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Effect of soil-moisture regime, seed rate and phosphorus fertilizer on growth and yield attributes and yield of late-sown lentil (*Lens culinaris*)

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ABSTRACT

A field experiment was conducted during the winter seasons of 1984–85 and 1985–86 at New Delhi on a sandy-loam soil to study the effect of soil moisture, seed rate and fertilizer on yield of 'Pant L 406' lentil (*Lens culinaris* Medikus). The soil was low in organic carbon and available P and medium in available K, with pH 7.3. Irrigation at 0.60 irrigation water depth : cumulative pan evaporation (IW : CPE) ratio (2 irrigations) produced taller plants with profuse branching and root nodulation and had more dry matter, pods/plant and grain and straw yields compared with irrigation at 0.35 IW : CPE ratio and no irrigation. During 1984–85 only 1,000-grain weight and harvest index also increased by irrigation. Higher seed rate (60 kg/ha) though adversely affected growth, yield attributes and nodulation, recorded higher grain and straw yields compared with lower seed rate (40 kg/ha). Further, the magnitude of increase in grain yield with 60 kg seed/ha with post-planting irrigation was greater. P application improved the growth and yield attributes, nodulation, grain and straw yields and harvest index. Phosphobacterial inoculation alone or in combination with 35 kg P_2O_5/ha showed positive response in terms of dry matter, nodulation and grain yield. The grain yield increased with increasing levels of P_2O_5 up to 70 kg/ha. The response to phosphobacterial inoculation alone could be observed with post-planting irrigations only.

A major proportion of lentil crop (*Lens culinaris* Medikus) is not planted until after the harvest of rice in December. The need for raising the productivity of such crops resulted in the development of concept of late-sown lentil (Ahlawat *et al.*, 1983). The development of short-duration genotypes having lesser sensitivity to environment has provided good scope to raise a successful late-sown crop with proper agronomic management.

Earlier work on irrigation of lentil pertains to normal sown crop and that too is based either on physiological stage or soil-moisture tension. In late-sown situation, the productivity of individual plant is adversely affected because the vegetative and reproductive periods are cut short due to early exposure to longer days and rapid rise in temperature late in the season. Higher seed rate may, therefore, be required to compensate the low productivity per plant in late plantings (Ahlawat *et al.*, 1983). The adverse effect on water uptake due to cold temperatures, especially during early growth stages of late-sown crop, may also adversely affect the absorption of phosphates by roots. Further, the root growth in late-sown crop is also limited. Hence the response of P in late-sown crop is also limited. Thus, the response of P in late-sown crop may be altered on account of irrigation, crop duration and plant density. Indentification of phosphate-solubilizing bacteria in soils, viz. *Pseudomonas* sp. and *Bacillus megaterium* var. *phosphaticum* has opened the possibilities of economizing on P fertilizer. However, meagre information is available on the role of these micro-organisms in crop production. Thus, the role of management inputs in lentil clearly shows that response to inputs in late-sown crop may vary from the normal sown crop. The present experiment was, therefore, conducted to find out the optimum level of soil-moisture regime, seed rate and phosphorus fertilizer, and also to evaluate the efficiency of phosphobacterial inoculation on the availability of native P in late-sown lentil.

MATERIALS AND METHODS

A field experiment was conducted during the winter seasons of 1984–85 and 1985–86 on a sandy-loam soil. The soil had 0.38–41% organic carbon, 0.058–0.060% total N, 8.81–9.13 kg/ha available P and 129.7–130.5 kg/ha available K, with pH 7.3. The field capacity and permanent wilting point values of 0–30 cm-soil layer were 18.70 and 7.65 respectively, with a bulk density of 1.53 g/cm^3. The treatments comprised 3 soil-moisture regimes [no post-planting irrigation and irrigation at 0.35 and 0.60 irrigation water depth : cumulative pan

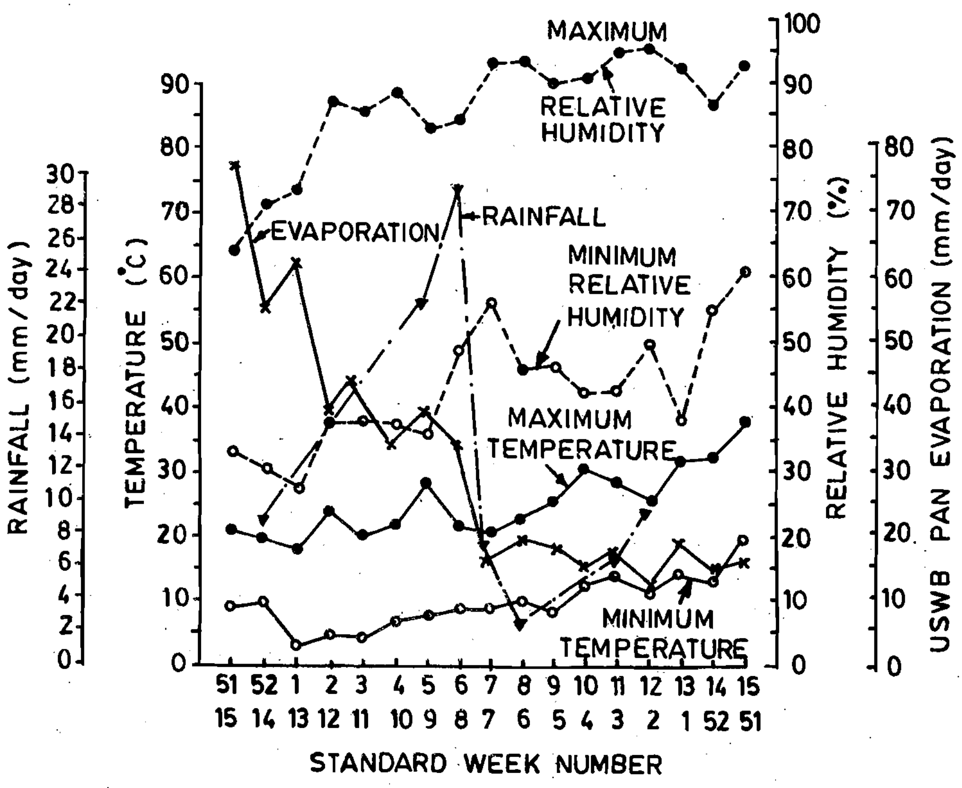

Fig. 1. Meteorological data during crop period (1984–85)

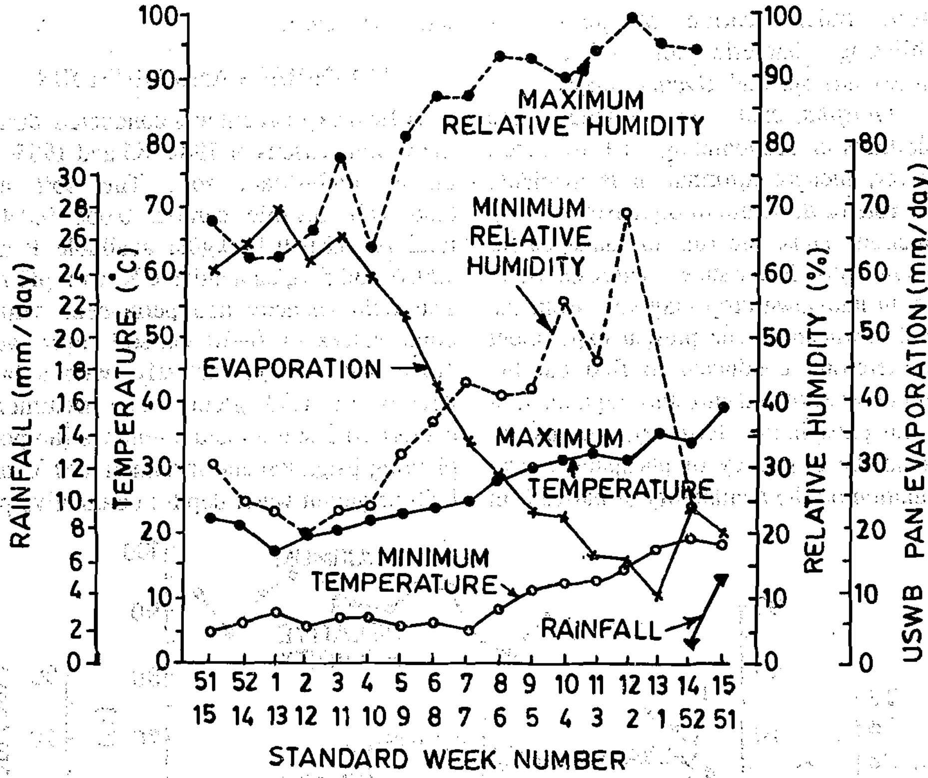

Fig.2. Meteorological data during crop period (1985–86)

evaporation (IW : CPE) ratio] and 2 seed rates (40 and 60 kg/ha) as main plots and 5 P treatments (no P, phosphobacterial inoculation, 35 kg P_2O_5/ha with and without phosphobacterial inoculation and 70 kg P_2O_5/ha) as subplots, replicated thrice in split-plot design. Lentil 'Pant L 1406' was sown with pre-sowing irrigation on 19 and 20 December in 1984–85 and 1985–86 respectively at the row spacing of 25 cm using the seed rate as per treatments. A uniform basal dose of 20 kg N/ha and P fertilizer (as single superphosphate) as per treatments were applied at sowing. The crop received 1 irrigation at 0.35 IW : CPE ratio on 28 February in 1984–85 and 13 March in 1985–86. At an IW : CPE ratio of 0.60, 2 irrigations on 11 February and 5 March in 1984–85 and 1 February and 17 March in 1985–86 were applied. Each irrigation consisted of 60 mm water. The water-table depth was below 2 m throughout the cropping season. Hence the ground-water contribution was considered to be negligible. The meteorological parameters recorded during the 2 crop seasons are depicted in Figures 1, 2.

RESULTS AND DISCUSSION

Effect of soil-moisture regime

Crop irrigation at 0.35 and 0.60 IW : CPE ratios improved plant growth (plant height,

Table 1. Growth and yield attributes of lentil as affected by soil-moisture regime, seed rate and P application

Treatment	Plant height (cm)		Branches/ plant		Dry matter/ plant (g)		Dry weight of nodules/plant 70 DAS (mg)		Pods/ plant		Seeds/ pod		1,000 grain weight (g)	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
*Soil-moisture regime**														
No post-planting irrigation	18.6	35.9	11.4	18.6	2.05	4.27	5.23	8.01	40.6	80.1	1.98	1.72	17.9	17.6
0.35	19.3	45.1	12.4	21.6	3.98	7.77	7.99	11.19	49.8	110.1	2.00	1.87	18.1	18.1
0.60	20.9	46.9	13.8	22.7	4.57	8.53	8.82	12.57	58.0	116.8	2.01	1.92	18.0	18.0
CD (P = 0.05)	0.5	1.1	0.4	0.8	0.16	0.34	0.23	0.20	1.0	2.7	NS	NS	0.2	NS
Seed rate (kg/ha)														
40	19.2	41.1	13.1	21.1	3.82	7.23	7.58	10.82	51.6	101.7	2.01	1.93	18.0	18.0
60	20.1	44.1	11.9	20.8	3.25	6.48	7.10	10.36	47.4	97.0	1.97	1.86	18.0	17.9
CD (P = 0.05)	0.4	0.9	0.4	NS	0.13	0.28	0.18	0.17	0.8	2.2	NS	NS	NS	NS
P_2O_5 (kg/ha)														
0	18.8	40.8	11.3	20.0	2.74	6.00	6.42	9.62	47.7	97.7	1.96	1.86	17.6	17.6
PBI	19.1	41.3	11.7	20.6	3.14	6.33	6.81	9.94	48.6	98.4	1.96	1.87	17.8	17.8
35	19.7	43.1	12.6	21.1	3.58	6.87	7.41	10.56	49.5	99.5	1.99	1.90	18.0	17.9
PBI	20.3	44.3	13.7	21.7	4.18	7.61	7.89	11.02	50.7	100.4	2.02	1.90	18.2	18.1
70	20.3	43.6	13.4	21.4	4.03	7.47	8.19	11.81	50.9	100.8	2.04	1.92	18.3	18.1
CD (P = 0.05)	0.7	1.3	0.5	0.8	0.17	0.29	0.22	0.37	1.0	2.0	NS	NS	0.3	0.3

*Based on IW : CPE ratio
A, 1984–85; B, 1985–86
PBI, Phosphobacterial inoculation

branches and dry matter/plant), nodulation and development of yield attributes (pods/plant, seeds/pod and 1,000-grain weight) compared with the crop receiving no post-planting irrigation (Table 1). The crop irrigated twice at 0.60 IW : CPE ratio, however, recorded higher values of growth and yield attributes and root nodulation than that with 2 irrigations at 0.35 IW : CPE ratio. The values of plant attributes during 1985–86 were, in general, higher due to well-distributed rainfall favouring cell-elongation and enlargement in moisture-stress-free environment. Similarly, applied water through irrigation favourably affected cell-elongation, turgidity and promoted various physiological processes including the uptake of nutrients, leading to improved plant growth and helped in the development of yield attributes (Murari, 1982; McKenzie *et al.*, 1986). The improvement in root nodulation by irrigation may be ascribed to improved physiological functions and production of adequate photosynthates for the use of *Rhizobia* in the process of root-nodule formation (Zablotowicz *et al.*, 1981).

The grain and straw yields were the highest when the crop received irrigation at 0.60 IW : CPE, followed by 0.35 IW : CPE and no post-planting irrigation (Table 2). Over the years, irrigation at 0.60 and 0.35 IW : CPE ratios respectively gave 110.4 and 87.3% higher grain yield than no post-planting irrigation. The corresponding values for straw yield were 46.2 and 31.9%.

The grain yield was markedly higher

Table 2. Grain and straw yields and hervest index of lentil as affected by soil-moisture regime, seed rate and P fertilizer

Treatment	Grain yield (q/ha)			Straw yield (q/ha)			Harvest index (%)	
	1984–85	1985–86	Pooled	1984–85	1985–86	Pooled	1984–85	1985–86
*Soil-moisture regime**								
No post-planting irrigation	3.50	8.20	5.85	8.78	15.23	12.00	28	34
0.35	7.43	14.50	10.96	11.90	19.77	15.83	38	42
0.60	8.80	15.82	12.31	14.09	21.00	17.54	39	43
CD (P = 0.05)	0.22	0.46	0.24	1.93	1.76	1.66	8	7
Seed rate (kg/ha)								
40	6.17	12.27	9.22	12.35	21.68	17.01	33	36
60	6.98	13.40	10.19	15.17	25.85	20.51	31	34
CD (P = 0.05)	0.18	0.37	0.20	1.57	1.43	1.35	NS	NS
P_2O_5 (kg/ha)								
0	4.33	9.16	6.97	9.16	18.33	13.97	31	34
PBI	4.70	10.42	7.56	9.78	19.03	14.40	32	35
35	7.34	13.57	10.46	13.45	21.86	17.65	35	38
35 + PBI	7.77	14.54	11.16	13.67	22.47	18.07	36	39
70	8.69	16.04	12.37	14.87	24.08	19.47	36	40
CD (P = 0.05)	0.41	0.37	0.27	2.91	2.53	2.85	2	2

* Based on IW : CPE ratio
PBI, Phosphobacterial inoculation

during 1985–86 than that during 1984–85. The effect of irrigation was more pronounced during 1984–85, being a dry year. The response of phosphobacterial inoculation could be observed during 1985–86 which was a favourable season in terms of soil moisture.

The increase in grain and straw yields by irrigation may be attributed to better development of growth and yield attributes. Murari (1982) and Sharma *et al.* (1983) also reported similar results.

Effect of seed rate

Higher seed rate (60 kg/ha) adversely affected growth (plant height, branches/plant and dry matter/plant), nodulation and yield attribute (pods/plant) compared with lower seed rate (40 kg/ha) (Table 1). This behaviour of seed rate could be attributed to competition among the plant communities for resources like nutrients, moisture and space. The results confirm the findings of Tripathi (1982).

Contrary to the higher values of growth and yield attributes in lower seed rate (40 kg/ha), higher seed rate (60 kg/ha) recorded maximum grain and straw yields because of more plant density/unit area (Table 2). In normal sown crop, the positive responses to increasing seed rates are usually confined up to 40 kg/ha (Sharma and Singh, 1986). The conditions under the present investigation were, however, different because of late-sown situations where per plant productivity decrease considerably because of the reduced duration of vegetative phase.

The interaction effect of soil-moisture regime and seed rate (Table 3) revealed that the magnitude of increase in grain yield by higher seed rate of 60 kg/ha over 40 kg/ha was greater with post-planting irrigations compared with no post-planting irrigation. It appears that increase in plant productivity becomes restricted at higher plant density under moisture-deficit condition of no post-planting irrigation.

Table 3. Grain yield (q/ha) as affected by soil-moisture regime × seed rate

Soil-moisture regime*	Seed rate (kg/ha)			
	1984–85		Pooled	
	40	60	40	60
No post-planting irrigation	3.32	3.67	5.57	6.12
0.35	6.87	7.99	10.38	11.55
0.60	8.32	9.27	11.70	12.91
CD (P = 0.05)	0.30	0.34		

*Based on IW : CPE ratio

Effect of P

Application of P improved the growth, yield attributes and nodulation (Table 1). Phosphobacterial inoculation alone had no effect on these attributes except dry matter in both the seasons and nodulation during 1984–85. However, phosphobacterial inoculation in combination with 35 kg P_2O_5/ha proved superior to 35 kg P_2O_5/ha for branches and pods/plant during 1984–85, and dry matter and nodulation in both the seasons. The response of applied P on plant attributes was variable. The dry-matter accumulation and nodulation in both the seasons and branches/plant and 1,000 grain weight during 1984–85 and pods/plant during 1985–86 increased up to 70 kg P_2O_5/ha, whereas in other cases, the response was confined up to 35 kg P_2O_5/ha only.

Phosphobacterial inoculation resulted in marked increase in grain yield (Table 2). Crop responded favourably up to 70 kg P_2O_5/ha. The combined application of 35 kg P_2O_5/ha and phosphobacterial inoculation gave

Table 4. Grain yield (q/ha) as affected by soil-moisture regime × P application (pooled)

Soil-moisture regime*	P_2O_5 (kg/ha)				
	0	PBI	35	35 + PBI	70
No post-planting irrigation	4.08	4.37	6.41	6.77	7.60
0.35	7.82	8.51	11.76	12.70	14.03
0.60	9.01	9.81	13.22	14.02	15.47
CD (P = 0.05)				0.47	

*Based on IW : CPE ratio
PBI, Phosphobacterial inoculation

higher grain yield than 35 kg P_2O_5/ha alone. The mean increase in grain yield with 70 kg P_2O_5/ha compared with no P_2O_5, phosphobacterial inoculation, 35 kg P_2O_5/ha and 35 kg P_2O_5/ha + phosphobacterial inoculation was 77.5, 63.6, 18.3 and 10.8% respectively. The improvement in the development of yield attributes with P was responsible for greater yields. The beneficial effect of phosphobacterial inoculation may be attributed to solubilization of native or applied P in soil by bacteria and thus making it available for plant use (Ahmed and Jha, 1977; Karnani and Mishra, 1981).

The interaction effect of soil-moisture regime and P application (Table 3) revealed that the response of phosphobacterial inoculation alone was observed with post-planting irrigations only. Further, 35 kg P_2O_5/ha with or without phosphobacterial inoculation gave similar yields under no post-planting irrigation. The response to other P treatments under differential moisture regimes was similar. The differential response of P under various soil-moisture regimes could be ascribed to the effect of soil moisture on nutrient absorption on one hand and the effect of water on the metabolic activities of the plant, soil aeration and concentration of soil solution on the other. Nema *et al.* (1984) reported higher P uptake with post-planting irrigations.

The relationship between grain yield and P application indicated quadratic response during 1984–85 and linear response during 1985–86 and in pooled data. The economic optimum dose of P_2O_5 during 1984–85 was 69.9 kg/ha, which gave a response of 4.25 q/ha.

The straw yield increased markedly up to 35 kg P_2O_5/ha only (Table 2). Phosphobacterial inoculation with and without P had no effect on straw yield compared with 35 kg P_2O_5/ha and no P respectively. Almost similar trend was observed for harvest index except that 70 kg P_2O_5/ha showed higher harvest index than 35 kg P_2O_5/ha during 1985–86. The improvement in plant growth with applied P was consequently reflected in the straw yield. Application of P caused proportionately greater increase in grain than in non-grain parts which resulted in higher harvest index of lentil.

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