulches on the yield (g/plant) at weekly intervals in different months of harvesting, total yield in 'Oso Grande'

Treatments	Yield (g/plant) at weekly interval in different months												Total yield (tonnes/ g/ ha)	Yield (tonnes/ ha)	
	February					March					April				
	1W	2W	3W	4W	Total	1W	2W	3W	4W	Total	1W	2W			Total
Black polyethylene	21.56	24.39	18.70	25.02	89.67	34.80	37.92	38.61	35.09	146.42	34.70	20.48	55.18	291.27	30.58
Transparent polyethylene	18.06	19.91	16.20	25.52	76.69	30.83	33.36	37.90	33.54	135.63	32.95	19.11	52.06	264.38	27.76
<i>Sarkanda</i>	15.80	17.94	14.13	18.29	66.16	27.95	31.79	34.83	32.84	127.41	30.43	17.84	48.27	241.84	25.39
Unmulched control	14.98	16.54	10.84	16.48	58.84	26.50	27.74	30.33	30.10	114.67	19.21	10.65		203.37	21.35
CD (<i>P</i> =0.05)	0.33	0.92	1.02	1.03		0.98	0.86	0.65	0.67		1.03	0.92		4.34	

W, Weeks

Phosphorous absorption kinetics in citrus (*Citrus* spp), grape (*Vitis vinifera*), mango (*Mangifera indica*) and banana (*Musa paradisiaca*)

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Key words : nutrient ions, absorption, reaction kinetics

Biochemical properties of plant roots is one of the most important factors influencing nutrient absorption by plants. Involvement of specific enzymes in complexing and inward movement of nutrient ions and the applicability of reaction kinetics to the entire process was proposed by Epstein and Hagen (1952). Initially nutrient absorption was thought to be biphasic but later investigations indicated it being multiphasic (Nissen *et al.* 1980). Refined and comprehensive models of nutrient absorption have been proposed by Nye and Tinker (1977), Silberbush and Barber (1983) and Barber (1984). But most of these studies pertain only to short-duration crops and annuals. An attempt was therefore made to study the same in fruit crops many of which are grafted on rootstocks having differential ability to absorb nutrients. The study was carried out on citrus rootstocks/scions (*Citrus* sp), grape rootstock/scion (*Vitis* sp) varieties, mango rootstocks (*Mangifera indica* L.) and several varieties of banana (*Musa paradisiaca* L.)

Kinetic parameters of nutrient absorption studied included $I_{\max}$ (maximum rate of nutrient absorption, p moles/cm/s), K_m (nutrient concentration at which inflow is $1/2 I_{\max}$, moles/litre) and $C_{\min}$ (nutrient concentration at which there is no net inflow, moles/litre). These parameters were determined during 1988-95 in the case of rootstocks and seedlings raised in the field. Seedlings (citrus and mango) or rooted cuttings of rootstocks (grape) were transferred to nutrient solutions with known P concentrations labelled with ^{32}P . Aliquots of the solutions were counted for ^{32}P in liquid scintillation counter (Packard Tricarb 1900 TR) at appropriate intervals up to 7 days and the activity of ^{32}P (dpm) equated with P concentration. Quadratic fit for P concentration against time and differentiations of the same gave the rate of absorption. Double reciprocal plotting of rate of absorption against concentration was done to arrive at $I_{\max}$ and K_m . Equating rate of absorption to zero in the quadratic equations yielded the $C_{\min}$ values. Rate of average net inflow I_n was calculated by the formula proposed by Nielson and Barber (1978) :

$$I_n = \frac{I_{\max} (C_s - C_{\min})}{K_m + (C_s - C_{\min})}$$

where C_s , equilibrium concentration of P (at 10 $\mu\text{moles/litre}$) in the soil solution.

In the case of field grown plants (Citrus varieties 'Coorg Mandarin' and 'Sweet Orange' and banana ('Cavendish' and 'Robusta') several feeding roots were separated *in situ* and immersed in nutrient solution containing known P (^{32}P) concentrations. Aliquots were drawn and $I_{\max}$, K_m , $C_{\min}$ and I_n determined as described earlier.

Maximum rate of P absorption ($I_{\max}$) was several times higher in banana and mango (1.39 to 13.78 pmoles cm/s) compared with the citrus and grape rootstocks/scions (0.47-0.771 pmoles/cm/s). 'Citrumelo', 'Bangalore Blue', 'Prior' and 'Nendran' had very high $I_{\max}$ among citrus, grape, mango and banana varieties/rootstocks respectively (Table 1).

The affinity of roots for P (K_m , $\mu\text{moles/litre}$) was low in citrus (8.46-184.9 $\mu\text{moles/litre}$) and banana (35.6-115.0) compared to mango (7.1-27.7) and grape (5.3-6.0). The highest affinity of P to roots was observed in 'Rough lemon' citrus (8.5), 'St. George' grape (5.32), 'Olour' mango (7.1) and 'Nendran' banana (35.6) among varieties/rootstocks.

The minimum P concentration in the equilibrium solution surrounding roots at which influx equals efflux ($C_{\min}$) ranged from 0.65-4.3, 0.44-0.63, 0.18-0.75 $\mu\text{moles/litre}$ among citrus, grape and mango rootstocks respectively. In general, mango rootstocks had very low $C_{\min}$. Inflow, a product of $I_{\max}$, K_m and $C_{\min}$ was high in mango (1.05-6.7) followed by banana (0.144-3.021) and was also in citrus (0.01-0.048) and grape (0.042-0.235) pmoles/cm/s).

Maximum rate of absorption ($I_{\max}$) the capacity factor in nutrient absorption connotes the number of sites on the root on which P can be bound and also the rate at which it is absorbed. Higher the $I_{\max}$ higher is likely to be the response to the applied fertilizer. Amongst polyembryonic mango rootstocks, 'Peach' and 'Prior' may be highly responsive and likewise the scions budded on them. 'Nendran', 'Bangalore Blue' and 'Citrumelo' may also be fertilizer responsive among

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Table 1 Kinetic parameters of phosphorous absorption

	Kinetic parameters			
	$I_{\max}$ ($\mu\text{moles/cm/s}$)	K_m ($\mu\text{moles/litre}$)	$C_{\min}$	I_n ($\mu\text{moles/cm/s}$)
<i>Citrus: Pot grown (in quartz sand)</i>				
Rough lemon (rootstock)	0.057	8.46	0.65	0.030
Rangpur lime (rootstock)	0.147	37.70	1.94	0.026
'Cleopatra mandarin' (rootstock)	0.215	32.38	2.55	0.040
'Trifoliate orange' (rootstock)	0.281	184.90	2.98	0.010
'Troyer citrange' (rootstock)	0.226	34.60	2.60	0.040
'Citrumelo' (rootstock)	0.333	138.72	4.33	0.013
'Coorg mandarin' (scion)	0.369	37.44	1.27	0.014
CD ($P=0.05$)	0.077	37.44	1.27	0.007
<i>Field grown plants</i>				
Sweet orange (cv Musambi) on Rangpur lime (scion)	0.171	26.87	2.45	0.038
Coorg mandarin on (scion) Rough lemon	0.123	27.22	1.32	0.030
<i>Grape : Field grown</i>				
St. Goerge (rootstock)	0.047	5.32	0.62	0.030
Thompson seedless (scion)	0.071	6.03	0.63	0.043
Anab-e-shahi (scion)	0.075	5.60	0.44	0.047
Bangalore blue (scion)	0.125	5.46	0.48	0.080
CD ($P=0.05$)	0.027	NS	NS	0.016
<i>Mango : Pot grown (in quartz sand)</i>				
'Kurukan'	2.86	16.88	0.26	1.05
'Moovandan'	3.54	27.74	0.75	0.89
'Nekkare'	2.91	10.65	0.38	1.38
'Olour'	7.15	7.07	0.25	4.14
'Peach'	10.18	8.29	0.39	5.46
'Vellikolamban'	8.98	10.02	0.18	4.44
CD ($P=0.05$)	NS	NS	NS	NS
<i>Bannana : Field grown</i>				
'Dwarf Cavendish'	1.39	86.80		0.144
'Robusta'	6.95	115.00		3.021
'Nendran'	13.78	35.62		0.688
'Monthan'	3.88	46.61		0.881
'Elakki' (Ney Poovan)	5.61	53.69		0.881
CD ($P=0.05$)	0.027	NS	NS	0.016

banana, grape and citrus respectively. Since Michaelis-Menten constant (K_m) is inversely related to the affinity of P to the absorption site 'Trifoliate orange', 'Citrumelo' (citrus), 'Moovandan' (mango) and 'Robusta' (banana) have low affinity for P due to high K_m . This is due to the involvement of specific enzymes which are unique to the crops as well as to the variety.

The threshold rhizospheric solution concentration at which inflow of the nutrient into the root reaches 0 (C_{min}) is important since varieties/rootstock which have low C_{min} can appropriate the nutrient even from marginal soils low in available phosphorous (Barrow 1978). The fact that polyembryonic rootstocks of mango and rootstocks of grape have low C_{min} indicates that these crops may be grown successfully in marginal soils, whereas citrus (rootstocks/scions) require a more fertile soil. 'Rough lemon', 'Vellaikolamban' and 'Anab-e-Shahi' rootstocks/varieties corresponding to citrus, mango and grape which have low C_{min} are likely to thrive in marginal soils.

Phosphorous inflow rate (I_n) which is comparatively high in polyembryonic mango rootstocks particularly in 'Olour', 'Peach', 'Prior' and 'Vellaikolamban' may have better P absorption efficiency and may respond better to its application. Amongst banana varieties which also have high inflow rates, 'Nendran' seems to respond better to P-fertilizer compared with other varieties because of its high I_n . 'Bangalore Blue' grape which has higher P inflow rate may similarly respond better to P-fertilization. All citrus rootstocks which have the lowest P inflow rates may show the least response to P fertilization.

In terms of suitability of a soil to a variety or response of a variety to applied P, the fruit crops and their varieties differ widely. These differences may be partly due to kinetic parameters of absorption or due to root morphology or ontogeny of the crop/variety. However, verification trials are required to confirm the influence of these kinetic parameters on P absorption. Further, these factors have to be considered to fine tune the genotypic adaptability as a substitute for P amendment on P deficient soils (Ponnamperuma 1982).

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Stability analysis for grain yield of barnyard millet (*Echinochloa frumentacea*)

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Key words : barnyard millet, high altitude, fertilizer treatment, grain yield, stability

Barnyard millet (*Echinochloa frumentacea* (Roxb.) Link) is cultivated at mid and high hills of Garhwal in the Himalayas under rainfed low fertility conditions. In contrast another cultivated species of barnyard millet (*E. crus-galli* ssp *utilis* (L) P. Beauv) is found promising under high hill condition (Bandyopadhyay 1998). In order to identify genotypes suitable for high hill condition at different level of soil fertility and to observe superiority of one species to other, the stability for grain yield was examined among different experimental cultivars of 2 barnyard millet species.

The experimental material comprised 10 varieties of *E. frumentacea* including 2 standard varieties and 8 local land races, and five selected lines of *E. crus-galli* ssp *utilis* developed by the University. Again, among local land races anthocyanin pigmented and non-pigmented lines were chosen with an understanding that pigmented lines would provide better resistance to cold stress at high altitude under high light intensity condition (Caldwell 1968, Levitt 1972). Experiment was conducted in an identical situation of farmers field at high altitude (2100 m MSL) at Ranichauri with 3 fertilizer treatments. Different status of soil fertility in the experimental field was maintained by employing 0-fertilizer, normal dose of chemical fertilizer and compost on 3 treatments respectively. Seeds were sown in randomized block design with 3 replications within each treatment. Plot size was 3 m × 1 m and the spacing between plants and rows were maintained at 10 cm and 25 cm respectively. The experiment was repeated twice in 2 consecutive years in April on 1996 and 1997. During crop growth recommended package of practices were followed. Observations were recorded on grain yield/plot. Stability analysis was carried out as per Eberhart and Russell (1966).

Significant genotypic differences existed among experimental cultivars (Table 1). This indicated that selection for superior genotypes could be practiced in experimental population. Fertilizer and genotype fertilizer interaction effect (G×F) showed significant variation both in linear as well as non-linear part of variance. Relatively higher values of

Table 1 Pooled analysis of variance for grain yield in barnyard millet over three fertilizer treatment

Source	df	Mean squares
Genotype (G)	14	75.20****
Fertilizer (F)	2	157.55****
G × F	28	8.35****
F (linear)	1	315.10****
G × F (linear)	14	16.07****
Pooled deviation	15	0.58*
Pooled error	90	0.30

*, ** Significant at P=0.05 and P=0.01 levels of probability against pooled error, +, ++ significant at P=0.05 and P=0.01 levels of probability against pooled deviation

variances were registered in linear components. This indicated that existing variation of grain yield over different fertilizer treatments were predictable for the expression of the trait.

Cultivars showed wide variation in grain production at high altitude (Table 2). Genotypes of *E. crus-galli* ssp *utilis* registered higher grain yield. High per cent of reproductive success among these cultivars suggested that the species *E. crus-galli* ssp *utilis* were better adapted to low atmospheric temperature at high hills. On the contrary, 4 local cultivars 2 each from pigmented and non-pigmented lines showed relatively higher grain yield among *E. frumentacea*. It was assumed that adaptation to cold stress for these local cultivars perhaps developed through indirect effect of evolution at high hills. Anthocyanin pigmentation was not directly associated with cold resistance in this species. Other cultivars, however, exhibited physiological limitation in production capacity at an exposure to cool climatic condition at higher elevation of hills.

The phenotypic stability was examined by the relative value of mean performance for grain yield, regression coefficient value and deviation from regression (Table 2). Non-significant deviation from regression was observed among all experimental cultivars except local 4 and local 8. This indicated that most of the experimental cultivars exhibited stability in grain yield. Among these stable

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Table 2 Estimates of stability parameters for grain yield in barnyard millet over three fertilizer treatments

Genotypes	Range (tonnes/ha)	Mean (tonnes/ha) (x)	Regression coefficient ($b_i \pm SE$)	Deviation from regression (S^2d_i)
<i>E. frumentacea</i>				
VL 21	0.40–0.80	0.66	0.20** $\pm$ 0.04	–0.26
VL 29	0.55–0.90	0.71	0.28* $\pm$ 0.13	0.09
Local-1(P)	0.70–1.60	1.15	0.99** $\pm$ 0.18	0.41
Local-2(P)	0.96–1.50	1.27	0.64** $\pm$ 0.13	0.07
Local-3(NP)	0.98–1.60	1.37	0.72** $\pm$ 0.01	–0.30
Local-4(NP)	0.90–1.35	1.06	0.38 $\pm$ 0.31	1.75*
Local-5(NP)	0.80–1.10	0.95	0.26** $\pm$ 0.05	–0.24
Local-6(NP)	0.80–1.15	0.95	0.17 $\pm$ 0.19	0.52
Local-7(NP)	0.45–0.85	0.63	0.34** $\pm$ 0.07	–0.19
Local-8(NP)	0.50–1.10	0.83	0.57 $\pm$ 0.27	1.32*
<i>E. Crusgalli ssp utilis</i>				
PRB 9402	0.55–1.90	1.30	1.92** $\pm$ 0.06	–0.20
PRB 9403	1.10–3.00	2.23	2.79** $\pm$ 0.11	–0.01
PRB 9404	1.10–2.80	2.13	2.50** $\pm$ 0.21	0.63
PRB 9501	0.90–2.10	1.66	1.87** $\pm$ 0.23	0.88
PRB 9602	0.35–2.00	1.14	1.75 $\pm$ 0.03	0.11

*, ** Significant at $P=0.05$ and $P=0.01$ levels of probability, + b_p significant against unit value of regression; P, anthocyanin pigmented NP, non-pigmented

cultivars 'PRB 9402', 'PRB 9501', 'PRB 9602', Local 1 and Local 3 showed regression coefficient near unity. It was, therefore, suggested that all these 5 cultivars possessed wide adaptation over different soil fertility levels at high altitude. Significantly higher regression coefficient value against unity was recorded in 2 experimental cultivars, viz 'PRB 9403' and 'PRB 9404'. This indicated that both of these 2 cultivars would perform well under favourable environmental condition of soil fertility at higher elevation of hills. However, the consistency in performance of high grain yield over different fertilizer treatments suggested that both 'PRB 9403' and 'PRB 9404' would be the most promising cultivars for high altitude regions of Garhwal hills in the

Himalayas under different fertility status of soil.

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Genetics of resistance in four germplasm donors against bacterial leaf blight of rice (*Xanthomonas oryzae* pv *oryzae*)

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Key words : resistance, allelic relationship, bacterial blight

Bacterial leaf blight caused by *Xanthomonas oryzae* pv *oryzae* is one of the most wide spread diseases of rice (*Oryza sativa* L.) in Asia, Africa and Australia. The disease causes

serious yield losses when it occurs in epidemic form (Durgapal 1985). Since effective chemical control of this disease is not available, use of resistant cultivars has been reported to be the most economical and sound approach for management of this disease. Several cultivars resistant to bacterial leaf blight have been identified and are being extensively grown in different parts of the world, however, evolution of new pathotypes have rendered many of these cultivars susceptible (Singh *et al.* 1998).

The wide variability existing in the pathogen can only be countered by identifying numbers of possible non-allelic

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Table 1 Reaction of isogenic lines, differentials and M P Rice Germplasm donors against *X. oryzae* pv. *oryzae* isolates of eastern Madhya Pradesh

Genotype	Genes present	Reaction against different isolates					
		6	6R	6-4R	6-5R	6-6R	6-7R
<i>Isogenic lines and differentials</i>							
'IRBB 1'	Xa-1	S	R	S	S	S	S
'IRBB 2'	Xa-2	S	R	S	S	S	S
'IRBB 3'	Xa-3	R	R	S	S	MS	S
'IRBB 4'	Xa-4	R	R	S	S	MS	MS
'IRBB 5'	xa-5	R	MS	S	MS	MS	MS
'IRBB 7'	Xa-7	MS	R	S	S	MS	MS
'IRBB 8'	xa-8	R	MS	S	S	MS	MS
'IRBB 10'	Xa-10	MS	MS	S	S	MS	S
'IRBB 1h'	Xa-1h	MS	R	MS	R	R	R
'IR 8'	Xa-11	S	R	S	S	S	S
<i>M P Germplasm donors</i>							
'H 82'		S	MS	MS	S	R	MS
'S 885'		MS	R	MS	S	R	MS
'S 152 II'		S	R	MS	S	R	MS
'K 2264'		S	R	MS	S	R	R
'MW10'	(S check)	S	S	S	S	S	S
'Madhuri'	(S check)	S	S	S	S	S	S

R, resistant; MS, moderately susceptible; S, susceptible

Table 2 Inheritance and allelic relationships of gene(s) for resistance present in donors of M P rice germplasm against *Xanthomonas oryzae* pv *oryzae*

Cross	Isolate used	Reaction of F ₁	F ₂ segregation (No. of plants)			X ₂	Reaction of F ₃ families (No. of progenies)				X ₂
			R	S	Ratio(R:S)		R	Sg	S	Ratio(R:Sg:S)	
H 82 × MW 10	6-6R	R	448	145	3 : 1	0.094	22	48	20	1:2:1	0.489
S 885 × MW 10	6R	R	580	185	3 : 1	0.273	20	44	26	1:2:1	0.844
	6-6R	R	578	185	3 : 1	0.419	24	42	23	1:2:1	0.303
S 152 II × MW 10	6R	R	450	140	3 : 1	0.508	18	46	26	1:2:1	1.467
	6-6R	R	453	138	3 : 1	0.857	26	40	26	1:2:1	1.565
K 2264 × MW 10	6R	R	400	112	3 : 1	2.667	21	49	24	1:2:1	0.362
	6-6R	R	398	109	3 : 1	3.315	20	50	26	1:2:1	0.916
	6-7R	R	396	114	3 : 1	1.905	24	48	16	1:2:1	2.181
H 82 × IRBB 1h	6-6R	R	406	30	15 : 1	0.296	43	48	9	7:8:1	1.303
S 885 × IRBB 1	6R	R	600	47	15 : 1	1.130	41	45	9	7:8:1	1.719
S 885 × IRBB 2	6R	R	400	23	15 : 1	0.476	40	44	9	7:8:1	1.894
S 885 × IR BB 3	6R	R	550	31	15 : 1	0.829	36	38	7	7:8:1	0.905
S 885 × IRBB 4	6R	R	562	28	15 : 1	2.278	41	46	9	7:8:1	1.607
S 885 × IRBB 7	6R	R	600	50	15 : 1	2.307	32	38	7	7:8:1	1.085
S 885 × IRBB 1 h	6R	R	571	38	15 : 1	0.021	31	42	8	7:8:1	2.315
	6-6R	R	565	40	15 : 1	0.135	42	40	9	7:8:1	2.714
S 885 × IR 8	6R	R	481	37	15 : 1	0.704	45	46	9	7:8:1	1.566
S 152 II × IRBB 1	6R	R	340	26	15 : 1	0.455	45	46	9	7:8:1	1.566
S 152 II × IRBB 2	6R	R	575	40	15 : 1	0.067	40	42	8	7:8:1	1.051
S 152 II × IR BB 3	6R	R	543	27	15 : 1	2.227	38	42	8	7:8:1	1.234
S 152 II × IRBB 4	6R	R	418	34	15 : 1	1.248	41	43	9	7:8:1	1.992
S 152 II × IRBB 7	6R	R	405	20	15 : 1	1.729	42	44	8	7:8:1	1.947
S 152 II × IR BB 1 h	6R	R	380	28	15 : 1	0.261	43	46	9	7:8:1	1.534
	6-6R	R	384	26	15 : 1	0.006	41	46	9	7:8:1	1.607
S 152 II × IR 8	6R	R	380	23	15 : 1	0.203	38	42	8	7:8:1	1.234
K 2264 × IRBB 1	6R	R	540	34	15 : 1	0.104	40	47	9	7:8:1	1.616
K 2264 × IRBB 2	6R	R	394	28	15 : 1	0.106	36	42	8	7:8:1	1.375
K 2264 × IR BB 3	6R	R	534	44	15 : 1	1.831	41	46	9	7:8:1	1.607
K 2264 × IRBB 4	6R	R	485	40	15 : 1	1.679	41	47	8	7:8:1	0.711
K 2264 × IRBB 7	6R	R	431	22	15 : 1	1.501	42	44	9	7:8:1	1.947
K 2264 × IR BB 1 h	6R	R	441	23	15 : 1	1.324	42	45	9	7:8:1	1.688
	6-6R	R	445	25	15 : 1	0.695	38	40	9	7:8:1	2.616
	6-7R	R	449	25	15 : 1	0.770	36	41	8	7:8:1	1.450
K 2264 × IR 8	6R	R	401	37	15 : 1	0.632	42	44	8	7:8:1	0.978

R, Resistant; S, susceptible

sources of resistance. So far 17 genes for resistance against this disease had been identified and near isogenic lines with monogenic resistance for some of these genes have been developed (Ogawa and Khush 1988). Regular screening of Madhya Pradesh rice germplasm accessions has resulted in the identification of several highly resistant donors (Sharma *et al.* 1987). In the study, 4 such donors were investigated for the mode of inheritance and allelic nature of resistant gene(s) possessed by them in context of known genes so as to identify as many non-allelic sources of resistance as possible.

Experimental strains consisting of isogenic lines ('IRBB 1', 'IRBB 2', 'IRBB 3', 'IRBB 4', 'IRBB 5', 'IRBB 7', 'IRBB 8', 'IRBB 10', 'IRBB 1h', differential ('IR 8'), donors of Madhya Pradesh rice germplasm ('H 82', 'S 885', 'S 152II', 'K 2264')

and susceptible checks ('MW 10', 'Madhuri') were inoculated with 6 isolates of *Xanthomonas oryzae* pv *oryzae* prevalent in eastern Madhya Pradesh as described by Thrimurthy *et al.* (1993). Reaction specificity of donors of Madhya Pradesh rice germplasm with those of isogenic lines and differentials were taken into account while attempting crosses to study inheritance pattern. All the 4 donors were crossed with susceptible check 'MW 10' and with the isogenic lines resistant against the same specific isolate(s) for which a particular donor was resistant. Genetic studies were carried out by inoculating with the same specific isolate(s).

The parental strains were field screened during *khari* 1995. Crosses in different combinations were made in the same year. Half of the F₁ seeds were raised during summer

season so as to advance the generation to F_2 . Parents, F_1 and F_2 populations were field screened during *kharif* 1996. From each of the F_2 population, 100 plants were randomly selected and F_3 progeny were field screened during *kharif* 1997 so as to confirm the behaviour of F_2 population. Three meter long single row of parents and F_1 consisting of 20 plants each, 22 m long 5 rows of F_2 plants and one row each of the 100 randomly selected plants of F_3 were planted simultaneously under field conditions. For inoculation, 48 hr-old-cultures of different pathotypes were multiplied on potato sucrose peptone agar media and the test strains were inoculated with bacterial inoculum containing 10^{7-9} CfU/ml through clipping method (Kauffman *et al.* 1973) at maximum tillering stage. If necessary, different tillers of the same plant were inoculated with different isolates and were marked with different colour tags.

Host reactions were recorded 21 days after inoculation following (0–9 scale) standard evaluation system of IRRI (IRTP 1988). For genetic analysis, plants with scores 1–3 were classified as resistant and those with scores 5–9 as susceptible as per the standard procedure suggested in the standard evaluation system of IRRI (Anonymous 1988). χ^2 test was used for determining the goodness of fit of genetic ratio.

The overall reaction of isogenic lines, differentials and accessions of Madhya Pradesh rice germplasm against different isolates of *Xanthomonas oryzae* pv *oryzae* (Table 1) indicated that among the known genes involved in the screening Xa-3, Xa-4, Xa-5 and Xa-8 were resistant against isolate 6; Xa-1, Xa-2, Xa-3, Xa-4, Xa-7, Xa-11 and Xa-1^h against 6R and Xa-1^h was resistant against 6-5R, 6-6R and 6-7R isolates. Among the donors of Madhya Pradesh rice germplasm, 'H 82' was resistant against isolate '6-6R', 'S 885', 'S 152 II' and 'K 2264' were resistant against isolates 6R and 6-6R. K 2264 also showed resistance reaction against isolate 6-7R.

Resistant reaction of F_1 plants from crosses between the resistant donors H 82, S 885, S 152 II and K 2264 and susceptible parent MW 10, their 3R : 1S segregation in F_2 and 1R : 2Sg : 1S segregation ratio of their F_3 progeny confirmed the presence of single dominant gene for bacterial blight resistance in H 82, S 885, S 152 II and K 2264 (Table 2). Allelic tests with resistant isogenic lines and differentials (Table 2) indicated that gene(s) for resistance possessed by H 82, S 885, S 152 II and K 2264 were different from Xa-1, Xa-2, Xa-3, Xa-4, Xa-7, Xa-11 and Xa-1^h genes. This was evident from 15R : 1S segregation ratio in F_2 when H 82, S 885, S 152 II and K 2264 were crossed with the parents carrying the known dominant resistant gene (IRBB-1, IRBB-2, IRBB-3, IRBB-4, IRBB-7, IR 8, IRBB-1^h). Their F_3 population segregated in 7R : 8Sg : 1S ratio confirming the F_2 results. The known bacterial blight resistant genes xa-5, xa-8 and Xa-10 showed susceptible reaction against all the isolates for which the Madhya Pradesh Rice Germplasm donors H 82, S 885, S 152 II and K 2264 showed

resistant reaction (Table 1). Thus the screening and allelic results clearly indicated that gene(s) for resistance present in donors of Madhya Pradesh rice germplasm were different from Xa-1, Xa-2, Xa-3, Xa-4, xa-5, Xa-7, xa-8, Xa-10, Xa-11 and Xa-1^h genes.

Sidhu *et al.* (1986) reported that none of the genes from Xa-1 to Xa-11 is effective in Punjab and the resistance to bacterial leaf blight in many rice appear to be due to new and yet undesignated genes. Non-allelic nature of genes for bacterial blight resistance present in Madhya Pradesh rice germplasm donors from that of Xa-1, Xa-2, Xa-3, Xa-4, xa-5, Xa-7, xa-8, Xa-10, Xa-11 and Xa-1^h genes have also been reported by Kumar *et al.* (1997). However, these donors need to be also studied for the allelic nature of the resistant gene present in them with Xa-12, xa-13, Xa-14, Xa-17 and Xa-21 genes identified at international level.

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Bio-potency of insecticidal crystal proteins of *Bacillus thuringiensis* against cotton (*Gossypium hirsutum*) bollworms*

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Key words : insecticidal crystal protein, *Bacillus thuringiensis*, Δ -endotoxins, *Helicoverpa armigera*, *Spodoptera litura*, *Earias vittella*

Insecticidal crystal proteins of *Bacillus thuringiensis* Berliner (Bt) gained spectacular significance in the context of transgenic cotton development programmes worldwide in recent years. A thorough knowledge on the bio-potency of insecticidal crystal proteins of *Bacillus thuringiensis* is essential for such a successful programme. Keeping in view, a comprehensive laboratory bioassay was done against three cotton bollworms, viz spotted bollworm (*Earias vittella* Fab.), American bollworm (*Helicoverpa armigera* Hubn.) and

tobacco budworm (*Spodoptera litura* Fab.) by artificial diet surface-incorporation technique. Perusal of literature reveals that limited work has been conducted on this aspect for *Helicoverpa* spp while that on *E. vittella* and *S. litura* is lacking.

Insects culture and standardization/modification of artificial diets

The artificial diet as suggested by Nagakatti and Satyaprakash (1974) for *Helicoverpa armigera* and Okamoto and Okada (1968) for *S. litura* were perfected for our laboratory condition. The diet-composition is presented in Table 1.

Artificial diet for *E. vittella* was standardized in our

* Short note

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Table 1 Comprehensive table for composition of modified artificial diets of *H. armigera*, *E. vittella*, and *S. litura* larvae

Constituents	<i>H. armigera</i>	<i>S. litura</i>	<i>E. vittella</i>
Fraction A			
Chickpea seeds	77.68g		35.0 g
Cotton seeds*			50.0 g
Wheat germ	5.60 g		5.0 g
Kidney bean flour		65.0 g	
Wheat bran		65.0 g	
Fraction B			
Agar-agar	12.00 g	10 g	15.0g
Fraction C			
Dried yeast powder	19.20 g	25.0 g	8.0 g
Casein	12.80 g	3.0 g	1.0 g
Ascorbic acid	4.60 g	4.0 g	1.2 g
Methyl-p-hydroxybenzoate	1.52 g	0.4 g	1.0 g
Sorbic acid	0.80 g	0.92g	1.0 g
Streptomycin sulphate	0.16 g	0.1 g	0.2 g
Cholesterol	0.16 g	0.25g	0.2 g
Becosule capsule		1 cap	
Olive oil		2–3 drops	
Formaldehyde (40%)	1.00 ml	0.80 ml	
Multivitamin		0.80 g	1 cap
ABDEC drops	0.80 ml		
α tacopherol (Vitamin E)	0.08 ml		1 cap
Distilled water	400 ml	600 ml	400 ml

* 'Pusa 8–6' cotton seeds

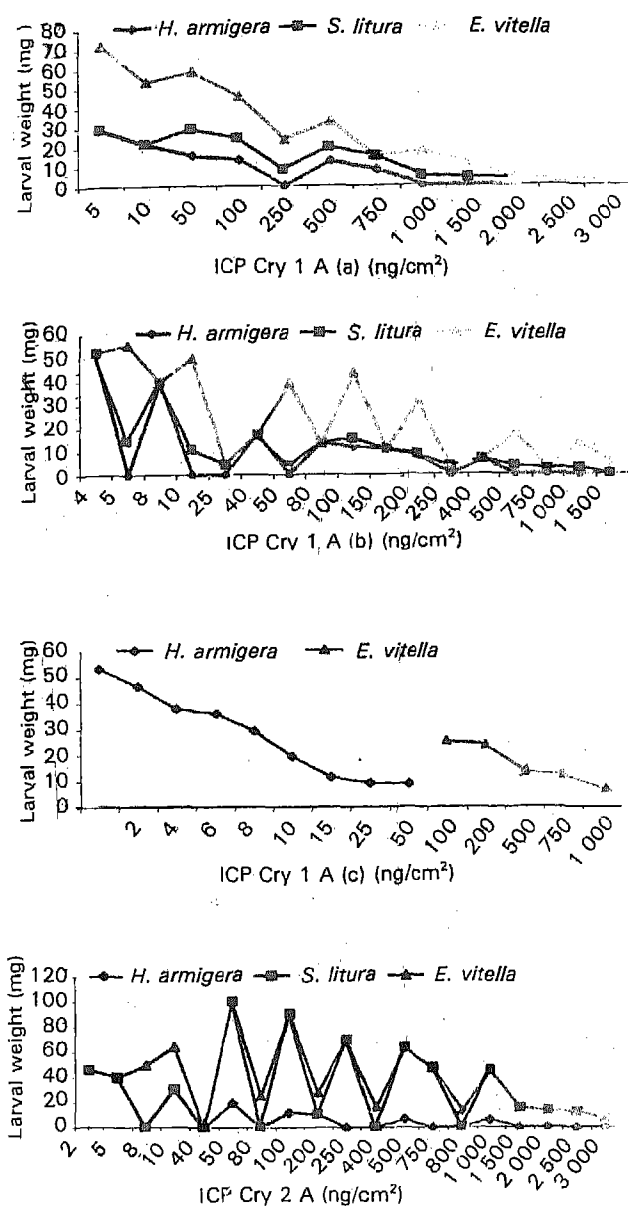


Fig 1 Effect on insecticidal crystal proteins on mean larval weight of cotton bollworms

laboratory according to Gupta *et al.* (1998). The test insects were maintained on the artificial diet for 8 generations without any adverse effect on the growth and development. The insect cultures as well as the bioassay was carried out at $27 \pm 1^\circ\text{C}$ temperature, $60 \pm 5\%$ relative humidity and 16D : 8L regime in culture room and incubator.

Preparation of insecticidal crystal proteins of *Bacillus thuringiensis*

Escherichia coli cell-culture was grown in 400 ml of Luria broth medium with Ampicillin (100 µg/ml) on a shaker at $37 \pm 1^\circ\text{C}$ for 48 hr. Cells were harvested by centrifugation at 10000 rpm for 10 min in Beckman J 2-21 centrifuge, J 14 rotor. The

cell pellets were resuspended in 100 ml lysis buffer (50 mM Tris, pH 8.0; 50 mM EDTA and 15% sucrose). After adding Lysozyme @ 0.5 mg/ml, incubation was done at 37°C with slow-shaking for 2 hr to overnight. Then the content was centrifuged and resuspended in 50 ml of Crystal Wash I (0.5M NaCl, 2% Triton-X 100). The sample was then sonicated by Sonifer 450 (Branson). Centrifugation and washing the pellets thrice with Crystal Wash I was done, followed the same with Crystal Wash II (0.5 M NaCl), and thrice more with sterile distilled water. Finally, the crystal was stored in distilled water at 4°C (Hoftey *et al.* 1986).

Solubilization of protein

The final sample was centrifuged, and the pellets were resuspended in 5–10 ml of solubilization buffer [50 mM sodium carbonate and 10 mM dithiothreitol, referred as 'standard solvent' (Huber *et al.* 1981)]. After incubation at 37°C for 3–4 hr with slow shaking, the solubilized crystal protein was quantified using bovine serum albumin as a standard (Bradford 1976).

Bioefficacy test of cry proteins by artificial-diet surface incorporation method

The insecticidal crystal proteins as obtained in the above procedure were used for the bioassays. Artificial diet was poured in the wells of multicellular tissue culture plates (12 cm × 8 cm) with 24 wells and in each well, appropriate amount of solubilized insecticidal crystal proteins was spread on surface by micro-pipette @ 50 µl/well containing calculated amount of the insecticidal proteins. Larvae of test insects (neonates of *H. armigera*, *S. litura*, and 3rd instar of *E. vittella*) reared on artificial diet were released to the multicellular tissue culture plates. Mortality data was recorded after 6 days of incubation at $27 \pm 1^\circ\text{C}$ and $60 \pm 5\%$ relative humidity, and the data was subjected to probit analysis (Finney 1981) after correction by Abbott's formula (Abbott 1925). Besides LC_{50} value, the larval weight (after termination of 6-day of exposure period) was taken in all treatments. The larval weights were correlated with the concentrations of insecticidal crystal proteins and the functional relationships were verified using MS-Excel (MS-Office 97) package.

The response of cotton bollworms to insecticidal crystal proteins of *Bacillus thuringiensis* is tabulated along with their regression equations (Table 2). Cry IA(c) was found 60-fold more toxic than Cry IA (a), by 9-fold than that for Cry IA(b), and about 13-fold more toxic to Cry IIA against *H. armigera* neonates. Padidam (1992) also reported in the case of this species that Cry IA(c) was more toxic than Cry IA(a) and IA(b). He found 12-fold higher toxicity for Cry IA(c) than Cry IA(b). Our result shows that Cry IA(b) was 1.7 times more toxic than Cry IA(a) for *S. litura* neonates. Similarly, Cry IA(c) was observed to be the most toxic among the four insecticidal crystal proteins tested, ie, Cry IA(a), Cry IA(b), Cry IA(c) and Cry IIA for the third instar larvae of *E. vittella*.

Larval weight as influenced by insecticidal crystal

Table 2 Concentration-mortality responses for cotton bollworms

Insecticidal crystal proteins (ICP)	*LC ₅₀ values (ng/sq cm)		
	<i>H. armigera</i> ← (neonates) →	<i>S. litura</i>	<i>E. vittella</i> (3rd instar)
Cry IA(a)	431.9 (Y=2.284+0.942x)	712.3 (Y=-0.35+1.725x)	224.5 (Y= 2.313 + 1.03 x)
Cry IA(b)	67.6 (Y=2.885+1.018x)	417.2 (Y= 3.35 + 0.57x)	229.3 (Y=-0.924+2.175x)
Cry IA(c)	7.1 (Y=3.340+1.514x)	Not tested	142.1 (Y= 2.651+ 0.978x)
Cry IIA	91.7 (Y=3.309+0.765x)	786.4 (Y=0.40 + 1.46x)	162.8 (Y=2.33+1.085x)

*LC₅₀ values were calculated by the concentration-mortality response study by probit analysis (Finney 1981)

proteins against the 3 bollworms were illustrated in Fig 1. Reduction in larval weight was observed in all cases demonstrating the growth retarding effect of insecticidal crystal proteins. Stoppage of feeding (anorexia) caused by insecticidal crystal proteins in susceptible insects are well known. Deterrence refers to effects on the behaviour of insects that cause them to consume less *Bacillus thuringiensis* (Dethier *et al.* 1960); it refers to effects on sensory responses not directly related to intoxication and paralysis of the gut. Less larval feeding leads to reduction in larval weight. The functional relationship between the concentration of insecticidal crystal proteins tested and mean weight of survived larvae revealed a logarithmic trend. The coefficients of determination were significant ($R^2 > 0.90$) in almost all cases of insecticidal crystal proteins tested (0.96, 0.93, 0.92, 0.96 and 0.95, 0.86, 0.97, 0.94 for Cry IA(a), Cry IA(b), Cry IA(c), Cry 2A tested on *H. armigera* and *E. vittella* respectively and 0.98, 0.72, 0.92 for Cry IA(a), Cry IA(b), Cry 2A tested on *S. litura*).

The data depicts that *H. armigera* is more susceptible to Cry proteins than *S. litura*. LC₅₀ value of Cry IA(c) for *H. armigera* was the least (7.1 ng/cm²). The mechanism of *Bacillus thuringiensis* Δ -endotoxins involves its binding to the midgut receptors, insertion into the membrane and pore formation. It is possible that different insecticidal crystal proteins have different receptors and pore formation ability in the midgut epithelium. Therefore, there is variation in efficacy in different caterpillar species; and within same species, different insecticidal crystal proteins act differently. From the above discussion, it is concluded that, in any transgenic plant development programme, it should be kept in mind that the expression of *Bacillus thuringiensis* toxins in the engineered plant should be sufficient to be effective in controlling all the associated bollworms prevailing in the agro-ecosystem.

ACKNOWLEDGMENT

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Damage potential of *Helicoverpa armigera* in linseed (*Linum usitatissimum*)*

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Key words : linseed, *Linum usitatissimum*, cultivars, tolerance, *Helicoverpa*, epidemic larval, density, damage potential, correlation yield

The gram caterpillar, *Helicoverpa armigera* (Hubner) is a predominant species causing economic damage to most

of the crops (Jayaraj 1982). Although, its infestation on linseed (*Linum usitatissimum* L.) has been reported to be of lesser significance (Gill 1987) yet no efforts have been made so far to document the extent of damage by this polyphagous pest in linseed crop under epidemic situations. Since, linseed is next to rapeseed-mustard in India in terms of area as well as production and a number of elite cultivars have been evolved the aim of the present

*Short note

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Table 1 Capsules/plant, larval density of *H. armigera*, magnitude of damage and yield in linseed cultivars

Cultivar	Capsules/plant	<i>H. armigera</i> larval density/10 plants	Damage to capsules	Seed yield (kg)
'OL 19-11'	13.6	12.0(3.4)*	61.1(51.6)**	208.1
'OL 18-4'	16.0	9.5(3.1)	63.0(53.1)	199.1
'OL 92-2-2'	12.8	9.5(3.1)	40.6(39.5)	612.1
'OL 93418-2'	12.6	12.0(3.4)	71.3(57.8)	118.0
'OL 3-11'	9.4	9.0(2.9)	76.6(67.3)	214.8
'OL 20-1'	12.3	15.0(3.8)	52.3(46.3)	197.4
'OL 3-2'	17.5	11.0(3.8)	55.0(47.9)	204.1
'OL 9344-1'	13.8	10.0(3.1)	42.9(40.8)	369.7
'OL 1-3'	11.1	16.0(3.9)	78.7(62.7)	175.5
'OL 2-7'	11.0	12.0(3.5)	56.0(48.5)	152.2
'OL 2-4'	4.2	10.5(3.2)	81.1(64.5)	15.9
'OL 3-1'	11.5	14.5(3.7)	79.4(63.0)	83.4
'OL 2-3'	6.3	12.0(3.4)	52.1(46.2)	47.8
'OL 22-1'	13.5	13.0(3.6)	34.5(35.8)	246.3
'OL 9349-2'	10.4	15.0(3.8)	73.5(59.6)	52.9
'OL 4-1'	6.6	8.5(2.9)	75.0(59.6)	52.9
'OL 92-4-2'	14.0	8.0(2.8)	54.5(47.6)	221.7
'OL 2-5'	6.7	15.5(3.9)	97.9(83.6)	13.0
'OL 92-16-3'	15.5	14.5(3.8)	44.9(42.1)	189.5
'OL 7-7'	13.2	15.0(3.8)	76.2(61.9)	68.8
'OL 93418-1'	15.8	20.5(4.5)	64.8(53.7)	112.7
'OL 93414-3'	7.9	13.0(3.6)	77.2(68.2)	76.8
'OL 19-6'	17.2	14.0(3.7)	62.0(51.9)	182.2
'OL 93421-1'	16.8	11.0(3.3)	33.1(35.1)	309.5
'OL 92-4-3'	12.4	14.0(3.7)	85.8(67.9)	61.5
'OL 93410-1'	18.6	13.5(3.6)	55.3(48.0)	227.4
'RLC-29'	17.1	18.5(4.3)	69.0(56.6)	38.5
'T-397'	11.3	12.0(3.5)	72.7(58.5)	64.1
'CD (P = 0.05)'	7.0	0.6	18.6	88.8

* Figures in parentheses are square root transformed values, **Figures in parentheses are corresponding angular values

Table 2 Influence of *H. armigera* larval density and capsules/plant on the magnitude of damage and yield in linseed

Correlation between the variables	Correlation coefficient(r)	Coefficient of determination (r^2 in %)
Larval density and damage to capsules	0.259	6.7
Larval density and yield	-0.399**	15.9
Larval density and capsules/plant	0.210	4.4
Damage to capsules and yield	-0.717**	51.5
Capsules/plant and damage to capsules	-0.509**	25.9
Capsules/plant and yield	0.422*	17.8

*P = 0.05 ; ** P = 0.01

study was to enunciate promising cultivars having tolerance to *H. armigera*.

A field experiment was conducted during 1997–98 at the Regional Research and Technology Transfer Station, Keonjhar (Orissa). Twenty eight linseed cultivars obtained from Kanpur were evaluated against *H. armigera* and replicated twice in a randomized block design. Each cultivar was sown in 6 rows of 5 metre length with spacings of 25 cm. The crop sown during last week of November was raised under pesticide free conditions following recommended agronomic practices.

The larval density of *H. armigera* at capsule formation stage and the percentage of infested capsules at harvest were recorded on 10 randomly selected plants. The capsule damage and larval density were correlated separately with yield and that of capsules/plant and analysed following standard statistical procedures.

Significant variation in larval population (8.0–20.5 / 10 plants) with respect to the test cultivars was observed (Table 1). Among the cultivars, 'OL 92-4-2', 'OL 4-1', 'OL 3-11', 'OL 18-4', 'OL 92-2-2' and 'OL 9344-1' harboured comparatively low larval density (< 10/ 10 plants) of *H. armigera*.

The capsule damage ranged from a minimum of 33.1 % (OL 93421-1) to a maximum of 97.9 % ('OL 2-5') with the average being 63.8 %. However, low capsule damage (33.1–42.9 %) with low to moderate larval density of 9.5 to 13.0/ 10 plants was recorded on the cultivars, viz OL 92-2-2, OL 9344-1, OL 93421-1 and OL 22-1. The cultivars OL 93418, OL 3-11, OL 2-4 and OL 4-1 sustaining high damage (71.3–81.1 %) with comparatively low larval density (8.5–12.0/10 plants) were preferred by *H. armigera*.

The larval activity during flower initiation stage was found maximum during the last week of February which coincided with capsule formation. Low minimum temperature (13.2–14.1 °C) coupled with high humidity (66.9–73.2 %) in December–January possibly favoured the outbreak of *H. armigera* in February. Earlier, Patnaik and Senapati (1996) have reported

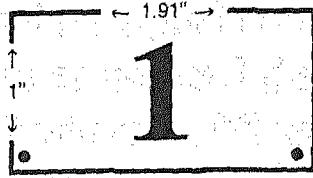
peak egg density of *H. armigera* within the thermal ranges of 11.5 °C to 24.6 °C and 72.2 % RH. The buildup of egg population seems to have taken place during January coinciding with flower initiation stage which concurrently led to perceptible larval activity at capsule formation stage in February causing extensive damage to the crop.

The capsule damage had inverse relationship with the number of capsules/plant ($r = -0.509^{**}$; $r^2 = 25.9\%$) (Table 2). Thus, capsules/plant could be an useful tool for determining the yield (13.0–612.1 kg/ha) following *H. armigera* damage to capsules ($r = -0.717^{**}$; $r^2 = 51.5\%$). Increase in larval population density resulted in reduction in yield ($r = -0.399^{*}$; $r^2 = 15.9\%$) and a reduction of 4.7 % in yield was recorded following an increase of one larva/10 plants. Among the cultivars tested 'OL 92-2-2' yielded maximum of 612.1 kg/ha followed by 'OL 9344-1' (369.7 kg/ha) and 'OL 93421-1' (309.5 kg/ha).

It is concluded from the studies that *H. armigera* can cause extensive yield loss in linseed. Since, erratic and variable cyclic incidence of this polyphagous pest is common (Lal *et al.* 1981) owing to changes in the climatic conditions adoption of linseed cultivars 'OL 92-2-2', 'OL 9344-1' and 'OL 93421-1' yielding reasonably (> 300 kg/ha) and showing tolerance to *H. armigera* infestation is suggested.

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Date of Sowing

Germination Period

Germination % Days

Seedling Survival %

No. of Poly. Bags

No. of Plants



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