CROP PRODUCTION

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Research review

Status of research and management of coastal saline soils for increasing crop productivity and future scope for improvement

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ABSTRACT

The review suggests improved management practices for the coastal saline soils. In the soils showing poor water-transmission property, addition of amendments like sand, rice husk or rice straw was found beneficial to improve leaching under limited water availability. Presence of subsurface drains also helped in increasing the leaching of salts in silty clay-loam soil. To increase nitrogen-use efficiency of waterlogged rice (*Oryza sativa* L.), volatilization loss could be effectively checked through its placement at 5 cm soil depth. Slower mineralization of organic nitrogen in saline soil and inadequate use of fertilizer nitrogen are the other reasons for poor nutrition of the crop. Availability of phosphorus depends on the *p*H and salinity of the soil, whereas potassium reserve in the soil is normally high, and therefore its application may be avoided in most of the soils. In view of the rising energy cost and limited input availability, recycling of organic wastes and use of renewable sources of bio-fertilizers as an integrated nutrient-management package prove useful for sustained production. Since irrigation water is scarce, additional surface resource may be created by storing the excess rainwater in monsoon in the dug-out pond in one-fifth of the farm holdings for multiple cropping. Underground water is under-utilized in coastal areas, and if properly utilized, along with surface sources, 43.86 million ha (forming 50% of the total cultivated area) may be brought under irrigation by 2010 AD. The coastal lands need protection against tidal inundation through protective embankments, designed suitably, preferably brick-pitched, with 1 m free board above the high-tide level. Planting of wind-breaks is useful in preventing wind erosion, particularly in areas having sand dunes. Excess rainwater in monsoon should be channelized through primary and secondary drains and let out through one-way sluice gate, designed to meet the drainage coefficient of the catchment. The existing low cropping intensity with generally only 1 crop of rainfed rice should be improved through multi-tier cropping systems, involving arable, horticultural, plantation and forest species along with improved soil, fertilizer and water management for greater land use and increased productivity.

In India coastal region covers more than 6 000 km strip along the East Coast (West Bengal, Orissa, Andhra Pradesh, Pondicherry and Tamil Nadu) and West Coast (Gujarat, Maharashtra, Karnataka and Kerala). It also occupies considerable area under Lakshadweep in the Arabian sea and the Andaman and

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Nicobar group of islands in the Bay of Bengal. Yadav *et al.* (1983) reported that the coastal saline soils are spread over 3.1 million ha, comprising more than 30% of the total salt-affected soils in India. This estimate includes 0.26 million ha of acid sulphate soils in Kerala and the Andaman and Nicobar group of islands (Singh *et al.* 1987), and 0.573 million ha under mangrove vegetation.

The area generally lags much behind the inland areas in terms of crop productivity, mainly because of unfavourable climate and the poor soil and hydrological conditions.

PROBLEMS OF COASTAL REGION

Climate

The coastal region is characterized by diverse ecosystems, having humid, subhumid or arid climate (CSSRI, Canning 1988). The annual rainfall is high in the coastal areas of Kerala, Andaman and Nicobar group of islands and West Bengal (1 750–3 000 mm) to very low in those of Saurashtra (650 mm) in Gujarat. Besides, its annual distribution is unimodal or bimodal, causing severe waterlogging to extreme moisture stress in the soil during different times in a year. The typical maritime climate of mild and short winter, fairly high relative humidity, low sunshine hours (3–7 hr daily) and high annual evapotranspiration (1 350–2 150 mm) are important considerations influencing the cropping pattern and the method of cultivation. Cyclone, particularly along the east coast, often dictates the cultivation at a few vulnerable places.

Physiography and soils

Most of the coastal areas have problematic soils, such as saline, alkaline, acid sulphate, and marshy and waterlogged soils, situated in low-lying areas, mainly along the deltas. Soil characteristics of this region vary widely, depending on their physiographic and climatic conditions. They are mostly heavy textured with salinity (electrical conductivity) 0.5 dS/m in monsoon to 50 dS/m in summer. Mostly NaCl followed by Na_2SO_4 are the dominant soluble salts. However, in acid sulphate soils of Kerala and Andaman and Nicobar group of islands Na_2SO_4 is the dominant salt. Normally there is abundance of cations in soluble salts in the order: Na > Mg > Ca > K. Chloride is the predominant anion, whereas bicarbonate occurs in traces and carbonate is absent. The soils in general are free from sodicity, except in a few pockets of south and west coast, where the sodium-absorption ratio exceeds 15 and attains value as high as 40. Most of the soils along the coast are slightly acidic to neutral or neutral to slightly alkaline (Yadav *et al.* 1983). Besides, there are location-specific problems, viz sea-water intrusion in unbunded low-lying areas, iron toxicity in Orissa, impeded drainage in 0.36 million ha area in coastal Andhra Pradesh and Tamil Nadu along the east coast as well as in parts of Kerala and Gujarat along the west coast, highly permeable sandy soils in parts of Gujarat, and highly leached low-fertility lateritic soils with severe erosion problem along with undulating topography in some parts of Maharashtra, Goa, Karnataka and Kerala (Kadrekar 1994, Subba Rao *et al.* 1994). In a few pockets of Sundarbans in West Bengal, subsurface soils show acidic layers (Bandyopadhyay and Sarkar 1987). The pyrites and other metal sulphides present in the reduced subsoils, when brought on to the surface, undergo oxidation and produce free sulphuric acid, which imparts strong acidic character to the soil. Further, in a few areas though the surface horizons are acidic, subsurface horizons still show the presence of free calcium carbonate (Maji *et al.* 1990). The soils of Lakshadweep islands are essentially coral sandy, calcareous and alkaline, whereas those of the Andaman and Nicobar group of islands are acidic, as well as low in organic matter and available phosphorus (Singh *et al.* 1988).

In view of poor nitrogen recovery by the crops due to heavy loss of the nutrient, particularly in saline and alkaline soils and also in deep waterlogged areas, by volatilization, leaching and run-off, fertilizer consumption is usually low. Out of 132 districts in the coastal states, 82 have fertilizer consumption of less than 50 kg/ha and 36 even less than 25 kg/ha (Dhar 1991).

Hydrology

Hydrology in the coastal areas is related mainly to rain-water management. Most of the area except north Gujarat is situated in humid and subhumid tropical regions and is low-lying with elevation of 4 m above the mean sea-level to even below the sea level. As a result, these areas suffer from (*i*) flooding by the river waters because of limited carrying capacities of river channels, having silted-up beds with flat gradients, (*ii*) inundation with sea-water, as a major portion of the area may be below the maximum high-tide level, (*iii*) serious surface-water congestion during the monsoon due to lack of surface drainage and outlets, (*iv*) ground water of high salinity, and (*v*) lack of irrigation facilities. Thus flood control, adequate drainage, rain-water conservation and ground-water utilization are the different components requiring appropriate attention (Rao 1991).

Cropping system

The net sown area of the east coast plains is 8.58 million ha, with a cropping intensity of 134%. The west coast has a net sown area of 2.77 million ha, with a cropping intensity of 125% (Subba Rao *et al.* 1994). Rice (*Oryza sativa* L.)-based cropping system is by far the most common in coastal areas, but the yield is much lower than in many countries. Mono or multiple rice cultivation, in vogue in several areas, impairs soil fertility greatly, declining the productivity (Yadav 1994). Small size of average operational holdings, as found in Kerala (0.36 ha) and West Bengal (0.92 ha), requires further change in the cropping system. Research focus for a long time has been on a single crop, and was not directed towards multiple cropping to meet the requirement of a mixed system that the farmer is interested in.

MANAGEMENT AND RECLAMATION PRACTICES

Soil management

Soil salinity is the main problem limiting crop growth in the coastal saline belt. Since the source of soil salinity is primarily the ground water-table enriched with salts present at shallow depth, the permanent reclamation of land is difficult and expensive. It is therefore necessary to reduce soil salinity to improve crop productivity. Suitable soil-management practices are to be evolved for successful crop cultivation. Under the condition of limited water availability, leaching of salts in the fine silty clay-loam soils, characterizing poor transmission property, with addition of amendments like sand, rice husk or rice straw, and its effect in crop yield was studied by Bandyopadhyay and Sen (1977) and Sen and Bandyopadhyay (1984). The role of spacing of 1.8 m deep open subsurface drains in removal of salts from the profile of a silty clay-loam soil was also studied (CSSRI, Canning 1988), showing leaching of 14 075 kg salt/ha at 15 m spacing. In 1964 (Talati 1971) attempts were made in Gujarat to reclaim 240 ha coastal saline soils by leaching in the presence of shallow drains 75 cm deep, spaced 65 and 115 m apart. During the 2 years of ponding, the initial salt content of 4.7 – 7.4% in the root zone decreased to 0.6 – 1.2%. With adequate availability of water, continuous ponding under multiple rice cropping proved useful in a silty clay-loam soil, since salts were leached from the entire soil profile up to 75 cm depth from an initial electrical conductivity 10 dS/m to a final value of 5 dS/m (Bandyopadhyay and Sen 1977).

Fertilizer management

Nitrogen: Most of the coastal saline soils are deficient in nitrogen. Besides, lesser utilization of nitrogenous fertilizer, mineralization of organic nitrogen in the soil and thus the release of native soil nitrogen to the plant in available form is very much slow in the salt-affected soils due to decrease in microbial population and their activities at the high salinity level. Bandyopadhyay and Bandyopadhyay (1983) revealed that the rate of both mineralization and immobilization of nitrogen in soil decreased considerably at salinity of ECe 10 dS/m and above. The increasing loss of nitrogen through NH_3 volatilization from applied nitrogenous fertilizer with increase in soil salinity was studied by Sen and Bandyopadhyay (1987), who further showed that this loss could be effectively reduced through placement of fertilizers at 5 cm soil depth (Sen and Bandyopadhyay 1986).

Phosphorus: The level of phosphorus in the coastal saline soils is highly variable and depends greatly on the nature and degree of salinity (Yadav 1980). The availability of soil phosphorus largely depends on the *p*H of the soil developed after hydrolysis of the salt. The increase in soil *p*H on hydrolysis reduces the availability of soil phosphorus. Very little work has been done on the transformation and availability of P to crops in coastal saline soils.

Potassium: The availability of potassium depends largely on the parent materials, clay minerals and weathering conditions. It also depends on the nature and amount of salts in the soil. Bandyopadhyay *et al.* (1985) reported that the coastal saline soils are rich in water-soluble, exchangeable, non-exchangeable and available K. High potassium-buffering capacity (PBC^K) and Gibb's free energy (ΔF) also indicate that the coastal saline soils have high potassium-supplying capacity.

In a long-term experiment conducted for 11 years, Bandyopadhyay and Maji (1990) observed that grain yield of crops in rice–barley (*Hordeum vulgare* L. sensu lato) rotation increased significantly only due to the application of N. Application of P did not lead to any significant increase in the yield of crops in the initial 8 years, after which the yield of barley alone increased. Available K content was high in the soil. The result indicates that a basal dose of 11 kg P/ha for rice and 5.5 kg P/ha for barley or for similar upland crops should maintain the fertility status of the soil, whereas K application may be omitted without any detrimental effect on soil fertility or crop yield. The K removal by the crop was compensated by K added through salt accumulation and release of non-exchangeable sources.

Micronutrients: Very little work has been done on the role of micronutrients in coastal saline soils. The soils are generally rich in micronutrients such as Fe, Mn, Zn, Cu, B and Mo. Maji and Bandyopadhyay (1989, 1990) revealed that the application of micronutrients to crops like safflower (*Carthamus tinctorius* L.) and rice either through soil application or foliar spray may not be beneficial to the crops. The coastal saline soils are subjected to great change in the chemical environment of the soil on submergence. Maji and Bandyopadhyay (1992) further found that on submergence the diethylene triamine pentaacetic acid extractable Fe and Mn contents of the soil increase but Cu content decreases.

Alternative source: Use of green-manure crops like prickly sesban [*Sesbania cannabina* (Retz.) Pers., syn *S. aculeata* Pers. var *cannabina* Baker] proved highly suitable for saline alkali soils (Keating and Fisher 1985, Evans and Rotar 1986). In favourable climate with proper management these crops accumulate more than 100 kg N/ha, mostly through biological N fixation, in 50–55 days, thereby increasing the yield of the following rice crops significantly (Singh *et al.* 1991). Likewise, application of green leaves of madre tree [*Gliricidia maculata* (H.B. & K.) Steud.] @ 10 tonnes/ha to the puddled soil before rice transplanting gives yield comparable to that given by inorganic fertilizer N, P and K @ 100, 50 and 50 kg/ha respectively (Chavan and Dongale 1994). Buresh and De Datta (1991), however, reported that N from leguminous green-manure and its residue normally meets only partial requirement of N for the following high-yielding rice variety. They reported high loss of N under the anaerobic–aerobic soil cycles typical of legume–lowland rice sequence, as well as higher production of methane and nitrous oxide from the lowland rice field. However, in view of the rising energy cost and limited input availability, recycling of organic wastes and use of renewable sources of bio-fertilizers, viz rhizobium cultures for pulse or legume and blue-green algae for waterlogged rice field, may play significant role in terms of integrated nutrient management for rice field (Kundu and Pillai 1992) in coastal saline areas.

Water management

Irrigation: In the east coast the areas substantially irrigated are south coastal Andhra Pradesh (56%), north coastal Tamil Nadu (57%) and Thanjavur delta (86%). In the west coast the extent of irrigation is much less, except the coastal districts of Karnataka (33%) (Raman *et al.* 1988).

As a significant portion of the river water is not chemically suitable for irrigation, and small and scattered land holdings generally occur in coastal areas, minor irrigation should assume greater importance than major irrigation in these areas. If all the surface and underground water resources are fully utilized, 43.86 million ha (50%) of total cultivated area may be brought under irrigation by 2010 AD (Raman *et al.* 1988).

Out of the different sources for minor irrigation, dug-out farm pond is particularly relevant for marginal and small farmers in coastal areas (CSSRI, Canning 1988). According to this method, irrigation resource may be created within the farm by harvesting excess rain-water and storing it in these ponds excavated up to 3 m depth on one-fifth land holding. The stored rain-water may be used to raise a second irrigated crop, with water requirement preferably not exceeding 15–20 cm. Even a third irrigated crop may be raised with the remaining water on one-third area of the land holding. It is estimated that even if 50% of the rain-water harvest is utilized, nearly 1 million ha-m irrigation source may be created in the coastal belt by this method. For life-saving irrigation of crops, improved (*doruvu*) technology (Rao 1991, Subba Rao *et al.* 1994) may be used, in which seeped-in water is collected in a conical pit, that may occupy one-fifth land holding to irrigate the rest area.

Flood control and drainage: Different aspects of flood control and drainage in coastal areas have been discussed and improved methods have been suggested (CSSRI, Canning 1988, Rao 1991). The land should be protected from tidal inundation through protective embankments with 3 : 1 slope at the river-end and 2 : 1 slope in the country-end, having 1 m free board above the high-tide level. Brick-pitching of earthen embankments, wherever possible, and planting of wind breaks (Nanda and Rai 1979) in areas having problems of coastal sand dunes proved useful. Excess rain-water, after retaining

20–25 cm water on rice fields, should be channelized through primary and secondary drains, appropriately designed, and let out through one-way properly designed sluice gate, installed on the river banks or any other suitable location, to meet the drainage coefficient for the area (Dhruvanarayana 1977, Rao and Dhruvanarayana 1979).

Crop management

The existing cropping intensity in coastal areas is low. The scope to increase the intensity in a rice-oriented cropping system should depend largely on the soil conditions and water availability. Multi-tier cropping systems involving arable cropping, horticultural and plantation crops, as well as agro-forestry should be given greater attention for better land use in these areas (Ghosh *et al.* 1991, Yadav 1994).

RESEARCH GAP AND FUTURE LINES OF WORK

It is necessary to prepare an inventory on the fertility status and water resource of the coastal belt on which informations are not adequate. Location-specific researches are warranted to develop integrated nutrient-management package, involving inorganic–organic–biofertilizer sources for sustainable crop production. Acid sulphate soils should be characterized in greater details, to help develop appropriate and location-specific management for improved crop productivity of these soils. Research is required for developing appropriate models on salt and water dynamics in soil and suggest improved water management in a given watershed. Study is necessary to improve leaching efficiency of the heavy textured soils under limited water availability. It is necessary to develop low-cost irrigation technology with higher efficiency. Additional water resources through harvest of excess rain-water may be created. Improved irrigation methods for conjunctive use of poor-quality water needs emphasis in future. For drainage and flood control, location-specific designs should be developed on a long-term perspective. Little attention has been paid in the past to meet these challenges scientifically. It is also important to develop contingency plans with the help of advanced telecommunication facilities to avoid cyclone and flood damage in sensitive areas. The feasibility of alternative land use with multi-tier cropping system has to be developed. Improved high-yielding lines with higher tolerance to salinity and moisture stress should be adopted. The future breeding strategies for rice (Siddiq 1994) in the coastal areas should concentrate on consolidation of already achieved yield gains in the irrigated ecosystem, evolution of better varieties under rainfed ecology, development of genotypes with higher genetic yield ceiling under irrigated and shallow lowland conditions, and anticipatory breeding to meet the impact of changing global climate.

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Effect of irrigation and foliar spray of nutrients on growth and seed yield of gram (*Cicer arietinum*)

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ABSTRACT

An experiment was conducted during the winter seasons of 1987–90 to study the effect of irrigation and foliar spray of nutrients on growth and yield of 'H 208' gram (*Cicer arietinum* L.). Irrigation at branching and pod-filling stages along with foliar application of 2% urea at 50% flowering gave the highest seed yield (1.7 tonnes/ha), the N, P and K uptake and water-use efficiency compared with other treatment combinations of foliar application (2% triple superphosphate, 2% potassium sulphate, water spray and no spray) and irrigation (no irrigation, 1 irrigation at branching, 1 irrigation at pod-filling stage and 2 irrigations at the branching and pod-filling stages).

The average yield of gram or chickpea (*Cicer arietinum* L.) is very low (741 kg/ha), because it is grown mostly unirrigated with no fertilizer (Prabhakar and Saraf 1991). It responds positively to the application of both fertilizer and irrigation (Singh *et al.* 1980, Sharma and Bhargava 1981, Raghu and Choubey 1983). Foliar application of nutrients can play a greater role in rainfed gram at the time of acute soil-moisture stress, when there is restricted nutrient uptake due to continuous dry spell. Since no work has been done on this aspect in this plateau region, an experiment was conducted to study the effect of nutrients on growth and seed yield of gram.

MATERIALS AND METHODS

The field experiment was conducted with 'H 208' gram at Ranchi during winter seasons of 1987–88 to 1989–90, with 4 levels of irrigation (I_1, no irrigation; I_2, 1 irrigation at branching; I_3, 1 irrigation at pod-filling; I_4, 2 irrigations, 1 each at branching and pod-filling); and 5 of nutrient spray (F_1, 2% urea, F_2, 2% triple superphosphate; F_3, 2% potassium sulphate; F_4, water spray; and F_5, no spray). The treatments were replicated thrice in split plots. The soil was sandy loam, poor in available N (220 kg/ha) and P (25 kg/ha) and moderate in K (174 kg/ha), with *p*H 6.1. Recommended dose of fertilizer N, P and K @ 20, 17.6 and 16.8 kg/ha respectively was applied in furrows at the time of seeding through urea, single superphosphate and muriate of potash. The seed was treated with *Rhizobium* culture. The crop was sown in rows 30 cm apart on 30 October, 8 November and 5 November during 1987–88, 1988–89 and 1989–90 respectively. The seed rate was 75 kg/ha. Measured quantity of water (6 cm) was delivered to each experimental plot. Water-use efficiency was calculated as yield per unit per centimetre water used. Nutrient spray was given as per

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treatments at 50% flowering of gram crop. The N, P and K content in seed and straw was analysed by the method of Jackson (1973). The total rainfalls received during the crop period were 9.0, 17.0 and 122.2 mm during 1987–88, 1988–89 and 1989–90 respectively. In the crop-growing period of 1987–88 there was no rain during the meteorological weeks 40–1 and 3–6. Only 1 effective rainfall (9.0 mm) was received during the meteorological week 2. The maximum temperature was 21.2–30.9°, and the minimum 5.6–19.8°C. The average relative humidity was 53–82. In 1988–89 there was no rain during the meteorological weeks 41–47, 49–52 and 1–6. Only 2 effective rainfalls (12.6 and 4.4 mm) were received during meteorological weeks 40 and 1. The maximum temperature was 21.2–29.4°C, and the minimum 5.6–20.2°C. The average relative humidity was 53–82. In 1989–90 there was no rain during the meteorological weeks 42–47, 49–51 and 1–6. Only 4 effective rainfalls (48.7, 7.0, 30.8 and 35.7 mm) were received during the meteorological weeks 40, 41, 48 and 52. The maximum temperature was 19.8–30.4°C, and the minimum 6.1–21.3°C. The average relative humidity was 45–80.

RESULTS AND DISCUSSION

Growth and yield attributes

Effect of irrigation: The values of all the growth and yield attributes were significantly higher at 2 irrigations applied at flowering and pod-filling stages of gram (Table 1). Irrigations also influenced the rooting pattern of the crop. The maximum horizontal spread of root (10.8 cm) was recorded with 2 irrigations, and the maximum vertical length of root (16.0 cm) in the control treatment (no irrigation).

Effect of nutrient spray: The values of all the growth and yield attributes were significantly higher at 2% foliar spray of urea applied at 50% flowering stage (Table 1).

Table 1 Growth, yield-attributing characters and seed yield of gram as influenced by irrigation and nutrient spray (mean data of 3 years)

Treatment	Plant height (cm)	Branches/ plant	Pods/ plant	1 000-grain weight (g)	Root (cm) Horizontal spread	Root (cm) Vertical length	Seed yield (kg/ha)	WUE* (kg/ha/ cm)
Irrigation								
T_1	29.0	7	23	129.4	5.6	16.0	780	30.2
T_2	33.8	11	41	132.2	7.5	13.0	1 030	24.5
T_3	35.8	12	49	133.4	8.0	11.6	1 180	17.9
T_4	39.4	13	55	133.8	10.8	9.9	1 340	11.5
CD (P=0.05)	0.332	0.175	0.599	0.330	0.072	0.103	31	
Nutrient spray†								
F_1	36.1	12	52	133.9	9.0	11.7	1 330	25.7
F_2	35.2	11	47	132.8	8.5	12.2	1 170	19.8
F_3	34.4	11	41	131.9	7.9	12.7	1 050	16.5
F_4	33.6	10	37	131.6	7.4	13.0	970	14.4
F_5	33.2	10	33	131.0	6.9	13.6	900	12.7
CD (P=0.05)	0.298	0.195	0.670	0.369	0.080	0.117	36	

Details of treatments are given under Materials and Methods

*WUE, Water-use efficiency; †at 50% flowering

Foliar application of the nutrients also influenced the root length. The maximum horizontal spread of roots (9.0 cm) was obtained at 2% foliar spray of urea and the maximum vertical length of root (11.6 cm) was in the control treatment (no spray).

Grain yield

Effect of irrigation: Irrigation at branching and pod-filling stages gave significantly higher seed yield owing to the increase in yield-attributing characters (Table 1). The result confirms the findings of Singh *et al.* (1980).

Effect of nutrient spray: The maximum seed yield was recorded at 2% foliar spray of urea. The urea spray was significantly superior to the remaining treatments of foliar spray (Table 1).

Interaction effect between irrigation levels and nutrient spray: The interaction between irrigation levels and nutrient spray had significant influence on the seed yield of gram (Table 2). The maximum seed yield was obtained with the foliar application of 2% urea. This interaction was significantly higher than that obtained under the remaining irrigation and nutrient-spray combinations.

Water-use efficiency

Effect of irrigation: The water-use efficiency decreased with the increase in levels of irrigation. The maximum water-use efficiency (30.2 kg/ha/cm) was recorded under no irrigation, whereas the lowest (11.5 kg/ha/cm) under 2 irrigations at branching and pod-filling stages (Table 1).

Effect of nutrient spray: Water-use efficiency was affected by different nutrient sprays. The maximum water-use efficiency (25.7 kg/ha/cm) was obtained under 2% foliar spray of urea, whereas the lowest (12.7 kg/ha/cm) under the control.

N, P and K uptake

Effect of irrigation: Irrigation levels significantly increased the N, P and K uptake by the gram crop. Among irrigation levels, 2 irrigations, 1 each at flowering and pod-filling stages, helped in increasing the maximum fertilizer uptake (Table 3).

Effect of nutrient spray: The significant increase in N, P and K uptake was found at 2% foliar spray of urea applied at 50% flowering stage. Increase in the nutrient uptake due to urea spray was 84, 180 and 117% more than under the control. This result confirms the finding of Dobariya *et al.* (1985).

On the basis of 3-year experimentation it was concluded that maximum growth and yield attributes, grain yield and the N, P and K uptake were obtained at 2 irrigations, 1 each

Table 2 Interaction effect between irrigation levels and nutrient spray on seed yield (kg/ha) of gram (mean data of 3 years)

Irrigation	Nutrient at 50% flowering					
	F_1	F_2	F_3	F_4	F_5	Mean
I_1	91	840	790	730	660	780
I_2	1 230	1 100	1 030	920	860	1 030
I_3	1 470	1 280	1 130	1 060	970	1 180
I_4	1 700	1 460	1 260	1 180	1 110	1 340
Mean	1 330	1 170	1 050	970	900	
CD (P=0.05)	34					

Details of treatments are given under Materials and Methods

Table 3 N, P and K uptake (kg/ha) as influenced by irrigation and nutrient spray in gram (mean data of 3 years)

Treatment	Uptake (kg/ha)		
	N	P	K
Irrigatio			
I_1	26.7	3.3	7.0
I_2	38.1	5.6	11.1
I_3	45.6	7.3	14.2
I_4	52.6	9.1	16.8
Nutrient spray†			
F_1	54.4	9.8	17.4
F_2	45.9	7.7	14.4
F_3	39.5	6.0	11.7
F_4	34.4	4.8	9.8
F_5	29.5	3.5	8.0

Details of treatments are given under Materials and Methods

†At 50% flowering

at branching and pod-filling stages, along with 2% foliar application of urea. Maximum water-use efficiency was observed under no irrigation and at 2% foliar application of urea.

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Effect of irrigation regime and nitrogen fertilization on bulb yield and water use of onion (*Allium cepa*)

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ABSTRACT

A field experiment was conducted during the spring seasons of 1991 and 1992 at New Delhi to study the effect of irrigation regime and nitrogen on water use and yield of 'Pusa Madhavi' onion (*Allium cepa* L.). Irrigations at 1.25 irrigation water : cumulative pan-evaporation (IW : CPE) ratio (14–16 irrigations) and 1.75 IW : CPE ratio (19–21 irrigations) were at par, giving 69.6 and 72.8% higher bulb yield respectively than 0.75 IW : CPE ratio (9–11 irrigations). The seasonal consumptive use was 500, 636 and 784 mm with irrigation at 0.75, 1.25 and 1.75 IW : CPE ratio respectively. The water-use efficiency was maximum (50.3 kg/ha/mm) at 1.25 IW : CPE ratio. N application up to 120 kg/ha gave significantly higher dry matter/bulb, 100-bulb weight, bulb diameter and bulb yield than 60 kg/ha. The net return/Re investment on N was Rs 12.4 at the optimum level of 131.4 kg N/ha. Increase in N level from 0 to 120 kg/ha increased the consumptive use and water-use efficiency from 560 to 628 mm and 38.1 to 52.1 kg/ha/mm respectively.

Irrigation is the single most important input in onion (*Allium cepa* L.) that accounts for 30–35% of the cost of cultivation. Inadequate and untimely application of water limits the productivity of onion (Palled *et al.* 1988). Onion is very sensitive to nitrogen fertilization, next to moisture. Increase in the demand on these inputs due to competing uses requires their more efficient use without adversely affecting the production. Hence an experiment was conducted to work out the optimum level of irrigation and nitrogen for 'Pusa Madhavi' onion, released for cultivation in north-western India.

MATERIALS AND METHODS

The field experiment was conducted during the spring seasons of 1991 and 1992 at New Delhi. The soil was well-drained, sandy loam having organic carbon 0.43%, total N 227 kg/ha, available P 13.6 kg/ha and available K 212 kg/ha, with *p*H 8.3. The field capacity, permanent wilting point and bulk density of the top 0–30 cm soil were 17.2%, 6.9% and 1.51 g/cc respectively. The water-table depth was below 2 m from the ground surface during both the cropping seasons. The effective rainfall during the cropping seasons of 1991 and 1992 was 95.8 and 43.4 mm respectively, and the total pan evaporation 830 and 815 mm.

Three levels each of irrigation [0.75, 1.25 and 1.75 irrigation water : cumulative pan-evaporation (IW : CPE) ratios with 50 mm irrigation water at each irrigation] and N (0, 60 and 120 kg/ha) were replicated 3 times in randomized block design. Seedlings of 'Pusa Madhavi' onion at 8 weeks were transplanted

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in the field at a row spacing of 15 cm and plant spacing of 10 cm on 15 January 1991 and 17 January 1992. The crop was harvested respectively on 30 and 28 May. Basal application of 22 kg P/ha and 40 kg K/ha was given at the time of transplanting. One-half N as per treatment was applied 1 week after transplanting and the remaining half at 45 days after transplanting. Before differential irrigation, 2 common irrigations were applied for better establishment of the seedlings. Irrigation was suspended 2 weeks before harvesting the crop. Data on mean daily evaporation were recorded with the help of USWB class A pan evaporimeter, whereas 50 mm water at each irrigation was applied with the help of Parshall flume of size 7.5 cm. Soil samples were collected from 0–60 cm depth before and after each irrigation as well as at the time of transplanting and harvesting. Water-use efficiency was worked out as the ratio of bulb yield to consumptive use. Ten bulbs were selected randomly from each plot at different growth stages (50, 70, 85, 100, 115 days after transplanting and at harvest) for computing the bulking rate as:

$$\text{Rate of bulking} = \frac{W_2 - W_1}{t_2 - t_1}$$

where W_2 and W_1, the bulb weight at time t_2 and t_1 respectively; and $t_2 - t_1$, the time interval (days) between the 2 observations.

RESULTS AND DISCUSSION

Rate of bulking

Irrigation regimes and nitrogen application appreciably influenced the rate of growth of bulb per unit time at different growth stages (Fig 1). The rate of bulking was the lowest at the initiation of the bulb, and increased with the advancement of growth period. The maximum bulking rate was observed during 85–100 days after transplanting at 1.25 IW : CPE ratio and 120 kg N/ha. Later it declined continuously toward crop maturity. This pattern

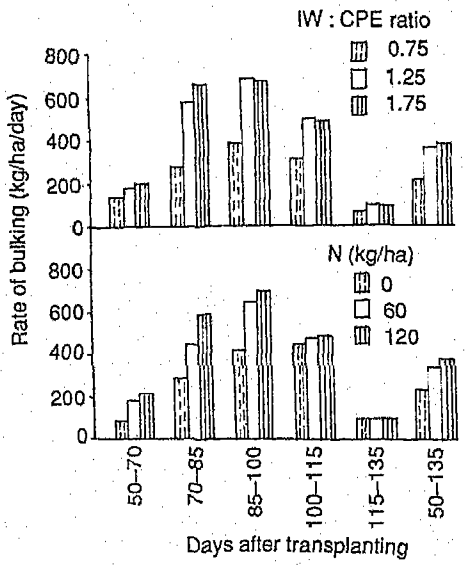

Fig 1 Rate of bulking of bulbs (kg/ha/day) as influenced by soil-moisture regimes and levels of nitrogen at different growth stages of onion

of rate of bulking might be ascribed to different amount of assimilates available for the bulb growth at different growth stages on account of variation in leaf area, which continues to increase even after the initiation of the bulb before entering the constant phase and then declined continuously 100 days after transplanting due to senescence of leaves in potato.

Realization of the bulb yield (%) during the growth period followed a sigmoidal pattern (Fig 2). Accumulation of bulb yield wasslow till 70 days after transplanting, then increased rapidly at uniform rate up to 115 days after transplanting, and became slow again towards maturity.

Bulb yield and attributes

Yield attributes such as dry matter/bulb, 100-bulb weight and bulb diameter increased significantly up to 1.25 IW : CPE ratio compared with irrigation at 0.75 IW : CPE ratio (Table 1). Moisture deficit at 0.75 IW : CPE

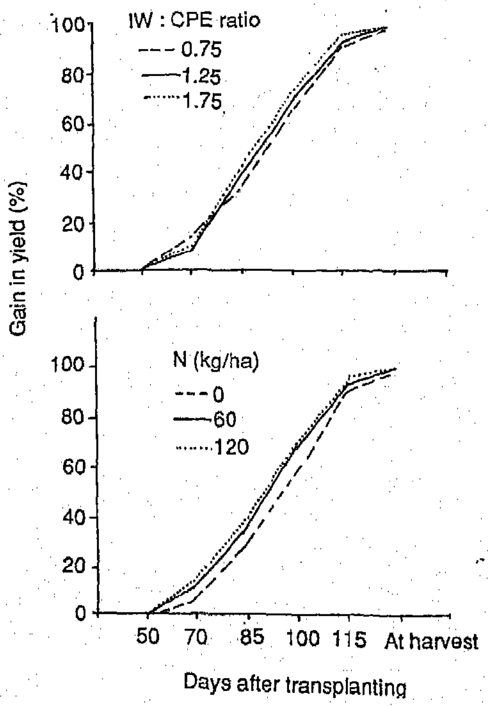

Fig 2 Bulb yield (%) at different growth stages of onion as influenced by soil-moisture regimes and levels of nitrogen

ratio led to lower vegetative growth, which adversely affected the yield components. On an average, bulb yield increased by 69.6 and 72.8% with irrigation at 1.25 and 1.75IW : CPE ratios respectively compared with that at 0.75 IW : CPE ratio. The result confirms the findings of Hegde (1986) and Singh and Sharma (1991).

The increase in N application also recorded significant increase in 100-bulb weight, bulb diameter and consequently bulb yield in both the years as well as in the pooled data. On an average, 37 and 53% increase in bulb yield was recorded with 60 and 120 kg N/ha respectively compared with the control. It confirms the results of Hegde (1986) and Singh and Sharma (1991).

Water use

On an average, total number of irrigations increased from 10 to 20 with increase in irrigation regime from 0.75 to 1.75 IW : CPE ratio (Table 1). Seasonal consumptive use was maximum (784 mm) at 1.75 IW : CPE ratio owing to sufficient water supply available for evapo-transpiration. The increase in the

Table 1 Effect of irrigation and N levels on yield attributes, bulb yield and water use of onion (Pooled data of two years)

Treatments	100-bulb weight (kg)	Dry weight/ bulb (g)	Bulb diameter (cm)	Bulb yield (kg/ha)	No. of irrigations	Irrigation requirement (mm)	Water requirement (mm)	Consumptive use (mm)	Water-use efficiency (kg/ ha/mm)	Moisture extraction (%) at soil depth (cm) 0–15	15–30	>30
Irrigation (IW : CPE)												
0.75	4.34	4.87	4.38	18 820	10	470	539	500	37.6	67	21	12
1.25	6.19	6.98	5.63	31 970	15	720	789	636	50.3	77	15	8
1.75	6.27	7.06	5.63	32 520	20	970	1 039	784	41.5	82	12	6
N (kg/ha)												
0	4.62	5.18	4.57	21 360				560	38.1			
60	5.72	6.48	5.42	29 220				598	48.8			
120	6.28	7.05	5.68	32 720				628	52.1			
CD (P=0.05)	0.52	0.29	0.16	1 380								

consumptive use with increase in moisture supply from 1.25 to 1.75 IW : CPE ratio did not increase the yield proportionately due to optimum level of soil moisture at 1.25 IW : CPE ratio, indicating 0.75 IW : CPE ratio a suboptimal moisture regime. Water-use efficiency was maximum at 1.25 IW : CPE ratio followed by irrigation at 1.75 and 0.75 IW : CPE ratios (Table 1).

Nitrogen fertilization increased the consumptive use of onion. Water-use efficiency also increased with increase in N level due to significant increase in bulb yield in relation to consumptive use. The result confirms that of Hegde (1986) and Palled *et al.* (1988).

Moisture-extraction pattern

Onion crop extracted maximum soil moisture from the top 0–15 cm soil layer, indicating a larger oot density and evaporation loss from the upper layer. About 82% of the soil moisture was extracted from 0–15 cm layer at 1.75 IW : CPE ratio, whereas 77 and 67% from 1.25 and 0.75 IW : CPE ratios respectively (Table 1). Proportional contribution from the lower layers was more under reduced water supply. Palled *et al.* (1988) also reported similar pattern.

Response analysis

The response equation of bulb yield and nitrogen showed a quadratic nature.

$$Y = 21360 + 167.33\,N - 0.61\,N^2$$

Application of N induced a linear increase in the beginning, but with further increase in level of N the subsequent increase in yield was at a decreasing rate. However, the decrease in marginal yield with each unit increase in N was not conspicuous, resulting in economic return beyond the maximum dose of N tried. Such a type of response is expected where economic product is located in underground parts or vegetative produce. On an average, economic optimum dose, N-use efficiency and net return/Re invested at the optimum dose of nitrogen were 131.4 kg N/ha, 87.2 kg bulb/kg N and Rs 12.4 respectively at sale value of onion Re 1.00/kg and cost of fertilizer N Rs 6.95/kg.

It was concluded that 'Pusa Madhavi' onion crop for bulb production requires 14–16 irrigations and 130 kg N/ha for optimum production during spring season.

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Rate and duration of siliqua and seed-filling period and their relation to seed yield in *Brassica* species

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ABSTRACT

The rate and duration of siliqua and seed-filling period were studied for different *Brassica* species differing in flowering behaviour under field condition. 'Varuna' indian mustard [*Brassica juncea* (L.) Czernj. & Cosson], 'Pusa Kalyani' brown sarson [*B. rapa* (L.) Thell. emend. Metzger var *ulti* (Prain) Schulz., syn *B. campestris* L. ssp *oleifera* (Metzger) Sinsk. var brown sarson], 'BO 706' rapeseed (*B. napus* L.) and 'Tall 1' ethiopian mustard (*B. carinata* A. Braun) were sown in 2 different seasons during 13 October–12 December at an interval of 10 days. The rate of dry-matter accumulation and duration of siliqua and seed-filling period decreased with delay in sowing. The actual and effective filling periods of siliqua were correlated with yield. The predicted data indicated shortening of 1.8, 4.6 and 1.3 days in actual filling period, effective filling period and seeds/siliqua respectively for every unit increase in mean temperature during 13 October–24 December. The actual and effective filling periods of siliqua increased by 4–5 days for every 1 hr increase in photoperiod above its mean value of 10.7–12.8 hr/day.

Numerous studies have been made on the contribution of the rate and duration of grain-filling period to grain yield in wheat (*Triticum aestivum* L. emend. Fiori & Paol.) (Saini and Dadhwal 1986), greengram (*Phaseolus radiatus* L.) (Nanda and Saini 1988) and *Brassica* spp (Singh and Bhargava 1988). More information is needed on the pattern of change in growth and development of siliqua and seeds in cytogenetically related oilseed *Brassica* species, and its influence on seed yield under different temperatures and photoperiods. This experiment was therefore taken up.

MATERIALS AND METHODS

The seeds of 'Varuna' indian mustard [*Brassica juncea* (L.) Czernj. & Cosson], 'Pusa Kalyani' brown sarson [*B. rapa* (L.) Thell. emend. Metzger var *ulti* (Prain) Schulz., syn *B. campestris* L. ssp *oleifera* (Metzger) Sinsk. var brown sarson], 'BO 706' rapeseed (*B. napus* L.) and 'Tall 1' ethiopian mustard (*B. carinata* A. Braun) were sown in the sequence during the first season on 13 and 23 October; 2, 10 and 21 November; and 4 and 12 December 1989; and during the second season on 25 October; 4, 14 and 24 November; and 4, 14 and 24 December 1990. The plot size was 4 m x 7 m. All plots received 87 kg/ha urea, 250 kg/ha single superphosphate and 66 kg/ha muriate of potash, ie N, P and K @ 40, 40 and 40 kg/ha. The seeds were sown in rows 45 cm apart and thinned to targeted population of 15 plants/m^2 after 2 weeks of germination, keeping plant-to-plant spacing 15 cm. Irrigation was given as and when necessary.

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Days to 50% flowering differed with species and sowing dates, ie 61–67, 49–59, 71–81 and 78–97 days in 'Varuna', 'Pusa Kalyani', 'BO 706' and 'Tall 1' respectively.

About 250–300 basal flowers of terminal racemes opening on a single day were tagged at 50% flowering in each plot. Beginning with the first sample at 4 days after tagging, 10 pods were collected from each of the 3 replicates, followed by sampling on alternate days till maturity. Samples were dried to constant weight at 80°C. Siliquae and seeds (when present) were weighed separately after drying.

The data on dry-matter accumulation of siliquae and seeds/siliqua for each sowing and variety were subjected to Richard's function-fitting analysis (Causton *et al.* 1978). The linear correlation coefficients were determined between actual filling period and effective filling period of siliquae and seed yield/m^2. A step-wise multiple regression was carried out to find out the impact of mean temperature and photoperiod from flowering to maximum pod weight on actual and effective filling periods of siliquae and seeds/siliqua.

As the general pattern of observations was similar in the 2 seasons, the results of only 1 cropping season (1989) are presented.

RESULTS AND DISCUSSION

Fitted growth curve using Richard's function-fitting analysis (Causton *et al.* 1978) showed that the pattern of dry-matter accumulation in 4 *Brassica* species sown on different dates was similar (Fig 1). Singh and Bhargava (1988) also showed a sigmoid pattern of dry-matter accumulation in the siliquae. Duration of actual filling period from flower opening to maximum pod weight was 39–79 (mean 57.2, CV 16%) and that of effective filling period 30–68 days in siliquae

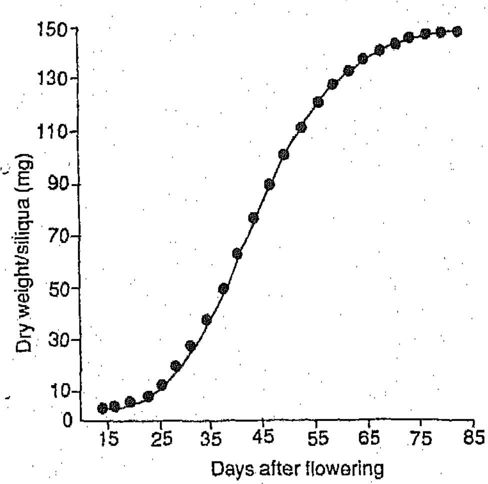

Fig 1 Change in dry weight of siliquae using Richard's function-fitting analysis of 'Varuna' indian mustard

(mean 51.5, CV 16%) and 24–56 days in seeds/siliqua (mean 42.2, CV 19%). In both cases, depending on the species and planting time, this period was longer in early-sown crops. The late-maturing varieties ('BO 706' rapeseed and 'Tall 1' ethiopian mustard) showed lesser effective filling period of siliquae and seeds/siliqua than the early maturing ones ('Pusa Kalyani' brown sarson and 'Varuna' indian mustard) (Table 1).

In general, the rate of dry-matter accumulation (b-value) of siliqua and seeds/siliqua increased with delay in sowing, although this increase was inconsistent in early maturing 'Pusa Kalyani' brown sarson and 'Varuna' indian mustard. The mean maximum dry weight of a siliqua was 130 mg (CV 10%) and that of seeds/siliqua was 74 mg (CV 13%). It indicates that 43% of the total siliqua weight was contributed by siliqua wall and 57% by seeds.

In all the species the dry-matter accumulation in siliqua wall started 10 days after flowering and continued till 45–55 days, whereas in seeds it started from 20–25 days

Table 1 Rate of dry-matter accumulation (b value ± standard error) in siliquae and its seeds, their maximum dry weight, actual filling period (AFP) and effective filling period (EFP) of 4 *Brassica* species sown on different dates in 1989

Date of sowing	Maximum dry weight (mg)		b values of EFP ± SE (mg/siliqua/day)		AFP of siliquae (days)	EFP (days)	
	Siliqua	Seeds/ siliqua	Siliqua	Seeds/ siliqua		Siliqua	Seeds/ siliqua
			'Pusa Kalyani' brown sarson				
13 Oct	138	78	2.53±0.18	1.81±0.12	68	55	43
23 Oct	129	75	2.44±0.11	1.63±0.09	68	53	46
2 Nov	136	75	2.44±0.12	1.56±0.07	65	56	48
10 Nov	132	73	2.24±0.16	1.37±0.06	63	59	53
21 Nov	115	60	1.86±0.12	0.97±0.05	56	52	53
4 Dec	107	53	1.92±0.09	1.13±0.03	58	56	46
12 Dec	104	47	2.10±0.12	1.04±0.03	52	49	44
			'Varuna' indian mustard				
13 Oct	145	86	2.17±0.09	1.54±0.07	70	67	56
23 Oct	131	73	1.98±0.09	1.31±0.04	71	62	55
2 Nov	123	75	1.85±0.12	1.27±0.02	70	66	59
10 Nov	132	76	2.22±0.09	143±0.03	65	60	53
21 Nov	127	73	2.21±0.08	1.43±0.05	58	55	51
4 Dec	120	67	2.37±0.06	1.66±0.07	55	50	40
12 Dec	126	66	2.83±0.10	1.85±0.10	51	44	36
			'BO 706' rapeseed				
13 Oct	158	96	2.43±0.17	1.72±0.11	68	65	56
23 Oct	142	84	2.43±0.12	1.72±0.08	65	58	49
2 Nov	150	84	2.58±0.09	1.83±0.06	64	58	49
10 Nov	140	87	2.61±0.11	1.85±0.09	56	53	43
21 Nov	141	80	2.79±0.10	2.17±0.14	54	51	36
4 Dec	133	79	2.76±0.13	1.89±0.12	53	48	42
12 Dec	131	73	2.54±0.24	1.67±0.15	54	52	43
			'Tall 1' ethiopian mustard				
13 Oct	125	65	2.30±0.07	1.57±0.07	61	54	41
23 Oct	123	69	2.21±0.07	1.56±0.07	60	55	44
2 Nov	125	68	2.31±0.08	1.63±0.16	59	53	42
10 Nov	122	70	2.57±0.12	2.00±0.09	53	49	35
21 Nov	122	72	2.66±0.14	1.87±0.10	53	47	38
4 Dec	121	67	2.35±0.17	1.46±0.07	54	51	45
12 Dec	98	72	2.16±0.14	1.92±0.10	48	45	37

after flowering. Thus during the first 20–25 days dry-matter accumulation remained confined to siliqua wall. The seeds showed 36% of the total siliqua weight by the time the dry weight of siliqua wall had reached maximum (Fig 2). Overlapping of seeds or siliqua-wall growth in the linear phase would result in competition for carbohydrates for 10 days. Subsequent increase in siliqua weight was entirely due to increase in seed weight without any change in siliqua-wall weight.

The rate of dry-matter accumulation of siliqua and seeds/siliqua (b-value) showed an inverse relationship with actual and effective

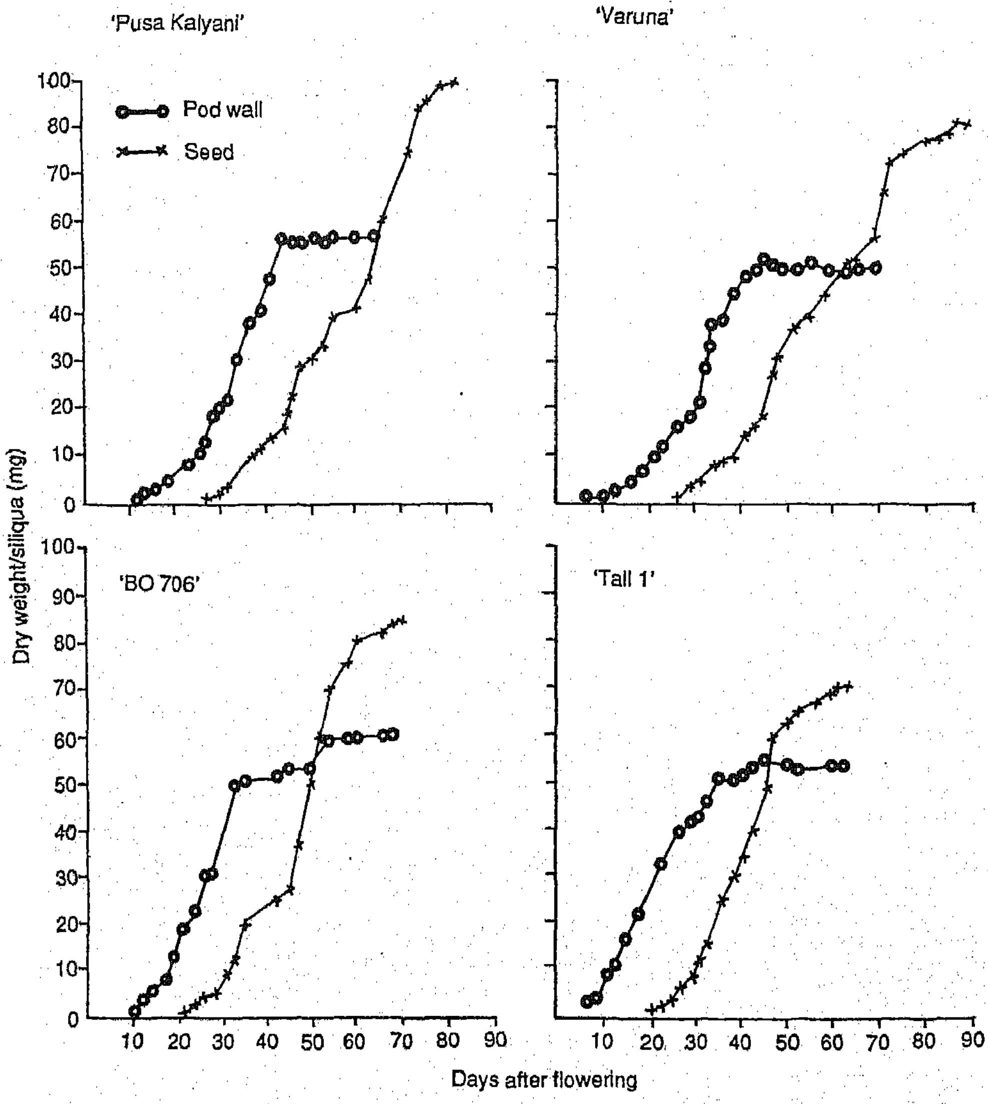

Fig 2 Pattern of change in siliqua wall and dry weight of seeds/siliqua of *Brassica* spp

Table 2 Correlation coefficients between seed yield and actual filling period (AFP) and effective filling period (EFP) of siliquae and seeds/siliqua for 4 *Brassica* species sown on different dates

Grain yield	Brown sarson	Indian mustard	Rapeseed	Ethiopian mustard
AFP	0.85^{*}	0.88^{*}	0.72^{*}	0.69^{**}
EFP (siliquae)	0.76^{*}	0.75^{*}	0.68^{**}	0.53^{**}
EFP (seeds/siliqua)	0.25^{NS}	0.60	0.70	0.25^{NS}

*P = 0.01 **P = 0.05

filling period of siliquae and seeds/siliqua. The b-value of seeds/siliqua of 4 *Brassica* species in different sowing dates was 1.8 mg/day. The smaller seed size (mean 5 mg/seed) of *Brassica* species was due to lesser rate of dry-matter accumulation (Table 1), although effective filling period was longer.

In all the species, the actual and effective filling periods of siliquae were positively correlated with grain yield/m^2. Guffy *et al.* (1991) confirmed the positive relationship between seed-filling period and yield in soybean [*Glycine max* (L.) Merr.]. The effective filling period of seeds/siliqua was not associated with grain yield in 'Pusa Kalyani' and 'Tall 1' varieties (Table 1). However, pooled data of 4 *Brassica* species showed positive correlation between grain yield/m^2 and actual filling period (R = 0.71), effective filling period (R = 0.70) and seeds/siliqua (R = 0.60) (Table 2).

Thus selection for a longer siliqua-filling period might be helpful in breeding for increased grain yield in *Brassica* species. Mean temperature and photoperiod from flowering to maximum siliqua weight were 14–25°C and day-length 10.7–12.8 hr/day. These parameters were negatively correlated with actual and effective filling periods of siliquae and seeds/siliqua (R = —80). Since both these parameters showed positive association with each other during these filling periods, it was not possible to calculate the extent of influence of either temperature or photoperiod as independent function on these durations.

The predicted data showed a shortening of 1.8, 4.6 and 1.3 days in actual and effective filling periods of siliquae and seeds/siliqua respectively for every unit increase in mean temperature during these durations. Wiegend and Cuellar (1981) indicated a shortening of 3.1 days of grain-filling/ °C increase in mean daily air temperature during grain-filling in wheat. Thus an increase in temperature decreased the pod and seed-filling periods in different species of *Brassica*.

Marginal changes of photoperiod as a function of temperature increased the actual and effective filling periods of siliquae by 4–5 days for every 1 hr increase in photoperiod above its mean value. This increase was only for 2 days in seeds/ siliqua.

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Ontogenetic approach to grain production in pearl millet (*Pennisetum glaucum*) based on path-coefficient analysis

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ABSTRACT

Path-coefficient analyses, based on the ontogeny of pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz] plant, were carried out during rainy seasons (*kharif*) of 1990 and 1991 to study the relationship among grain yield, yield components, pre-flowering period and threshing ratio. Thirty genotypes were grown for 2 years at Jodhpur under natural moisture stress during grain-filling stage. Variation in grain yield primarily depended on threshing (%) and panicles/m^2. However, 500-grain weight had negligible influence on seed yield. More days to flowering affected adversely the threshing (%), whereas panicles/m^2 positively influenced it via pre-flowering period. High threshing ratio increased the 500-grain weight considerably. The variation in panicle length did not significantly influence any trait.

A number of grain-production studies in pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz] include correlations between grain yield and various yield-contributing characters (Virk 1988). Path-coefficient analysis allows separation of direct influence of each yield component on grain yield from the indirect influences caused by the inter-relationship among them. In cereals yield components are formed in succession and the yield components developing earlier can influence those developing later, whereas converse is not true. This study was undertaken to utilize path-coefficient analysis for investigating the relationship among grain yield, yield components, pre-flowering period and threshing ratio (grain weight : panicle weight) in pearl millet.

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MATERIALS AND METHODS

Thirty genotypes of pearl millet were grown during the rainy seasons of 1990 and 1991 at Jodhpur.

The amount of precipitation received during the pre-flowering period was 721 and 164 mm and during post-flowering period was 57 and 17 mm in 1990 and 1991 respectively. Total number of rainy days were 3 in 1990 and 0 in 1991 during grain-filling period. Therefore the crop experienced terminal drought during the grain-filling stage in both the years.

The experiment was laid out in randomized complete-block design with 3 replications. Each plot consisted of 4 rows of 4 m length, spaced 60 cm apart. Seeds were sown with hand-plough in 1990 and with planter in 1991. The plants were thinned to a spacing of 15 cm 2 weeks after sowing. The plots were kept free of weeds. Fertilizer was applied @ 40 kg N/ha and 8.7 kg P/ha each year.

The duration of pre-flowering period (days to flowering) is equal to the number of days from sowing to emergence of stigma in 50% of the plants in a plot (Maiti and Bidinger 1981). Threshing (%) was determined as the ratio of total grain weight : panicle weight of the plants harvested from 2 central rows of 1 m length (1.2 m^2) in both the years. Panicle length (cm) was measured on main shoots of 5 competitive plants in a plot at the time of maturity. At harvest, data were taken on panicles/m^2 and grain yield and on 500-grain weight (from duplicate samples of 500 grains taken at random from the bulk plot harvested).

Correlation coefficients between all possible pairs of 6 characters were computed from the mean of 3 replicates for each genotype. Since the effects due to year were significant in all the characters except days to flowering and threshing (%), the correlation coefficients were calculated using the mean values of genotypes in each of the 2 years (n = 60) rather than using the means of each genotype for all the years (n = 30). Each set of correlation coefficients was subjected to path-coefficient analysis and direct and indirect effects were estimated as per Dewey and Lu (1959). Grain yield, threshing (%) and 500-grain weight were taken as dependent characters in path-coefficient analyses.

RESULTS AND DISCUSSION

The analysis of variance revealed that genotype had greater effect on all the traits studied except panicles/m^2. The environment also influenced significantly all the characters except days to flowering and threshing (%). Change in rank and magnitude of genotypes resulted in significant genotype x environment interactions for all the characters except panicle length. The result confirms the finding of Virk *et al.* (1988).

Grain yield was significantly related to threshing (%) (Table 1). In cereals grain yield depends strongly on the efficiency of the genotype to remobilize pre- and post-anthesis assimilates for the grain production under condition where water is the limiting factor (Austin *et al.* 1980). Panicles/m^2 and 500-grain weight also showed significant influence on grain yield. Mahalakshmi *et al.* (1985) reported similar relationship of grain weight with yield under moisture stress in late season. Grain yield showed significant negative correlation with days to flowering. This was not unexpected, as the early-maturing genotypes complete their life-cycle when adequate moisture is available in the soil profile (Mahalakshmi *et al.* 1988). Panicle length was not related to any trait studied. The result confirms the finding of Virk (1988).

Higher threshing (%) resulted in more 500-grain weight (Table 1). This might be due to high remobilization of assimilates to the developing grains. Longer duration of pre-flowering period affected inversely the threshing (%), 500-grain weight and panicles/m^2. This could be attributed to the setting and grain-filling in late poor flowering genotypes when the moisture stress becomes severe towards the end of the growing season, and thus affecting adversely threshing (%) and consequently the seed weight.

The direct effect obtained in path analysis indicated that grain yield depended mainly on threshing (%) and panicles/m^2 (Table 2). Number of panicles per unit area is a major factor determining yield in pearl millet (Soman *et al.* 1987). The 500-grain weight had no significant influence on grain yield. When grain-filling takes place in cereals under limited moisture supply, as in this study, yield can considerably be stabilized by greater contribution through assimilation before and immediately after anthesis, leading to small variation in seed weight (Austin *et al.* 1980). The duration of pre-flowering period had a significant negative influence on threshing (%) (Table 2) and threshing ratio had positive influence on seed weight (Table 2). The longer duration of pre-flowering period in cereals induces high water consumption in the pre-anthesis period (Fischer 1981) and leaves behind inadequate soil moisture during grain-filling period. The panicles/m^2 did not significantly modify threshing (%), panicle length and seed weight (Table 1). Our result agrees with those of Mukherji *et al.* (1982) and Khairwal *et al.* (1990).

The indirect effect of each yield component on grain yield was in general small, except for the indirect effect of 500-grain weight through threshing (%) (0.221; Table 2). It confirms the influence of threshing ratio on grain yield.

Table 1 Correlation coefficients among grain yield and other characters in pearl millet

Character	Grain yield	500-grain weight	Panicle length	Threshing (%)	Panicles/m^2
Days to flowering	—0.549**	—0.475**	0.194	—0.334*	—0.496**
Panicles/m^2	0.510**	0.211	—0.160	0.166	
Threshing (%)	0.642**	0.417*	—0.107		
Panicle length	**0.070	—0.191			
500-grain weight	0.417*				

*P = 0.05, **P = 0.01

Table 2 Path-coefficient analysis showing direct (bold) and indirect effects of traits on grain yield, threshing (%) and 500-grain weight of pearl millet

Character	Days to flowering	Panicles/m^2	Threshing (%)	Panicle length	500-grain weight	Correlation coefficient
			Grain yield			
Panicles/m^2		**0.408**	0.088	—0.012	0.026	0.510**
Threshing (%)		0.068	**0.531**	—0.008	0.052	0.642**
Panicle length		—0.065	—0.057	**0.076**	—0.024	—0.070
500-grain weight		0.086	0.221	—0.014	**0.124**	0.417*
			Threshing (%)			
Days to flowering	**—0.326**	0.001		—0.008		—0.334*
Panicles/m^2	0.162	**—0.003**		0.007		0.166
Panicle length	—0.064	0.001		**—0.044**		—0.107
			500-grain weight			
Panicles/m^2		**0.126**	0.063	0.021		0.211
Threshing (%)		0.021	**0.382**	0.014		0.417*
Panicle length		—0.020	—0.041	**—0.130**		—0.191

*P = 0.05, **P = 0.01

The indirect effect on threshing (%) and 500-grain weight by various traits was not so important (Table 2), except for indirect effect of panicles/m^2 on threshing ratio through days to flowering (0.162; Table 2). It indicates good influence of panicles/m^2 through pre-flowering period.

It was concluded that threshing ratio and panicles/m^2 are the most important factors that determine pearl millet yield under drought-prone environment and seed weight exercises a negligible effect on grain yield.

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Stability analysis for yield and component characters in ricebean (*Vigna umbellata*)

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ABSTRACT

An experiment was conducted during 1988–91 to study the stability parameters for yield and 3 component characters in 11 genotypes of ricebean [*Vigna umbellata* (Thunb.) Ohwi & Ohashi]. Genotype x environment (G x E) interaction was significant for pods/plant, clusters/plant, pod length and yield/plant. Both linear and non-linear components were predominant in G x E interaction for all the characters, except for clusters/plant where linear component accounted for most of the G x E interactions. Genotypes 'RB 49' (19.89 g/plant) and 'RB 40' (20.40 g/plant) were high yielding and most stable for all the characters and could be utilized in a breeding programme. No significant correlation was observed among the 3 stability parameters (mean, bi and S^2_{di}) for all the characters. These parameters may therefore be considered while breeding stable varieties of ricebean.

Though work has been done on nutrition, evolution, taxonomy and cultural practices of ricebean [*Vigna umbellata* (Thunb.) Ohwi & Ohashi], information is meagre on the extent of its genotype x environment (G x E) interaction. The crop is highly sensitive to environment fluctuations (Chandel *et al.* 1988). Hence an experiment was conducted to work out the extent of G x E interaction to isolate high-yielding, stable genotypes that may be used either as a variety or as a donor parent in a breeding programme.

MATERIALS AND METHODS

The material consisted of 11 genotypes of ricebean, viz 'RB 4', 'RB 56', 'C x M 12 P 13', 'RB 40', 'RB 49', 'C x M 8 P 2', 'RB 26', 'RB 39', 'RB 17', 'RB 53' and 'RB 32'. These were grown in randomized block design with 3 replications during the rainy seasons of 1988–91. The plot consisted of 3 rows of 10 plants each, with 15 cm plant-to-plant spacing and 50 cm row-to-row spacing. The crop received a basal dose of 10 tonnes farmyard manure and 20 kg N/ha, and was grown in gravelled sandy-loam soil under rainfed condition. Data were recorded on 5 random competitive plants for clusters/plant, pods/plant, pod length and yield/plant at maturity. Average data of 5 plants were utilized for statistical analysis. The stability parameters were worked out as suggested by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

Environment (year)-wise analysis of variance revealed that significant differences existed among genotypes under each environment for clusters/plant, pods/plant, pod length

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and yield/plant. The pooled analysis of variance also revealed significant differences among genotypes and environments, indicating the presence of genetic variability among the genotypes. Highly significant mean squares due to environments + (G x E) interactions suggested that the genotypes interacted considerably with environmental conditions. A major portion of these interactions could be attributed to the linear component, indicating that the prediction of seed yield was possible in the environments. Though the pooled deviations were nonsignificant for all the characters, the genotype 'C x M 8 P 2' showed significant deviation from regression for all the characters except for clusters/plant. It indicates that both predictable (linear) and non-predictable (non-linear) components contribute significantly to the differences in stability among genotypes.

Samuel *et al.* (1970) and Paroda and Hays (1971) emphasized that linear regression (bi) could simply be regarded as a measure of response of a particular genotype, whereas the deviation around regression line (S^2_{di}) is the most appropriate measure of stability. Genotypes with bi=1 and lowest deviation around regression line could be termed most stable and vice-versa. Accordingly, it was possible to judge the stability of genotypes, with due consideration to their mean performance and linear response.

Table 1 Estimates of mean and stability parameters in 11 genotypes of ricebean

Line	Clusters/plant			Pod length (cm)			Pods/plant			Yield/plant (g)		
	Mean	bi	S^2_{di}	Mean	bi	S^2_{di}	Mean	bi	S^2_{di}	Mean	bi	S^2_{di}
'RB 4'	12.10^{abc}	1.05^{ψ}	–0.78	9.09^{bc}	0.90^{ψ}	–0.15	47.58^{cde}	1.16^{ψ}	$71.82^{\psi\psi}$	17.73^{bc}	1.13^{ψ}	–2.32
'RB 56'	12.54^{a}	1.00^{ψ}	0.16	9.07^{bc}	1.10^{ψ}	–0.20	52.28^{ab}	1.14^{ψ}	–19.55	19.33^{ab}	1.39	–3.58
'C x M 12 P 13'	11.00^{cd}	0.90^{ψ}	–0.48	9.01^{bcd}	1.02^{ψ}	–0.22	46.03^{def}	0.65	–6.05	16.70^{cd}	0.87^{ψ}	$5.70^{\psi\psi}$
'RB 40'	12.68^{a}	0.89^{ψ}	0.96	9.33^{ab}	1.10^{ψ}	0.14	51.98^{ab}	1.27	–9.70	20.40^{a}	1.12^{ψ}	–3.69
'RB 49'	12.06^{abc}	1.03^{ψ}	–3.27	9.60^{a}	0.94^{ψ}	–0.029	48.18^{bcd}	1.14^{ψ}	14.16	19.89^{a}	1.14^{ψ}	–1.97
'C x M 8 P 2'	12.65^{a}	1.27	1.72	9.06^{bc}	0.85^{ψ}	$1.49^{\psi\psi}$	51.23^{abc}	1.59	$105.75^{\psi\psi}$	20.68^{a}	0.87^{ψ}	$6.04^{\psi\psi}$
'RB 26'	12.13^{ab}	1.01^{ψ}	0.65	8.82^{cd}	1.11^{ψ}	–0.02	50.28^{abcd}	1.01^{ψ}	–7.89	19.29^{ab}	0.48	–2.94
'RB 39'	12.76^{a}	1.19^{ψ}	1.40	9.09^{bc}	1.07^{ψ}	–0.05	52.63^{a}	1.09^{ψ}	53.92	17.61^{c}	1.10^{ψ}	$4.94^{\psi\psi}$
'RB 17'	11.39^{bcd}	0.50	0.80	8.57^{d}	0.89^{ψ}	–0.26	42.40^{f}	0.37	24.48	15.67^{d}	0.88^{ψ}	–3.65
'RB 53'	12.20^{ab}	1.26	1.56	8.93^{bcd}	0.63	$0.69^{\psi\psi}$	48.25^{bcd}	1.07^{ψ}	34.81	18.20^{bc}	1.09^{ψ}	$8.92^{\psi\psi}$
'RB 32'	10.58^{d}	0.91^{ψ}	0.62	9.20^{abc}	1.39	–0.15	43.25^{ef}	0.51	–14.60	16.85^{cd}	0.91^{ψ}	–2.14
Mean	12.02		9.20		48.55		18.40					
r(x, bi)	0.54		0.24		0.63		0.21					
$r(x, S^2_{di})$	0.21		–0.05		0.17		–0.10					
$r(b, S^2_{di})$	0.16		–0.46		0.50		–0.12					

Figures for mean followed by same letter are not significantly different from each other, according to Duncan's Multiple Range Test at P = 0.05

r, Correlation coefficient; bi, regression coefficient; S^2_{di}, deviation from regression

For clusters/plant the deviation from regression (S^2_{di}) was non-significant for all the genotypes, whereas regression (bi) deviated significantly from unity in 4 out of the 11 genotypes, indicating preponderance of linear regression for the G x E interactions (Table 1). The genotypes 'RB 49', 'RB 40', 'RB 56' and 'RB 39' were stable and had high mean value for this character. For pod length, all the genotypes except 'C x M 8 P 2' and 'RB 53' were stable. Genotypes 'RB 53' and 'RB 32' had their bi deviating from unity suggesting that both linear and non-linear components were responsible for G x E interactions in these genotypes.

Genotypes 'RB 4' and 'C x M 8 P 2', for pods/ plant, showed S^2_{di} significantly deviating from 0 but were adaptable (bi=1). Lines 'RB 17', 'RB 32' and 'C x M 12 P 13' were better suited to poor-yielding environments or stress conditions, as their bi were less than 1. But the genotype 'C x M 8 P 2' was unstable and better suited to high fertility and better management conditions, because its bi was greater than 1. The genotypes 'RB 56', 'RB 40', 'RB 39 and 'RB 26' were stable and had higher mean values for the character.

For grain yield/plant 4 genotypes had S^2_{di} deviating from 0, but had better adaptability. 'RB 56', though stable and high yielding, was better suited to high fertility or better yielding environments, whereas 'RB 26' was better suited to poor fertility. Considering all the characters simultaneously, the genotypes 'RB 49' and 'RB 40' appeared promising and could either be used as variety *per se* or as a donor in a hybridization programme for breeding high-yielding stable varieties. The correlation coefficients (r) among 3 stability parameters (mean, bi and S^2_{di}) indicated no significant association among these parameters (Table 1), indicating the involvement of different genetic systems in the control of these 4 characters. Hence all the 3 parameters may be taken into account while breeding for stable varieties of ricebean. The simple use of mean values, as suggested in other crops (Sanghi and Kandalkar 1983) may not be useful in ricebean.

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Short Communications

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Regulation of flowering in chrysanthemum (*Chrysanthemum indicum*) by gibberellic acid application

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The normal period of cropping in commercial chrysanthemum (*Chrysanthemum indicum* L.), a short-day plant in southern states of India, is July–December. The peak production resulting in a glut in the market is in October. Regulation of flowering in florist's chrysanthemums through photoperiodic or chemical means is well known. Photoperiodic manipulation to advance or delay the flowering in commercial chrysanthemum grown in India is not practicable because the crop is raised in fairly large areas in open fields. Plant-growth regulators like gibberellins alter the photoperiodic requirement of many flowering plants (Krishnamoorthy 1981). This study was taken up to regulate the time and duration of flowering in chrysanthemum with gibberellic acid (GA_3) to avoid market glut at peak production.

The experiment was laid out in completely randomized design with 4 treatments and 10 replications. Rooted terminal cuttings of 'Co 1' and 'Co 2' chrysanthemum were planted in pots during the last week of July 1992. The treatments consisted of GA_3 at 100, 150 and 200 ppm and a control. GA_3 was sprayed on whole plant at 30 and 45 days after planting.

Data on number of days to first flowering, plant height, internodal length, number of suckers, number of flowers/plant, flower-stalk length, floral diameter, flower yield/plant and flowering duration were recorded. The treatment effects were compared using 'F' test at $P = 0.01$ and $P = 0.05$.

The GA_3 application at all the 3 levels increased the plant height, number of branches and internodal length in both the cultivars (Table 1). The effect of GA_3 was more pronounced in 'Co 1' than in 'Co 2' (Fig 1). In 'Co 1' GA_3 at 150 ppm proved significantly superior to 100 and 200 ppm in increasing plant height and internodal length, whereas at 200 ppm it proved superior in 'Co 2'.

'Co 1' plants sprayed with 100 ppm GA_3 flowered earlier (25 days), gave higher flower yield (39.8 g) and had a longer flowering duration (32 days) than the control. In 'Co 2' the same treatment showed earliness (27 days earlier than the control), but flower yield as well as duration of flowering were greater and longer with GA_3 at 200 ppm (Table 2). GA_3 200 and 150 ppm gave equal flower yield. Both these levels increased the flower-stalk length and floral diameter.

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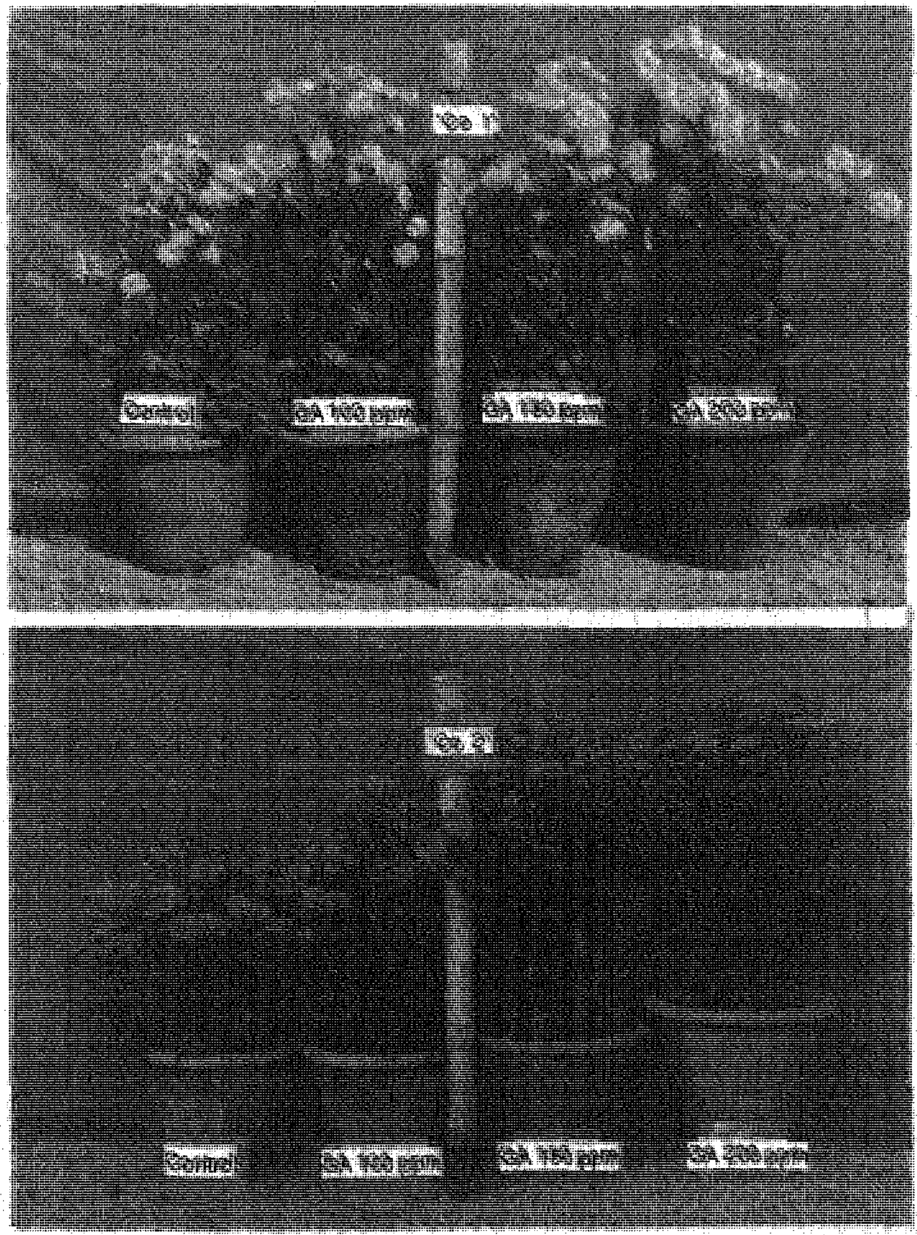

Fig 1	Effect of GA_3 (100, 150 and 200 ppm) on chrysanthemum. *Top*, 'Co 1'; *bottom*, 'Co 2'

Table 1 Effect of gibberellic acid (GA_3) on growth characters of chrysanthemum

Treatment	Plant height (cm)	Branches/ plant	Inter-nodal length (cm)	Suckers/ plant
		'Co 1'		
Control	56.0	21.8	2.75	8.22
GA_3				
100 ppm	68.5	36.5	3.78	10.38
150 ppm	70.9	33.5	4.74	11.55
200 ppm	70.4	34.0	4.63	12.43
CD (P=0.01)	1.99	3.54	0.12	0.33
		'Co 2'		
Control	39.05	16.4	2.50	2.80
GA_3				
100 ppm	46.09	19.0	3.25	3.84
150 ppm	44.80	18.5	3.41	2.40
200 ppm	46.36	16.4	3.75	2.13
CD (P=0.01)	1.65	2.8	0.09	0.14

Chrysanthemum requires long days for vegetative growth and short days for flowering. GA_3 is known to substitute the long-day requirement of many crop plants (Krishnamoorthy 1981). In this experiment sprays of GA_3 at 30 and 45 days after planting hastened the flowering with increased number of branches and internodal length. Sen and Maharana (1971) obtained increased growth and more number of nodes in chrysanthemum by GA_3 at 100–200 ppm. Nagarjuna *et al.* (1988) recorded earlier flowering by 17–21 days through GA_3 at 200 ppm. At 100 ppm it induced early flowering and increased the fresh and dry weight of flower stalk (Koriesh *et al.* 1989). Our study confirms these findings, but the optimum concentration of GA_3 for higher flower yield and flowering duration varied with the cultivar.

Table 2 Effect of GA_3 on yield characters of chrysanthemum

Treatment	Days for flowering	Flowers/ plant	Flower yield/plant (g)	Flower-stalk length (cm)	Floral diameter (cm)	Flowering duration (days)
			'Co 1'			
Control	91	68.5	88.1	8.01	4.5	90
GA_3						
100 ppm	66	111.1	127.9	10.24	5.2	122
150 ppm	70	108.5	115.7	10.82	5.5	115
200 ppm	72	110.4	117.3	10.64	5.6	115
CD	3.12**	5.83**	7.15**	2.12**	0.16**	6.12**
			'Co 2'			
Control	110	76	116.7	7.41	4.3	93
GA_3						
100 ppm	83	115.1	145.2	8.63	4.8	120
150 ppm	87	123.5	188.4	9.15	5.1	120
200 ppm	88	128.4	194.9	9.26	5.3	125
CD	3.85**	6.45**	8.97**	NS	0.15*	7.3**

*P = 0.05, **P = 0.01

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Effect of iron deficiency on photosynthetic characters, phytomass production and nutrient composition of sesame (*Sesamum indicum*)

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Iron nutrition increases the root growth, especially lateral roots, whereas its deficiency reduces photosynthetic rate and total chlorophyll content (Terry 1980). With increase in iron concentration in the nutrient solution, iron content increases in the plant tissue but P concentration decreases (Clark *et al.* 1988). Since no serious effort was made to investigate the effect of iron deficiency on nutrient composition and photosynthetic characters in sesame (*Sesamum indicum* L.), this experiment was conducted.

The experiment was carried out in solution culture during 1989–90. Seeds of 'TC 25' sesame were sown in plastic trays containing acid-washed quartz sand. Sesame seedlings were transferred 12 days after sowing to 7 litre-capacity plastic troughs containing 0, 0.05, 0.10, 0.15, 0.20 and 0.25 ppm Fe solution. Each treatment was replicated 5 times with 3 plants in each replication. The nutrient solution was a modified form of Hoagland's formulation (Johnson *et al.* 1957). The culture solution was aerated by bubbling air into the solution. The solutions were changed at weekly intervals and the plants were sampled 25 days after transplanting. The sampled plants were separated into root, stem and leaf, dried separately at 80°C for 48 hr in a hot-air oven and their weights were determined. Physiologically active Fe was estimated by atomic-absorption spectrophotometer, as described by Katyal and Sharma (1980). Samples were digested in acid (10 : 4 HNO_3 : $HClO_4$) for estimating total Fe, P, Zn, Mn and Cu contents following the procedures of Jackson (1967). Specific leaf weight, net photosynthetic rate (calculated in terms of increase in specific leaf weight per day) and chlorophyll content were also determined.

Plant height increased with increase in Fe level in the growth medium (Table 1). The reduction in plant height was 59 and 57% at 0 and 0.05 ppm Fe compared with other treatments. The tap-root length and leaf area increased with increase in Fe level, but the effect was distinct from 0.20 ppm level onwards.

The Fe deficiency decreased the chlorophyll a, b and total chlorophyll contents. It sharply decreased the photosynthetic rate, perhaps due to low chlorophyll content. Mehrotra *et al.* (1988) reported the role of Fe in activation of photosynthetic enzymes and also its deficiency, which causes severe reduction in photosynthesis and chlorophyll content. It also decreased the specific leaf weight (which was low at 0 ppm Fe), owing to low and

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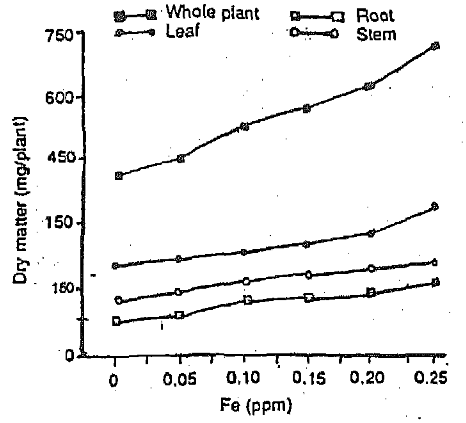

Fig 1 Effect of Fe on dry weight of whole sesame plant

negative photosynthetic rate and dry-matter accumulation.

The Fe deficiency decreased the dry weight of leaves, stem and root, leading to reduction in dry weight of whole plant (Fig 1). Leaves added maximum weight to dry mass of the plant and the root-growth suffered the maximum in Fe-deficient medium. The latter was caused by the decrease in taproot length and its dry mass. Iron deficiency also affected dry matter of stem and leaf, though to a lesser extent than in root.

The total iron (Fe^{3+}) content of the lamina was related to the Fe concentration in the nutrient media. The leaves showed deficiency

Table 1 Effect of Fe level on morphological and photosynthetic characters and nutrient composition 'TC 25' sesame

Plant character	Fe concentration (ppm)						
	0	0.05	0.10	0.15	0.20	0.25	CD (P=0.05)
*Morphological character**							
Plant height (cm)	7.6	7.9	11.3	12.0	12.9	13.3	1.1
Taproot length (cm)	7.9	8.2	8.7	9.2	10.2	10.9	0.9
Leaf area (cm^2)	67.9	68.3	70.5	77.6	88.3	109.0	6.3
*Photosynthetic character**							
Total chlorophyll (mg/g)	1.90	2.31	2.68	4.18	4.53	5.01	0.48
Chlorophyll a (mg/g)	1.14	1.38	1.60	2.50	2.74	3.03	0.48
Chlorophyll b (mg/g)	0.76	0.93	1.08	1.16	1.79	1.98	0.18
Specific leaf weight (mg/cm)	3.01	3.10	3.22	3.35	3.29	3.20	0.06
Photosynthetic rate (mg CO_2/dm^2/day)	—87.0	—23.0	—9.0	75.0	94.0	110.0	12.3
*Nutrient composition**							
Total Fe^{3+} (ppm)	75.0	76.0	79.0	98.0	121.0	137.0	3.0
Iron† (ppm)	0.51	0.71	0.87	1.96	2.78	3.43	0.19
P (%)	0.62	0.59	0.56	0.55	0.54	0.53	0.04
Zn (ppm)	118.0	107.0	95.00	92.00	88.00	85.00	3.00
Mn (ppm)	170.0	163.0	138.0	126.0	112.0	102.00	5.00
Cu (ppm)	28.0	26.0	25.0	23.0	22.0	21.00	4.00
P : Fe^{2+}	1.22	0.83	0.64	0.28	0.19	0.15	
Zn : Fe^{2+}	231.37	150.70	109.19	46.94	31.65	24.78	
Mn : Fe^{2+}	333.33	229.58	158.62	64.29	40.29	29.74	
Cu : Fe^{2+}	54.90	36.62	28.74	11.73	7.91	6.12	
Fe^{3+} : Fe^{2+}	147.06	107.04	90.00	50.00	43.53	33.94	

*38 days after sowing, †Orthophenanthroline iron (Fe^{2+})

symptoms when total iron was 98 ppm in 38-day-old seedlings. The physiologically active iron (Fe^{2+}) in the lamina was highest at 0.25 ppm Fe and decreased significantly with decrease in Fe level. Its content was significantly low even at 0.05 ppm, where mild chlorosis was observed, but the total Fe content at this level was on a par with that of the control. The leaf-chlorophyll content and photosynthetic rates were closely related to physiologically active Fe rather than total Fe content. Hence physiologically active Fe gave good index of chlorosis. The contents of P, Zn, Mn and Cu in the lamina decreased with an increase in Fe level. Clark *et al.* (1988) reported antagonistic effect of Fe on P, Zn, Mn and Cu in sorghum [*Sorghum bicolor* (L.) Moench]. Ratios of P, Zn, Mn and Cu and total Fe with physiologically active Fe also decreased with increase in Fe concentration in the medium due to low physiologically active Fe in the Fe-deficient plants.

It was concluded that Fe-deficiency reduces the dry matter and photosynthetic rate and physiologically active Fe gives good index of chlorosis in sesame.

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Variation in tuber dormancy of andigena potato (*Solanum tuberosum* ssp *andigena*)

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In subtropical plains of India, sudden rise in temperature after harvest of potato (*Solanum tuberosum* L.) crop in February–March requires immediate disposal of potato for table purpose or storage at low temperature. If varieties with longer dormancy are available, the sale of ware potato in the market can be regulated for a longer period and the seed-tubers can be kept even in country stores, till next season. Genotypes with long dormancy possess better keeping quality (Howard 1974, Kaul and Mehta 1988). Andigena potato [*Solanum tuberosum* ssp *andigena* (Juz. & Buk.) Hawkes] forms good parental material for breeding improved potato cultivars for Indian plains. *S. tuberosum* ssp *andigena*, when crossed with *S. tuberosum* shows heterosis in the progeny (Tarn and Tai 1983) for several economic characters. Hence an experiment was conducted to screen germplasm of *S. tuberosum* ssp *andigena* for identifying parental lines with extreme tuber dormancy.

The study was conducted during autumn season 1989 with 375 accessions of *S. tuberosum* ssp *andigena*. These were grown in field (2 rows of 5 tubers/accession) under recommended cultural practices. The haulms were cut when the crop was 100 days old. From the harvest, 10 tubers of each accession were kept in brown paper bags and stored at room temperature (maximum 11–25°C and minimum 9–23°C) for 6 months starting from 7 January 1990. Observations on chitting or sprouting of tubers were recorded at 1-week intervals. The time interval between harvest and chitting (sprout length ≥ 0.5 mm) of 50% tubers was considered as the dormancy period. On the basis of their dormancy period the accessions were grouped into 5 classes, viz (*i*) extremely short dormancy, (*ii*) short dormancy, (*iii*) medium dormancy, (*iv*) long dormancy and (*v*) extremely long dormancy.

A wide range of variation was observed in the dormancy (6–25 weeks). The mean dormancy period was 14 ± 3.5 weeks. Eleven genotypes had dormancy of 21 weeks, viz 'JEX/A 7', 'JEX/A 7b', 'JEX/A 15', 'JEX/A 24', 'JEX/A 29', 'JEX/A 38', 'JEX/A 47', 'JEX/A 49', 'JEX/A 69', 'JEX/A 237' and 'JEX/A 294'. It confirms the report of CIP, Lima (1974) that group *S. tuberosum* ssp *andigena* possesses extremes of tuber dormancy period than *S. tuberosum* potato. Among the genotypes 10.7% had the dormancy period of 0–9 weeks, 38.7% of 10–13 weeks, 33.3% of 14–17 weeks and 14.4% of 18–21 weeks.

The genotypes belonging to extremely short dormancy and extremely long dormancy are of particular interest to the breeders, because the former may be potential parents in

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the breeding programme for regions where 2–3 successive crops of potato are grown in a year. Long dormancy may be useful where only 1 crop is grown, and the ware or seed-tubers are required for long storage particularly for the traditional (country) method of storage. Some of these accessions, viz 'JEX/A 80', 'JEX/A 288', 'JEX/A 410', 'JEX/A 426', 'JEX/A 429' and 'JEX/A 480', also possess 2–4% higher dry matter than the best control 'Kufri Dewa' (22%). The study revealed wide variability for tuber dormancy in *S. tuberosum* ssp *andigena*.

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Inheritance of resistance to white rust (*Albugo candida*) in an interspecific cross between indian mustard (*Brassica juncea*) and rapeseed (*B. napus*)

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White rust, caused by the fungus *Albugo candida* (Pers. ex Lev.) Kuntze, has recently become the most wide-spread and destructive disease of indian mustard [*B. juncea* (L.) Czernj. & Cosson] in India. Singh and Singh (1987) reported yield loss up to 30% in indian mustard. High degree of resistance to white rust is commonly observed in rapeseed (*B. napus* L.) but is rare in *B. juncea*. It is possible to cross these 2 species successfully and transfer the desirable genes to *B. juncea*. Since no attempt has been made to obtain information on the genetics of resistance to *A. candida*, present study was undertaken to study the inheritance of resistance to white rust in an interspecific cross *B. juncea* x *B. napus*.

A synthetic line of *B. napus*, 'Indian Synthetic Napus 706', identified resistance to white rust under artificial inoculation and a widely grown variety of *B. juncea*, 'Varuna', susceptible to white rust, were used in the crossing programme carried out during the winter season 1987 at New Delhi. The F_1 hybrid seeds were treated with 0.5% ethylenediaminetetraacetic acid for 13 hr after pre-soaking in water for 8 hr to increase recombination in the F_1. The treated F_1M_1 and untreated F_1 seeds were sown during winter season 1988. The F_1 plants were backcrossed to both susceptible and resistant parents. The F_1 and F_1M_1 plants were also selfed to obtain seeds for F_2 and F_2M_2 populations. The parents, F_1, F_2, F_2M_2 and BC_1F_1 were grown in randomized complete-block design replicated 3 times on 17 November 1989—20 days later than normal season for adequate disease pressure. For artificial disease inoculation, the inoculum suspension (leaves infected with white rust were crushed in sterilized distilled water) was sprayed once 50 days after sowing. To maintain humidity in the field, the crop was irrigated twice, 40 and 60 days after sowing. Absence of rust pustules on the inoculated leaves was considered a sign of resistance. Data were subjected to chi-square analysis.

All the F_1 and F_1M_1 plants obtained from the crosses, including reciprocals of 'Indian Synthetic Napus 706', and 'Varuna' gave resistant plants. It indicates that the resistance carried by 'Indian Synthetic Napus 706' is expressed as a dominant phenotype and this character is controlled by nuclear genes. The F_2 and F_2M_2 showed a segregation ratio of 13 resistant (R) to 3 susceptible (S), with a good fit in all the crosses (Table 1). Progenies from the backcrosses to the susceptible parent segregated in the ratio of 1 R : 1 S. Backcros-

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Table 1 Inheritance of resistance to white rust in an interspecific cross 'Varuna' *B. juncea* x 'ISN 706' *B. napus*

Selection no.	Cross	Generation	No. of plants Resistant	Susceptible	Total	χ^2	Probability	Mode of segregation
1	'Varuna' x 'ISN 706'	F_1	117	0	117			
2	'ISN 706' x 'Varuna'	F_1	119	0	119			
3	'Varuna' x 'ISN 706'	F_2	234	42	276	2.26	0.10–0.20	13 : 3
4	'ISN 706' x 'Varuna'	F_2	167	31	198	1.43	0.20–0.30	13 : 3
5	'Varuna' x 'ISN 706'	F_2M_2	169	34	203	0.53	0.30–0.50	13 : 3
6	'ISN 706' x 'Varuna'	F_2M_2	181	41	222	0.01	0.70–0.80	13 : 3
7	('Varuna' x 'ISN 706') x 'Varuna'	B_1	112	123	235	0.52	0.30–0.50	1 : 1
8	('ISN 706' x 'Varuna') x 'Varuna'	B_1	124	126	250	0.01	0.80–0.90	1 : 1
9	('Varuna' x 'ISN 706') x 'ISN 706'	B_2	136	0	136			
10	('ISN 706' x 'Varuna') x 'ISN 706'	B_2	129	0	129			
11	'Varuna'	P_1		All				
12	'ISN 706'	P_2	All					

ses to resistant parent gave all resistant plants. The pattern of segregation ratios of 13 R : 3 S in F_2 and 1 R : 1 S in backcrosses indicates the presence of digenic inheritance with dominant and recessive gene interaction. With this gene interaction, only 2 F_2 phenotypes result when a dominant gene at 1 locus (eg AA or Aa) and the recessive gene at the other locus (bb) produce the same phenotypic effect. The other dominant gene (eg BB or Bb) alone is not capable of producing resistance and this gene is without any phenotypic expression of its own. Susceptibility would be expressed when the genes at this second locus (eg BB or Bb) are dominant either in homozygous and heterozygous condition.

Gene symbols for resistance and susceptibility were proposed on the basis of dominant and recessive epistatic interaction in the parents and segregating populations (Table 2). Genetic symbols were assigned to susceptibility in accordance with genetic nomenclature suggested for *Brassica* (Fan *et al.* 1983). The genetic symbols ac_1 and Ac_2 are proposed for susceptibility. The resistant genotypes would be Ac_1 – – – and ac_1ac_1 ac_2ac_2, showing dominant epistasis of

Table 2 Proposed genetic constitution for resistance and susceptibility to white rust in parents and interspecific cross derivatives of *Brassica* spp

Population	Genotype	Phenotype
'Varuna'	ac_1ac_1 AC_2AC_2	S
	ac_1ac_1 AC_2ac_2	S
'Indian Synthetic Napus 706'	AC_1AC_1 ac_2ac_2	R
	AC_1AC_1 AC_2AC_2	R
Segregating populations	AC_1AC_1 ac_2 ac_2	R
	AC_1ac_1 AC_2AC_2	R
	AC_1ac_1 AC_2ac_2	R
	ac_1ac_1 ac_2ac_2	R
	ac_1ac_1 AC_2ac_2	S
	ac_1ac_1 AC_2AC_2	S

R, Resistant; S, susceptible

the Ac_1 allele on Ac_2 allele and a dosage effect of the ac_2 allele. The susceptible genotypes would be ac_1ac_1 Ac_2 –. Tiwari *et al.* (1988) reported monogenic dominant resistance of white-rust resistance in interspecific hybrids of *B. juncea* with *B. napus* and ethiopian mustard (*B. carinata* A. Braun). Fan *et al.* (1983) proposed genetic ratios 15 : 1 and 63 : 1 of resistance and susceptibility.

Thus our results are partly in agreement for the number of genes with those of Fan *et al.* (1983), indicating that the susceptibility of 'Varuna' (*B. juncea*) to the local Delhi pathotype of *A. candida* is conditioned by 2 genes, with dominant and recessive gene interaction. Our result is based on only limited number of parents and their progenies. Still the information might help determine the size of population and breeding strategies to be adopted in incorporating white-rust resistance in commercial varieties.

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Nitrogen economy in pearl millet (*Pennisetum glaucum*) and blackgram (*Phaseolus mungo*) intercropping system under rainfed conditions of Vindhyan plateau

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Short-duration pulses like blackgram (*Phaseolus mungo* L.) and greengram (*P. radiatus* L.) are grown predominantly in association with pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz]. Bhati and Manohar (1989) reported reduction in yields of short-statured legumes when intercropped with pearl millet. However, Singh *et al.* (1989) reported overall nitrogen economy in cereal and legume intercropping system due to inclusion of legumes. Thus there is a need to ascertain the appropriate nitrogen levels for component crops of pearl millet and blackgram in intercropping system in relation to production potential and nitrogen economy. Hence an experiment was conducted on these aspects in Ultisols of Vindhyan plateau.

The experiment was conducted under rainfed situation during rainy seasons of 1989 and 1990 at Barkachha in medium-deep Ultisol. The soil was sandy clay-loam, having *p*H 6.5 and the available N, P and K 142, 3.6 and 190 kg/ha respectively. The rainfall during the growing period (June–October) was 999.8 mm in 1989 and 1 119.7 mm in 1990.

Randomized block design was followed with 3 replications. There were 15 treatment combinations, viz T_1, sole pearl millet with N_{80} (recommended dose); T_2, sole pearl millet with N_{60}; T_3, sole pearl millet with N_{40}; T_4, sole blackgram with N_{20} (recommended dose); T_5, sole blackgram with N_{10}; T_6, sole blackgram without N; T_7, pearl millet with N_{80} + blackgram with N_{20}; T_8, pearl millet with N_{80} + blackgram with N_{10}; T_9, pearl millet with N_{80} + blackgram without N; T_{10}, pearl millet with N_{60} + blackgram with N_{20}; T_{11}, pearl millet with N_{60} + blackgram with N_{10}; T_{12}, pearl millet with N_{60} + blackgram without N; T_{13}, pearl millet with N_{40} + blackgram with N_{20}; T_{14}, pearl millet with N_{40} + blackgram with N_{10}; and T_{15}, pearl millet with N_{40} + blackgram without N. For 100% plant population in sole crops, 6 kg seed/ha of 'WCC 75' pearl millet was sown at 45 cm row spacing and 20 kg seed/ha of 'Type 9' blackgram was sown at 30 cm row spacing.

In intercropping system the plant population of pearl millet was kept as in the sole crop (100%) and 1 row of 75% plant population (15 kg seed/ha) of blackgram was grown between 2 rows of pearl millet. Recommended doses of 17.5 kg P/ha and 33.2 kg K/ha for sole pearl millet (100% population) and 17.5 kg P/ha and 16.6 kg K/ha for 100% population of blackgram along with N as per treatments were applied in furrows 2–3 cm below the seed. For 75% of N of various treatments were

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applied. Crops were sown on 5 July 1989 and 13 July 1990. Weeding and plant-protection measures were taken as and when required.

The maximum grain yield and grain-yield recovery of pearl millet was recorded in T_7, which was comparable to that of T_{10} (Table 1). It indicates that in the intercropping system the full yield of pearl millet at recommended dose of N could be realized by applying 20 kg/ha less N, provided the recommended dose of 20 kg N/ha is applied to blackgram. Thus it saves 20 kg N/ha in pearl millet due to N transfer from legume component to the cereal component.

This result confirms the finding of Sharma and Chaubey (1991). The yield and yield recovery of pearl millet decreased at lower levels of N applied to the sole crop. In all the treatment combinations the yield recovery was less than 100% except in T_7 (104.7%), T_8 (100.4%) and T_{10} (103.8%). The grain yield of blackgram was reduced in intercropping than in sole crop. The yield of blackgram was 61% in T_7, 56.2% in T_8 and 62.8% in T_{10}. The reduction in yield of blackgram may be due to shedding effect of pearl millet. Patil and Patil (1989) reported similar result. The highest pearl millet-equivalent yield (3 035 kg/ha) was in T_{10}, which was comparable to that in T_7. The total production and yield advantage decreased at lower N level. The highest net return/rupee invested (Rs 2.86) was recorded

Table 1 Effect of treatments on yield and yield recovery of pearl millet and blackgram and return per rupee invested

Treatment	Pearl millet		Blackgram		Pearl millet equivalent (kg/ha)	Return/Re (Rs)
	Grain yield (kg/ha)	Grain-yield recovery (%)	Grain yield (kg/ha)	Grain-yield recovery (%)		
T_1	1 672	100.0			1 672	2.27
T_2	1 469	87.9			1 469	2.13
T_3	1 223	73.1			1 223	1.92
T_4			616	100.0	2 068	2.31
T_5			528	85.2	1 772	2.03
T_6			445	72.2	1 494	1.76
T_7	1 715	104.7	376	61.0	2 977	2.68
T_8	1 678	100.4	346	56.2	2 839	2.60
T_9	1 625	97.2	305	49.5	2 649	2.46
T_{10}	1 736	103.8	387	62.8	3 035	2.86
T_{11}	1 494	84.9	360	58.4	2 702	2.58
T_{12}	1 438	86.0	305	49.5	2 461	2.39
T_{13}	1 435	85.8	376	61.0	2 697	2.67
T_{14}	1 311	78.4	348	56.5	2 479	2.50
T_{15}	1 239	74.1	323	52.4	2 323	2.38
SEm ±	61.2		15.2		59	
CD (P = 0.05)	178.5		43.8		171	

Price: Pearl millet Rs 210/100 kg, blackgram Rs 705/100 kg
The details of treatments are given in text

from T_{10}, followed by T_7 (Rs 2.60). Thus intercropping blackgram with pearl millet could lead to saving 20 kg N/ha in pearl millet.

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Relative performance of granular fertilizers in irrigated rice (*Oryza sativa*)

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Despite agronomic efforts to improve the nitrogen-use efficiency, the recovery of fertilizer N applied to transplanted rice (*Oryza sativa* L.) is seldom more than 30–40% (De Datta 1987). The use of prilled urea as a source of N is invariably associated with various mechanisms of nutrient loss, which are of considerable significance and practical relevance for increasing the nutrient-use efficiency and grain yield of rice. The present investigation was taken up to evaluate the effect of supergranulation of urea and diammonium phosphate and to identify more efficient granular fertilizers suitable for broadcasting in a puddled rice-soil system, instead of prilled urea.

The study was carried out during dry season (December–March 1991–92) and wet season (June–October 1992) in clay-loam soils (Vertisol) of Hyderabad. The soil had *p*H 8.3, cation-exchange capacity 45 meq/100 g soil, total N 220 kg/ha and available P 10 kg/ha. The recommended fertilizer N, P and K were applied uniformly @ 90, 60 and 50 kg/ha respectively. Nitrogen was applied in 2 equal splits, the first half basal and the second half at panicle-initiation stage. The trial was laid out in randomized block design with 9 treatments, replicated 4 times. The treatments were: T_1, the control; T_2, prilled urea + single superphosphate; T_3, prilled urea + diammonium phosphate; T_4, prilled urea + large granular diammonium phosphate; T_5, large granular urea + single superphosphate; T_6, large granular urea + diammonium phosphate; T_7, large granular urea + large granular diammonium phosphate; T_8, urea supergranules + single superphosphate; and T_9, urea supergranules + large granular diammonium phosphate. Seedlings of 'Rasi' at 25 days were transplanted on 27 January 1992 in the dry season, and on 1 August 1992 in the wet season, using 2–3 seedlings/hill, 10 cm apart in rows 20 cm apart, following a plant population of 50 hills/m.

All the fertilizer treatments significantly improved the rice yield compared with the control. The plants in the control plots showed sparse tillering and pale-yellow leaves up to maximum tillering stage, which showed normal green colour later due to ramification of roots in the subsoil, from which additional nutrients were drawn after the tillering stage.

The grain yield was significantly high with application of urea supergranules + large granular diammonium phosphate (T_9) and urea supergranules + single superphosphate (T_8), when N was placed in the root zone. Other granular forms of fertilizers such as large granular diammonium phosphate also recorded higher grain yield than the application of prilled urea + single superphosphate (T_2), registering 34.5% more yield during dry season and 23.4% during wet season (Table 1). This might be attributed to the partial

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Table 1 Effect of granular fertilizers on grain yield, N response and benefit : cost ratio of rice

Treatment	Dry season 1991					Wet season 1992				
	Grain yield (tonnes/ha)	N response (kg grain/kg N)	Gross return (Rs/ha)	Net return	Benefit: cost	Grain yield (tonnes/ha)	N response (kg grain/kg N)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit: cost
T_1	2.89		10 115	5 365	2.13	2.65		9 275	4 525	1.92
T_2	4.76	20.8	16 660	10 103	2.54	3.96	25.7	13 860	7 303	2.11
T_3	5.16	25.2	18 060	11 809	2.89	4.71	22.9	16 485	10 234	2.64
T_4	5.64	30.5	19 740	13 320	3.07	5.33	29.8	18 655	12 235	2.91
T_5	5.20	26.3	18 200	11 565	2.73	4.99	26.0	17 465	10 830	2.63
T_6	5.13	24.9	17 955	11 473	2.78	4.79	23.8	16 765	10 283	2.59
T_7	5.48	28.8	19 180	12 529	2.88	5.26	29.0	18 410	11 759	2.77
T_8	6.10	35.7	21 350	14 715	3.22	5.73	34.2	20 055	13 420	3.02
T_9	6.40	39.0	22 400	15 749	3.37	6.12	38.6	21 420	14 769	3.22
CD (P = 0.05)	0.43					0.38				

Details of treatments are given in text

Prices of the fertilizer (Rs/kg): Prilled urea, 3; single superphosphate, 3.25; diammonium phosphate, 8.20; large granular urea + urea supergranules, 3.50; diammonmuim phosphate, 9.50

placement effect achieved by sinking of bigger granules in the soft mud at the time of basal application, the slow dissolution rate of bigger granules and the prolonged availability of deep-placed fertilizer materials from the reduced zone because of better chance of retention of N in the ammoniacal form; thereby minimizing the nutrient loss and increasing the efficiency of nutrient use. The highest N response was recorded with urea supergranules + large granular diammonium phosphate (T_9). Pillai and Krishnamurthy (1983), Subbaiah and Sharma (1987) and Subbaiah (1990) also reported higher efficiency of modified urea materials, such as urea supergranules when placed at 5–8 cm depth by root zone, indicating its usefulness for rainfed lowland rice areas. The larger granules are advantageous in submerged soil, where N cannot be top-dressed with advantage, because excessive standing water acts as a physical barriers for the top-dressing.

The benefit : cost ratio was high with all granular fertilizers, being highest under urea supergranules + large granular diammonium phosphate (T_9), during both the seasons.

It was concluded that large granular forms of N and P fertilizers are better than powdered or prilled forms like prilled urea + single superphosphate for increasing the nutrient-use efficiency and grain yield of rice in lowland.

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Effect of nitrogen, phosphorus and zinc on growth and yield attributes of rainfed horsegram (*Macrotyloma uniflorum*) in Rajasthan

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Horsegram [*Macrotyloma uniflorum* (Lam.) Verdc.] is grown on marginal land in Rajasthan. The crop shows deficiency symptoms of various nutrients. Hence an attempt was made to study the effect of nitrogen, phosphorus and zinc on yield of this crop.

The field experiment was conducted at Sumerpur during the rainy seasons of 1991 and 1992. The soil was loamy sand, low in available nitrogen (133 kg/ha) and medium in phosphorus (17 kg/ha) and potassium (185 kg/ha), with *p*H 7.8. The treatments comprised 3 levels each of N (0, 10 and 20 kg/ha) and P (0, 8.80 and 17.60 kg/ha) and 2 levels of Zn (0 and 4.1 kg/ha), replicated 3 times in factorial randomized block design. The fertilizers were applied at sowing. 'Kulthi Selection 2' horsegram was sown on 14 July 1991 and 22 July 1992 with 20 cm row-to-row and 15 cm plant-to-plant spacings. The total rainfall received during the crop period was 228 mm in 1991 and 830 mm in 1992.

Nitrogen @ 10 kg/ha gave significantly higher seed yield than the control, but it was on a par with that at 20 kg N/ha (Table 1). Pods/plant, pod length and seeds/pod showed a similar trend. N @ 10 kg/ha increased the seed yield by 275 kg/ha compared with the control, giving 59.0% more yield. N application up to 20 kg/ha significantly increased the ripening period and plant height. Patra (1991) also reported response to N up to 20 kg/ha in horsegram.

Application of P up to 8.80 kg/ha increased the seed yield significantly. Pods/plant, pod length and seeds/pod showed a similar trend. The maturity of crop decreased significantly by 5.6 days at 17.60 kg P/ha compared with the control. However, plant height remained unaffected. Our result confirms the finding of Singh and Singh (1992). The application of N and P increased the pods/plant, seeds/pod, pod length and 1 000-seed weight, which in turn increased the seed yield. The correlation coefficients of seed yield with pods/plant (0.852), pod length (0.766), seeds/pod (0.892) and 1 000-seed weight (0.805) were positive and significant at 5% level.

Application of Zn did not significantly influence the seed yield. However, 4.1 kg Zn/ha increased the pods/plant by 7.09% compared with the control. It also decreased the ripening period of the crop by 4.2 days compared with the control. Thus rainfed horsegram grown on marginal lands of Rajasthan needs 10 kg N/ha and 8.80 kg P/ha and no zinc.

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Table 1 Effect of nitrogen, phosphorus and zinc on growth, yield attributes and seed yield of horsegram (pooled data of 2 years)

Treatment	Growth attribute			Yield attribute				Seed yield (kg/ha)
	Days to maturity	Plant height (cm)	Branches/ plant	Pods/ plant	Pod length (cm)	Seeds/ pod	1 000-seed weight (g)	
N (kg/ha)								
0	100.3	51.3	17.3	45.0	3.85	4.21	28.3	466
10	101.2	54.9	19.7	60.5	4.30	4.50	30.5	741
20	105.8	60.3	22.5	63.1	4.51	4.69	31.7	765
SEm ±	1.08	0.58	0.65	1.05	0.19	0.20	0.37	8
CD (P = 0.05)	3.18	1.75	1.80	3.04	0.57	0.59	1.08	25
P (kg/ha)								
0	103.1	54.2	18.3	50.2	3.87	3.90	27.7	592
8.80	101.2	55.0	20.1	58.2	4.13	4.70	30.4	677
17.60	97.5	55.2	23.3	60.7	4.60	4.89	31.7	695
SEm ±	1.08	0.58	0.65	1.05	0.19	0.20	0.37	8
CD (P = 0.05)	3.18	NS	1.80	3.04	0.57	0.59	1.08	25
Zn (kg/ha)								
0	102.7	55.2	21.3	55.0	4.18	4.31	30.0	653
4.1	98.5	55.9	20.3	58.9	4.35	4.62	30.7	657
SEm ±	0.85	0.44	0.54	0.84	0.14	0.14	0.28	6.5
CD (P=0.05)	2.55	NS	NS	2.50	NS	NS	NS	NS

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Effect of phosphorus and potassium on yield and quality of hedge lucerne (*Desmanthus virgatus*)

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Most of the livestock farmers in Tamil Nadu feed their animals with graminaceous fodder like sorghum [*Sorghum bicolor* (L.) Moench], maize (*Zea mays* L.) and pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz]. To provide balanced nutrition to the cattle in lactation and to work bullocks, a mixture of grass and leguminous fodder is more important because it provides enough energy as well as proteins. Hence an experiment was conducted to find out the optimum dose of fertilizers required for producing good-quality fodder of hedge lucerne (*Desmanthus virgatus* Willd.) with high yield.

The trial was laid out during July 1989 at Kattupakkam. There were 10 treatments comprising 3 levels of P (13.2, 26.4 and 39.6 kg/ha) and K (12.6, 25.2 and 37.8 kg K/ha). These were: T_1, P_0K_0 (0 kg/ha P and 0 kg/ha K); T_2, $P_{13.2}K_{12.6}$; T_3, $P_{13.2}K_{25.2}$; T_4, $P_{13.2}K_{37.8}$; T_5, $P_{26.4}K_{12.6}$; T_6, $P_{26.4}K_{25.2}$; T_7, $P_{26.4}K_{37.8}$; T_8, $P_{39.6}K_{12.6}$; T_9, $P_{39.6}K_{25.2}$; and T_{10}, $P_{39.6}K_{37.8}$. Factorial randomized block design was adopted replicated thrice.

The crop was raised in the non-calcareous sandy clay-loam soil, having medium level of available N, P and K, with *p*H 7.4. Farmyard manure @ 25 tonnes/ha was applied basal and incorporated into the soil. Nitrogen @ 10 kg/ha was applied basal at the time of sowing.

At the time of sowing, P and K were applied as per the treatment combinations. The seeds were sown in plots of 8 m x 5 m at a spacing of 50 cm between the rows, keeping a solid stand within the rows. Irrigation was given once in 10–15 days, depending on the soil-moisture content. First harvest was taken 90 days after sowing at a height of 50 cm from the ground level and the green-fodder yield was recorded. Subsequent harvests were taken at 45-day intervals and the yields were recorded. After each harvest, weeding and earthing-up operations were done, followed by irrigation. After 3 harvests, interploughing was done with country plough.

A known weight (10 g) of the green-fodder samples was collected and dried in an oven at 105°C for 8 hr. The samples were weighed to find out the moisture content, and were powdered. Crude-protein content in the plant samples was estimated by determining the N content and multiplying it by a factor 6.25 (Gopalakrishnan and Lal 1985).

Application of 26.4 kg P/ha and 37.8 kg K/ha gave the maximum green-fodder yield, with an increase of 65.2% compared with the control (Table 1). All the fertilizer treatments indicated the importance of P in increasing the

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Table 1 Green-matter yield (tonnes/ha) and crude-protein content (%) of hedge lucerne under different fertilizer treatments (mean data of 10 cuttings)

Treatment	Green-matter yield	Crude-protein content
T_1	7.46	18.27
T_2	7.94	18.72
T_3	8.49	18.75
T_4	9.25	18.82
T_5	9.60	18.99
T_6	11.05	18.91
T_7	12.33	19.13
T_8	9.79	18.82
T_9	9.64	18.83
T_{10}	8.92	18.83
SE	1.28	1.98
CD (P=0.05)	3.84	5.94

The details of treatments are given in text

yield of green matter; application of higher levels of P decreased the yield of green fodder.

Analysis of plant samples revealed that the treatment T_7 ($P_{26.4}K_{37.8}$) gave the maximum crude-protein content of 19.13% compared with the control. Application of P and K to leguminous crops hastens and encourages the development of N-fixing bacteria, which in turn increases the N content. Shanmugasundaram (1985) also reported an increase in crude-protein content on addition of N.

It was concluded that the application of medium level of P (26.4 kg/ha) and higher level of K (37.8 kg/ha) increases the yield of protein-rich fodder.

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Seasonal incidence of stem weevil (*Hypolyxus truncatulus*) and its effect on growth and grain yield of amaranth (*Amaranthus hypochondriacus*)

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Grain amaranth (*Amaranthus hypochondriacus* L.) is grown on a limited scale all over India. Though it is affected by a number of insect pests, stem weevil (*Hypolyxus truncatulus* Boh.) severely affects the crop (Ram *et al.* 1989). The affected stem becomes weak and splits, resulting in excessive water loss and drying up of plants. Heavy infestation of the weevil was observed during rainy seasons of 1987 and 1988 at the research farm at Delhi. Since little information is available on the type of insects attacking grain amaranth and on their control, the present study was undertaken during 1989–90 and 1990–91 to identify the season during which the crop could escape stem-weevil infestation.

'Annapurna' was sown on 10 different dates during 1989–90 and 1990–91 in factorial randomized block design with 4 replications. At the time of harvest, observations were recorded on plant height and panicle length on 5 randomly selected plants from each plot. For recording grain yield, all the

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Table 1 Effect of sowing date on stem-weevil infestation, growth and yield of grain amaranth (mean data of 1989–90 and 1990–91)

Sowing date	Stem-weevil infestation (%)	Plant height (cm)	Panicle length (cm)	Grain yield (kg/ha)
I week of Feb	69.10	88.25	30.25	140
I week of Mar	78.00	102.25	27.60	109
II week of Mar	87.30	125.40	21.75	0
I week of Apr	73.60	137.75	0	0
III week of Jul	45.40	149.20	38.50	817
I week of Aug	40.40	107.10	35.55	826
III week of Aug	35.30	122.70	28.00	592
I week of Sep	30.60	99.40	32.80	731
I week of Oct	21.80	93.05	28.70	652
I week of Nov	26.10	72.60	32.60	756
II week of Dec	34.70	33.70	14.70	320
SEm	4.33	2.93	1.37	0.79
CD (P = 0.05)	9.77	6.71	3.63	1.75

plants were taken. Data on infestation by stem-weevil were recorded by splitting the stem showing wilting, and drying and calculating the plant population (%) infested. The data were statistically analysed.

Grain amaranth showed more vegetative growth when sown during March–August. However, amaranth sown during March–April did not produce grain because of heavy stem-weevil infestation and absence of grain-filling due to high temperature. Lack of flowering in April-sown crop may be attributed to photosensitive nature of 'Annapurna'. When the crop was sown in September–October it showed reasonable vegetative growth, good grain yield and lowest stem-weevil infestation. Budhraja *et al.* (1984) and Singh *et al.* (1991) also reported a decline in stem-weevil infestation in sorghum [*Sorghum bicolor* (L.) Moench] and pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz] beyond August.

It was concluded that stem-weevil infestation in grain amaranth may be effectively controlled by sowing the crop by the end of September or first half of October.

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Run-off and soil loss from inward- and outward-sloping terraces

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In Kullu valley terraced fields (constructed on the basis of farmers' own experience) are being cultivated in traditional manner. These terraces invariably have outward cross slope and are haphazardly oriented, having longitudinal slope in different directions. Crops are grown in these fields on sloping lands, having a slope of more than 10%. This causes soil erosion on disturbance of top layer during cultivation. The rainfall (mean of 1988–89 to 1990–91) in this valley is 527.3 mm during the winter season (October–April) and 525.8 mm during the rainy season (May–September). The evaporation is 458.8 mm during winter and 678.8 mm during rainy seasons. Since 750–1 125 mm/year is the medium rainfall (Tandon 1991), the experimental site gets medium rainfall of 1 053.1 mm/year. Michael and Ojha (1981) mentioned that in heavy rainfall areas bench terraces having inward slope are more effective than those having outward slope, which are effective in low-rainfall areas with a permeable soil of medium depth. The depth of our experimental site was shallow (45 cm), receiving medium rainfall. No work has been done on this aspect in Kullu valley. An experiment was therefore conducted to evaluate the effectiveness of inward or outward cross-slope terraces in the presence of pure and mixed crops and to study the economics of these crop patterns in this area.

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The trial was conducted during 1988–89, 1989–90 and 1990–91 in 2 terraces at farmers' fields, located near Bajaura, having inward and outward cross slope of 2.5%. The 2 terraces were divided into 3 equal plots (62.9 m^2). The treatments consisted of maize (*Zea mays* L.), blackgram (*Phaseolus mungo* L.) and maize + blackgram during rainy season and wheat (*Triticum aestivum* L. emend. Fiori & Paol.), lentil (*Lens culinaris* Medikus) and wheat + lentil (2 : 1) during the winter season. The maize crop failed due to acute drought in 1989 and 1990, whereas it could not be sown in 1991 due to very late onset of monsoon. Thus the result of this study is restricted to winter season only.

The soil was gravelly sandy loam, having *p*H 6.4, low in available P (2 kg/ha), medium in organic carbon (249 tonnes/ha), available N (273 kg/ha) and available K (174 kg/ha). The soil depth was shallow (45 cm). Fertilizer N, P and K were applied to 'S 308' wheat @ 90, 20 and 25 kg/ha respectively, and N and P to 'HPL 5' lentil @ 10 and 17 kg/ha. The wheat and lentil crops were sown in the first week of December during the first 2 years, and on 15 January in the third year due to late arrival of the winter rains.

The run-off water from each plot was allowed to drop as a sheet flow in the channel dug out along the entire length of the terrace. The surface of the channel was covered with polythene sheet to eliminate the sediment and infiltration loss during its flow towards the container. The channel was also covered from the top with galvanized iron sheet for checking rain-water flow into the channel. At the downstream end of each channel, section pits were dug for placing drums to collect the run-off water from each plot. The water from the riser was allowed to fall in the channels of outward-sloping terrace and was drained off separately from inward-sloping terraces during 1988–89 and 1989–90. But it was drained off separately in both the types of terraces during 1990–91 and was thus not included in the calculations of run-off and soil loss in the field. These losses were computed after each storm during 15 February–23 May (98 days) in 1988–89, 20 December–5 May (137 days) in 1989–90 and 10 March–27 May (69 days) in 1990–91. Total rainfall during these periods was 206, 635 and 189 mm, which was collected from the nearby observatory. The aerial distribution of the rainfall was assumed the same at both the locations for calculation.

During 1988–89 and 1989–90 the run-off and soil loss were higher from terraces with outward than from the terraces with inward slope (Table 1). The average run-off and soil loss were 95 and 17% more in outward-sloping terrace than in inward-sloping terrace. The reason may be that rain drops falling on riser's surface in the former contributed to the surface run-off. In addition to increasing the volume of run-off water, it increased the velocity of flow, resulting in greater loss of soil. But in terraces with inward slope the run-off water from riser's surface did not form a part of the channel flow, and thus to the volume collected. Under natural conditions when the surface run-off from the riser is not cut off by a channel, the surface run-off from the terrace starts collecting along the entire length of the riser of inward-sloping terrace. The undulating condition of the terrace causes some resistance to the flow of run-off, which takes sometime for infiltration. In the outwardly sloping terrace the surface run-off passes without any resistance. This causes greater volume of run-off in outward-sloping terrace compared with the inward-sloping one. However, during 1990–91, when this part of run-off was not allowed to cross the experimental plots of outward-sloping terrace, there was almost no variation in the surface run-off and soil loss due to variation in the direction of cross slope. Thus in the medium-rainfall area bench terraces having inward slopes are more effective than terraces with outward slope with a soil of shallow depth.

Table 1 Effect of inward and outward slopes on amount of run-off and soil loss in 1988–89 and 1989–90

Crop	Run-off (mm)/ha				Run-off (% of rainfall)				Soil loss (tonnes)/ha			
	Mean of 2 years†		1990–91		Mean of 2 years		1990–91		Mean of 2 years		1990–91	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Wheat	3.55	7.33	1.84	1.90	0.85	1.75	0.97	1.01	3.59	4.20	0.29	0.29
Lentil	3.84	7.08	1.73	1.88	0.91	1.69	0.92	0.99	3.84	4.69	0.21	0.39
Wheat + lentil	3.73	7.36	1.85	1.91	0.89	1.75	0.98	1.01	4.37	4.82	0.39	0.29
Mean	3.71	7.22	1.81	1.89	0.88	1.73	0.96	1.00	3.93	4.59	0.30	0.32

In, Inward slope; Out, outward slope; †1988–89 and 1989–90

Table 2 Effect of inward and outward slopes on crop yield and return

Crop	Produce	Yield (kg/ha)				Return‡ (Rs/ha)			
		Mean of 2 years†		1990–91		Mean of 2 years		1990–91	
		In	Out	In	Out	Gross	Net	Gross	Net
Wheat	Grain	3 579	3 438	1 629	1 980	14 756	13 964	7 561	6 769
	Straw	6 155	5 933	2 769	3 366				
Lentil	Grain	1 169	1 258	1 081	787	14 588	14 299	11 287	10 998
	Straw	1 989	2 141	1 838	1 538				
Wheat	Grain	2 385	2 047	1 034	1 232	9 279	8 751	4 747	4 219
	Straw	4 058	3 460	1 758	2 094				
Lentil	Grain	90	145	469	254	1 476	1 380	4 461	4 365
	Straw	236	376	1 046	568				

In, Inward slope; Out, outward slope

†1988–89 and 1989–90; ‡Average of inward and outward slopes

Price (Rs/100 kg): Wheat grain, 300; lentil grain, 1 100; wheat straw, 70; lentil straw, 60; cost of fertilizer (Rs/100 kg): urea, 235; superphosphate, 95; muriate of potash, 130

When run-off from the riser was not cut off during 1989–90, the soil loss from inward-and outward-sloping terraces was 6.44 and 7.34 tonnes/ha in 4½ months. This loss, calculated on yearly basis, may exceed the maximum tolerable soil loss (t-value) of 12.5 tonnes/ha/year (Brady 1990). But during 1988–89 the average soil loss was 1.42 and 1.85 tonnes/ha in 3 months for inward-and outward-sloping terraces respectively, which is within the limit of t-value. The differences could be attributed to higher precipitation during 1989–90 than during 1988–89.

On an average, the run-off did not differ under different crops during the period of investigation. But the mean soil loss under wheat + lentil and lentil was respectively 17 and 8% more than that under wheat.

The yield of crops (Table 2) did not differ consistently due to variation in the slope. The reduction in yield in outward-sloping terrace might be apparent after some years due to continuous erosion of top soil. The net return (gross return — cost of fertilizer) was almost similar for wheat and lentil and was 38–41% higher than that of wheat + lentil calculated, on the basis of mean values of 1988–89 and 1989–90 (Table 2). However, during 1990–91 lentil and wheat + lentil gave 63 and 21% higher net return than that of wheat alone. Thus under very late-sown condition, which is often encountered under rainfed condition, lentil followed by wheat + lentil is more remunerative than pure crop of wheat.

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CROP PROTECTION

Short Communications

Indian Journal of Agricultural Sciences 64 (4) : 266–7, April 1994

Rust incidence in late-sown wheat (*Triticum aestivum*)

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Received: 6 July 1992

Leaf rust of wheat (*Triticum aestivum* L. emend. Fiori & Paol.) caused by *Puccinia recondita* Rob. ex Dorm. and stem rust caused by *Puccinia graminis tritici* Erikss. & Henn. have been the major constraints in stabilizing the yield in central and peninsular India. In view of a generally high incidence of rust in the late-sown wheat, an experiment was conducted to compare the development of rust in normal-sown wheat with that in late-sown one.

A National Heat Tolerance Screening Nursery was planted at Indore, under 3 dates of sowing, viz 15 November (normal sown), 15 December (late sown) and 15 January (very late sown) during 1990–91 and 1991–92 to identify suitable wheat varieties that could withstand the high temperature prevailing in this region during the grain-filling period under late-sown conditions. Six high-yielding varieties of bread wheat were taken, viz 'HD 2270', 'HD 2285', 'HD 2329', 'HD 2402', 'HI 977' and 'Sonalika'. Two population densities, viz 250 000 and 300 000 plants/ha, using seed rate of 100 and 125 kg/ha respectively were maintained. There were 3 replications under each level of population density, making 6 replications under each date of sowing. The plot size was 4.14 m^2, comprising 6 rows of 3 m length, sown 23 cm apart. Adequate irrigation and recommended levels of fertilizers were applied.

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Although no rust inoculation was attempted in the nursery, the plots of breeding material and the pathological nurseries wherein artificial rust epiphytotic was created (using mixture of prevalent and virulent pathotypes of leaf and stem rusts) served as the source of inoculum that got established in the National Heat Tolerance Screening Nursery. The nursery was located in an isolated plot, separated from the inoculum source by 100 m wide plot of dryland wheat. These conditions simulated natural infection better than the usual method of rust infection within the test plots.

The disease spread fairly uniformly in the nursery, and there was no significant difference in rust development between the 2 levels of population density or among different replications within each date of sowing.

Terminal rust reaction was recorded on appropriate dates, combining disease severity

Table 1 Rust incidence in wheat varieties under different dates of sowing

Variety	Terminal disease severity in crop sown on					
	15 Nov		15 Dec		15 Jan	
	LR	SR	LR	SR	LR	SR
'Sonalika'	tMS-tS (5 MS-S)	tMS-tS (5 MS-S)	5 MS-S (40 MS-S)	5MS-S (40 MS-S)	40 MS-S (80 MS-S)	5 MS-S (30 MS-S)
'HD 2270'	tMR-tMS (5 MR-tMS)	*	5 MR-MS (40 MS-S)	tR-tMR (5 R-MR)	40 MR-MS (80 MS-S)	tR (tMR-tMS)
'HD 2285'	tS-5S (40 S)	*	30 S (80 S)	tR-tMR (10 R-tMS)	60 S (100 S)	F-tR (tR)
'HD 2329'	5 MR-tMS (10 S)	*	10 MS-S (60 MS-S)	tMR-tMS (10 S)	40 MR-MS (80 MS-S)	tR-tMR (tS)
'HD 2402'	tR-tMR (5 R-MR)	*	tR-tMR (5 R-MR to tS)	tR-tMR (tMS)	5 R-MR (10 MR- MS)	F-tR (tR)
'HI 977'	tMR (tS)	*	tMR-tMS (20 MR-MS to 10 S)	tR-tMR (10 MR-MS)	10 X (60 MS-S)	tR-tMR (5 R-MR)

LR, Leaf-rust infection; SR, stem-rust infection, tS, traces; MS, moderately susceptible; MR, moderately resistant; tMS, traces of moderately susceptible pustules

Figures in parentheses denote the maximum levels of rust infection

*No visible infection

with response (modified Cobb's scale of Melchers and Parker 1992, and pustule type).

The rust incidence increased with the delay in sowing. The development of leaf rust remained low in November sowing in all the varieties except 'HD 2285', which showed maximum infection up to 40 S on a few plants. All the varieties sown in November except 'Sonalika' remained free from stem-rust infection.

The severity of leaf rust, as indicated by coefficient of infection, was less than 10.0, except in 'HD 2285'. All the varieties except 'HD 2402' and 'HI 977' expressed higher levels of disease in the maximum range (values in parentheses in Table 1), indicating their inherent susceptibility, in January-sown plots. 'HD 2402' wheat alone emerged the rust-resistant variety.

The stem-rust development remained restricted in all the varieties sown in December and January except 'Sonalika' (Table 1).

It was concluded that under late sowing 'HD 2402' is the most resistant variety and 'HD 2285' the most susceptible.

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Indian Journal of Agricultural Sciences 64 (4) : 268–9, April 1994

Sampling plan for estimating nymphal population of white-backed planthopper (*Sogatella furcifera*) in rice (*Oryza sativa*)

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Received: 13 April 1993

Among the insect pests attacking rice (*Oryza sativa* L.), white-backed planthopper [*Sogatella furcifera* (Horvath)] is emerging as a serious pest. Its attack leads to yellowing of foliage, severe hopperburn and poor plant growth (Atwal *et al.* 1967, Grist and Lever 1969). Dhaliwal and Singh (1983) reported its severe outbreak in Punjab. Since the information on appropriate sampling technique for estimating white-backed population of planthopper is meagre, an experiment was conducted on this aspect.

During 1986, nymphs of white-backed planthopper were counted from different sampling units, viz 1, 2, 3, 4 and 5 hills/spot, in a farmer's field. The observations were taken at 1-week intervals from the last week of August to third week of September, ie during peak activity of the pest. For each sampling unit, all the tillers from a hill were tapped with hand and the nymphs falling on standing water or ground and those left on the plants were counted. Total 8–12 observations for each sampling unit were made on each sampling date. The time required to actually observe the planthopper population in the various sample sizes was also recorded. The means and variances of planthopper population were worked out for different sampling units. The appropriate sample size through relative net cost method and number of samples required for population estimation were determined as per Southwood (1978). The sampling unit showing the least value of relative net cost was considered the appropriate size of the sample. Before determining the number of samples, the distribution pattern of planthopper population in the appropriate sample size was worked out following the Morisita's index of dispersion (Southwood 1978).

The population of white-backed planthopper on rice was 9.67, 8.42, 8.93 and 11.27 nymphs/hill in the last week of August, and the first, second and third weeks of September respectively during 1986. The mean population was 9.56 nymphs/hill, which equals the economic threshold value reported for the adoption of need-based control measures (PAU, Ludhiana 1986).

The value of relative net cost was the lowest in the sampling unit of 3 hills/spot (Table 1). Thus it was considered the most appropriate sample size for precise estimation of planthopper population on rice. Variance of population on unit basis decreased with the increase in sample size from 1 hill to 3 hills/spot. However, with further increase in the size of sample, the variance showed an abrupt increase. More than 1 value of Morisita's index of dispersion (1.026) and highly significant 'F' ratio (1.711^{**}) indicated that the planthopper population was distribu-

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Table 1 Determination of sample size for estimating population of white-backed plant hopper

Sample size (hills/spot)	Variance*	Time taken for sampling (sec)	On unit basis		Relative net cost
			Variance	Time (sec)	
1	24.05	34.93	24.05	34.93	840.07
2	37.26	57.48	18.63	28.74	535.43
3	40.93	80.03	13.64	26.68	363.92
4	145.08	102.18	36.27	25.55	926.70
5	152.92	126.18	30.58	25.24	771.84

*Based on 40 observations

ted in an aggregated manner. Based on this, 6 samples were determined as the appropriate number. It was concluded that 3 hills from each of the 6 spots in a field constitutes the sampling unit for estimating the nymphal population of white-backed planthopper in rice.

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Indian Journal of Agricultural Sciences 64 (4) : 270–1, April 1994

Biology and feeding potential of black beetle (*Chilocorus nigritus*), a predator on date palm scale (*Parlatoria blanchardii*)

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Received: 8 September 1992

Among the various insect pests, date palm scale (*Parlatoria blanchardii* Targioni-Tozzetti) causes 70–80% loss in fruit yield by direct attack (Smirnoff 1957). Its chemical control is very difficult, because its all stages occur throughout the year, and many adults remain alive beneath the dry fibres, where they are unaffected by chemical spray.

Muralidharan *et al.* (1992) reported for the first time that a coccinellid, *Chilocorus nigritus* Fabr., feed on this scale and reducing its population considerably. Jalali and Singh (1989) studied the biology of *C. nigritus* on 9 diaspine scales, viz *Melanaspis glomerata* (Green), *Quadraspidiotus perniciosus* (Comstock), *Aspidiotus destructor* (Signoret), *Aulacaspis tubercularis* (Signoret), *Hemiberlesia lataniae* (Signoret), *Aonidiella aurantii* (Maskell), *Chrysomphalus aonidum* (L.), *Aonidomytilus albus* (Cockrill) and *Lepidosaphes cornutus* (Ramk). In this experiment the biology and feeding potential of *C. nigritus* was studied on this new host.

The study was conducted at Mundra during August 1990 at room temperature (maximum 32.49°C, minimum 27.29°C and relative humidity 72%). The adult *C. nigritus*, collected from the field and reared on *P. blanchardii*, formed the nucleus culture for the study. For its biology observations were recorded on incubation period, fecundity, longevity etc. The feeding potential was studied by providing pre-counted scales (100) to each instar and recording the number of adult scales consumed per day. Freshly scale-infested pinnae collected from the field were used. Glass test-tubes (15 cm x 2.5 cm) were used for rearing and other studies.

The elongate eggs are laid singly or in a group of 2–3. The eggs require 6.11 ± 0.09 days to hatch. Among the 4 larval instars, the third instar has the most prolonged durations (3.83 ± 0.20), followed by the second instar (3.83 ± 0.12). The larval durations of the first and fourth instar are 3.5 ± 0.11 and 3.76 ± 0.11 days respectively. A pre-pupal period of 2.47 ± 0.13 days and pupal period of 6.63 ± 0.12 days is observed. The female starts egg-laying after 5.00 ± 0.82 days of emergence, with a fecundity of 151.2 ± 7.83 eggs/female. The male and female longevity is 50.21 ± 6.12 and 76.13 ± 8.13 days respectively. Jalali and Singh (1989) recorded similar observation on incubation period (6.1 days) when it was reared on *Hemiberlesia lantaniae* and a pupal period of 6.5 days when reared on *Aonidomytilus albus*. However, the total larval period varies greatly with different hosts.

Among various instars (Fig 1) the fourth instar consumes the highest number of scales (55.58 ± 4.38), followed by third instar (34.79 ± 2.94). The first instar removes the scale covering and consumes the soft body only (8.39 ± 0.55), whereas the fourth instar and adult devour the entire scale body including

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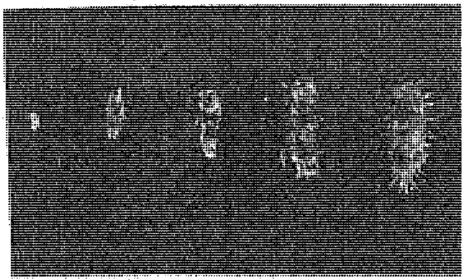

Fig 1 Egg and different instars of *C. nigritus*

the external coverings. Hence during the larval period on an average 437.35 scales are consumed by various instars. The adult consumes 20.86 ± 1.19 scales/day and average 1 317.72 scales during the life period. Ahmad (1970) reported almost similar feeding potential of *C. nigritus*, when it was reared on *Lepidosaphis* sp. Due to high consumption of prey, high fecundity and long life-cycle etc, this predator may be effectively exploited for the biological suppression of *P. blanchardii* scales on date palm.

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BOOK REVIEWS

Indian Journal of Agricultural Sciences 64 (4) : 272–3, April 1994

The Essentials of Viruses, Vectors and Plant Diseases. 1993. Basu A N and Giri B K. Wiley Eastern Ltd, 4835/24 Ansari Road, Daryaganj, New Delhi 110 002. viii + 242 pp. 24 cm x 16 cm. Rs 400. ISBN 81-224-0431-6.

Similar to cold and influenza in man, mosaic and other diseases caused in plants by the viruses are difficult to control. The plant viruses cause serious loss not only in yield but also in the quality of the produce. The study of plant virology is therefore extremely important in the field of plant protection for the students as well as teachers and researchers. The book under review makes good attempt to provide the fundamental aspects of plant viruses, their vectors and the management of viral diseases, especially for Indian conditions.

The subject is treated under 14 chapters. Starting with a brief introduction, the book provides details of viruses in 5 chapters. Their chemical composition and structure and the variation in their genomic organization reflect their different behaviour with the host and the differences in symptom expression and vector transmissibility. They possess only 1 type of nucleic acid and are unable to divide by binary fission, behaving differently from a typical plant cell. The binomial system of nomenclature could not be applied to them satisfactorily, and hence they are classified according to the symptoms of diseases caused by them, and given vernacular or common names only. The symptoms of viral diseases may be apparent externally as well as internally, but may be latent too. But the plants may show symptoms similar to those of viral diseases also due to some nutritional deficiency or phytotoxaemia, caused by the toxic effect of salivary secretion of arthropod vectors. The study of the mode of infection and action of viruses inside the host plant and their replication has been greatly facilitated by advancements in molecular biology. Their isolation is the first requisite to study their host range, physico-chemical properties, purification, electron microscopy and molecular aspects including genomic organization. It has been possible to characterize and identify a large number of plant viruses.

As the viruses are not able to penetrate the plant cuticle by themselves, they seek the help of other biological agents, the vectors. Arthropods, aphids, whiteflies, mealybugs, psyllids, leafhoppers and planthoppers, thrips, beetles, mites and some other insects, as well as other agents like some nematodes and fungi, play an active role in their transmission to the plant hosts. The homopteran insects have therefore developed special mouth-parts and feeding mechanisms that help in dissemination of viruses. The viruses and their vectors show specific relationship. The viruses may be persistent or non-persistent, and may show different modes of transmission. Various techniques have been developed to study the virus-vector relationships. Of major significance is the study of the plant diseases caused by them: in cereals, grain legumes, vegetables, fruit crops, oilseeds, fibre crops, plantation crops and narcotic plants.

The management of these diseases is possible through cultural means as well as through some chemical and biological measures. Some non-viral agents also induce diseases in plants similar to those caused by viruses, and require effective control.

The interrelationship of viruses with the environment, their ecology, may help us greatly in understanding their nature and adopting appropriate remedies.

The book provides fundamental information on these aspects in effective manner. In addition to inclusion of references with each chapter, it lists additional literature for further reading. An index is given at the end and there are 11 colour illustrations showing important symptoms of viral diseases in plants.

The book is produced well but priced high.

R S GUPTA
(Editor)

Indian Journal of Agricultural Sciences 64 (4) : 274, April 1994

Agricultural Marketing in India (edn 2). 1992. Acharya S S and Agarwal N L. Oxford & IBH Publishing Co. Pvt Ltd, 66 Janpath, New Delhi 110 001. xxii + 403 pp. 21.5 cm x 14.0 cm. Rs 85 (softcover). ISBN 81-204-0117-4.

All the efforts of scientists and farmers to achieve high yield and better quality of agricultural products might fail if the produce is not marketed well. Effective marketing not only helps proper utilization of the produce that might otherwise perish or go waste but also prove an incentive to the farmers to devote full energy enthusiastically to achieve the best results from the field. Marketing requires some produce, the market and the relevant infrastructure, as well as the agents like farmers, the middlemen like traders and co-operatives, and the government. To spread the benefits of agricultural marketing in India equitably, the farm products and inputs (fertilizer, seed, fuel, implements, credit) should be distributed efficiently and at the minimum cost from the producer to the consumer. The second edition of the book under review aims to tackle these problems, especially in view of liberalization of trade and industry and new initiatives taken by our government to link the Indian economy with the world trade.

The book contains 9 chapters. The problems in marketing are discussed in the first 3 chapters, explaining the theoretical (structure, development, forces and price models of market), historical and evolutionary trends of agricultural marketing in India. The marketing system (agencies, channels, farm inputs) and the role of government (agencies, co-operatives, control mechanism) is highlighted in the next 3 chapters. The major factors that help in evaluating the various market forces like cost and price are considered in the next chapter, followed by training facilities in this field and the position of research and statistical data. A new addition to this edition is the chapter on external trade, which weighs the position, share and role of Indian trade (in farm products) in the world. The policy and prospects, especially the new export-import policy of 1992–97, throw some rays of hope of greater Indian share in the global agricultural marketing in near future.

Bibliography is given at the end, grouping the references under books, reports, and journals/magazines; followed by author-subject index.

The book appears a good bargain for college students and is quite useful for the teaching community as well as policy planners engaged in agricultural marketing in India.

R S GUPTA
(Editor)

Publications Received

Traditional Indian Agriculture: an Annotated Bibliography. 1993. Vijayalakshmi K. Wiley Eastern Ltd, 4835/24 Ansari Road, Daryaganj, New Delhi 110 002. x + 113 pp. 22 cm x 14 cm. Rs 125. ISBN 81-224-0584-3.

The references are grouped under 11 chapters, viz History, Plant sciences, Classification, Land, Specific crops, Irrigation, Agricultural implements, Food, Folklore, Animal sciences and Livestock. Besides, there are 2 Appendixes on Manuscripts on plant sciences and Manuscripts on animal sciences, together with an Author index.

Agricultural Research through International Cooperation : the Indian Experience. 1993. Srivastava, Roli and Srivastava G C. Oxford & IBH Publishing Co. Pvt Ltd, 66 Janpath, New Delhi 110 001. xii + 144 pp. 22.25 cm x 14.25 cm. Rs 195. ISBN 81-204-0777-6.

The book contains 7 chapters, viz Introduction, The National Agricultural Research System of India, International Agricultural Research Resources, Collaborative modes, India's links with external agencies, Impact evaluation and Looking ahead. Bibliography, Appendix, Acronyms and Index are also given.

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ANNOUNCEMENT

The Indian Society of Pest Management and Economic Zoology, Nauni, Solan, plans to organize a National Symposium on Emerging Trends in Pest Management during 27–29 June 1994. Last date for submission of abstracts is **30 April 1994** and for full papers **15 May 1994**. Further details can be obtained from Dr O P Bhalla, Department of Entomology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh (India) 173 230. Telephone : (0179285) 2240, Fax : 91-01792 (5225), Telegram : VANUDYAN.