

## Growth and yield response of pea (*Pisum sativum*) to moisture stress, phosphorus, sulphur and zinc fertilizers

S. KASTURIKRISHNA<sup>1</sup> AND I. P. S. AHLAWAT

Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012

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### ABSTRACT

A field experiment was conducted at New Delhi during 1992-94 to study the growth and yield responses of pea (*Pisum sativum* L.) cv. 'Swastik' ('DMR 11') to moisture stress and application of phosphorus, sulphur and zinc. The moisture stress at flowering appeared to be most critical in influencing the yield of pea. Higher values of vine length, leaf area index, dry matter, yield attributes, grain and straw yields, harvest index, nutrient uptake (N, P, K and Zn) and consumptive water use were noticed with no moisture stress treatment. Application of 26.2 kg P/ha resulted in marked improvement in growth and yield attributes and yield, nutrient uptake (N, P, K and Zn), consumptive water use, water use efficiency, and soil available P at harvest. The soil available N showed improvement up to 13.1 kg P/ha only. Combined application of 40 kg S + 5 kg Zn/ha showed marked improvement in growth and yield attributes, grain and straw yields, nutrient uptake (P, K and Zn), consumptive water use and water use efficiency. The differences between 40 kg S/ha and 40 kg S + 5 kg Zn/ha were not marked in S uptake in both the seasons, and N uptake in 1993-94.

**Key words :** Pea, Moisture stress, Phosphorus, Sulphur, Zinc, Growth, Yield

In India, field pea (*Pisum sativum* L.) occupies 0.49 million/ha and contributes 0.42 million/tonnes of the pulse production. With the availability of short-duration and high-yielding varieties, it is becoming increasingly popular in many parts of the country. However, the average productivity of pea is low (628 kg/ha). One of the important factors responsible for poor yields is use of poor management technology. A number of investigations have convincingly proved that pea invariably responds to higher levels of improved production technology such as the supply of irrigation at most sensitive stage (Barky *et al.*, 1995), application of phosphate (Yadav *et al.*, 1992), sulphur (Jain *et al.*, 1984) and zinc (Singh *et al.*, 1992). It has been amply

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**Present address:** <sup>1</sup>Research Station, Central Tobacco Research Institute, Jeelugumilli, West Godavari Andhra Pradesh 534 456

proved that providing adequate moisture at some of the moisture-sensitive phenological stages of the crop improves symbiotic N-fixation and productivity (Rao *et al.*, 1977; Wahab and Zahran, 1979). Information on the response to pea to moisture stress, phosphorus, sulphur and zinc is, however, scarce. Therefore, it is of interest to investigate the response to pea to moisture stress, phosphorus, sulphur and zinc.

### MATERIALS AND METHODS

The field experiment was conducted at the Indian Agricultural Research Institute, New Delhi, during the winter seasons of 1992-93 and 1993-94. The soil was sandy loam with

pH 7.3; 0.046 and 0.044% total N; 8.96 and 9.20 kg/ha available P; 161.0 and 159.5 kg/ha available K; 10.00 and 10.62 ppm available S, and 0.51 and 0.52 ppm of DTPA-extractable Zn in 0-30 cm soil depth in the respective growing seasons.

The experiment was laid out in split plot design replicated thrice with combination of 4 moisture stress treatments (moisture stress either at vegetative or flowering or pod filling stage and no moisture stress) and 3 phosphorus levels (0, 13.1 and 26.2 kg P/ha) as main plot treatments and 3 sulphur and zinc combinations (no S and no Zn, 40 kg S/ha and 40 kg S + 5 kg Zn/ha) as sub-plot treatments. The crop was sown in rows 30

**Table 1.** Vine length, leaf-area index and dry-matter accumulation/plant of pea as influenced by moisture stress, phosphorus, sulphur and zinc

Treatment	Vine length at harvest (cm)		Leaf-area index (90 DAS)		Dry-matter at harvest (g/plant)	
	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94
<i>Moisture stress</i>						
At vegetative stage	154.26	175.67	0.96	1.01	10.90	14.27
At flowering stage	159.00	183.20	0.99	1.06	9.11	13.13
At pod-filling stage	163.16	189.34	1.01	1.10	10.13	13.57
No stress	175.58	204.56	1.05	1.14	12.36	15.58
CD (P = 0.05)	10.68	11.06	0.05	0.05	0.71	0.52
<i>Phosphorus (P-kg/ha)</i>						
0	151.52	172.61	0.96	1.03	8.83	12.05
13.1	165.99	187.05	1.02	1.08	10.99	14.67
26.2	171.79	204.91	1.03	1.13	12.05	15.99
CD (P = 0.05)	8.89	9.33	0.04	0.04	0.62	0.45
<i>Sulphur and zinc (kg/ha)</i>						
Control (no S and no Zn)	153.27	179.31	0.98	1.05	9.80	13.04
40 S	164.73	190.65	1.01	1.08	10.74	14.44
40 S + 5 Zn	171.31	194.61	1.02	1.10	11.33	15.23
CD (P = 0.05)	2.62	4.23	0.02	0.03	0.55	0.42

cm apart on 9 November in 1992 and 11 November in 1993. A uniform starter dose of 25 kg N/ha as urea was applied at sowing with the adjustment of its dose where DAP was applied. The entire dose of P, S and Zn as per treatment was applied before sowing. The pea cultivar was 'Swastik' ('DMR 11'). The crop was harvested on 20 March in 1993 and 17 March in 1994.

## RESULTS AND DISCUSSION

### *Effect of moisture stress*

Imposing moisture stress, at various phenological stages, caused perceptible variations in growth attributes, viz. vine length, leaf-area index (LAI) and dry matter accumulation (Table 1). Crop with no moisture stress had significantly higher vine length as compared with moisture stress at any of the 3 stages. The difference between moisture stress at vegetative and pod filling stage was also marked in 1993-94 where moisture stress at pod filling recorded higher vine length than stress at vegetative stage. Omitting 1 irrigation at any one stage, i.e. vegetative or flowering or pod formation has also been reported to suppress vine length (Barky *et al.*, 1985). Crop with no moisture stress and moisture stress at pod-filling stage recorded similar values of leaf-area index. Anderson and White (1974) observed that irrigating crop from flowering to maturity showed enhanced plant height and leaf area. No moisture stress treatment recorded significantly higher dry matter when compared with moisture stress at any of the three stages.

Crop with no moisture stress recorded significantly more number of pods/plant and 1,000 grain weight followed by moisture

stress at vegetative stage (Table 2). Stress at flowering had pronounced adverse effect on gains/pod and 1,000 grain weight. Crop with no moisture stress produced higher grain yield than the crop subjected to moisture stress at different stages. As discussed earlier crop with no moisture stress maintained superiority to other treatments with respect to growth and yield attributes and consequently resulted in higher grain yield (Table 2).

The crop with no moisture stress had higher N content in grain, and P content in grain and straw (data not reported). The increased N content in grain could be ascribed to greater root activity and BNF in this treatment. The higher N and P content coupled with higher yields resulted in substantial increase in N and P uptake (Table 3). The increase in P content and its uptake with water supply was due to the nature and behaviour of P in the soil. Phosphorus is highly immobile in soil even with adequate soil moisture conditions. Therefore adequate water supply enhanced the P uptake through larger root mass and greater solubilization of phosphate. The uptake of K, S and Zn also increased with no moisture stress when compared with moisture stress at any one stage (vegetative or flowering or pod filling) mainly because of increased dry-matter accumulation.

The consumptive water use (CU) was the highest in no moisture stress treatment due to faster release of moisture from top soil layer and better root and leaf growth (Table 4). The higher water use efficiency (WUE) in this treatment was mainly because of proportionately greater increase in yield than CU. Since the yield was most adversely

**Table 2.** Yield and yield attributes as affected by moisture stress, phosphorus, sulphur and zinc

Treatment	Pods/ plant		Grains/ pod		1,000-grain weight (g)		Grain yield (t/ha)		Straw yield (t/ha)		Harvest index (%)	
	1992- 93	1993- 94	1992- 93	1993- 94	1992- 93	1993- 94	1992- 93	1993- 94	1992- 93	1993- 94	1992- 93	1993- 94
<i>Moisture stress</i>												
At vegetative stage	4.70	6.14	4.44	4.41	227.04	228.44	1.58	2.07	2.05	2.68	43.52	43.53
At flowering stage	4.18	6.24	3.98	3.87	225.79	226.57	1.26	1.83	1.77	2.54	41.61	41.86
At pod-filling stage	4.22	5.46	4.66	4.71	225.29	229.09	1.47	1.97	1.90	2.55	43.73	43.65
No stress	4.96	6.27	4.93	4.93	227.12	230.66	1.84	2.38	2.27	2.94	44.79	44.81
CD (P = 0.05)	0.19	0.32	0.22	0.22	0.62	0.65	0.05	0.07	0.09	0.09	1.40	0.42
<i>Phosphorus (P-kg/ha)</i>												
0	3.92	5.26	4.24	4.27	224.98	226.18	1.24	1.69	1.70	2.32	42.27	42.24
13.1	4.63	6.14	4.55	4.56	226.46	228.94	1.60	2.14	20.6	2.75	43.72	43.75
26.2	4.99	6.68	4.71	4.61	227.48	230.95	1.78	2.36	2.24	2.96	44.24	44.79
CD (P = 0.05)	0.15	0.27	0.20	0.22	0.52	0.52	0.04	0.06	0.09	0.08	1.26	1.28
<i>Sulphur and zinc (kg/ha)</i>												
No S and no Zn	4.24	5.68	4.38	4.38	225.47	226.66	1.41	1.88	1.85	2.46	43.10	43.29
40 S	4.57	6.10	4.49	4.49	226.62	229.14	1.56	2.09	2.02	2.71	43.51	43.50
40 S+5 Zn	4.74	6.31	4.59	4.57	226.83	230.27	1.65	2.21	2.12	2.86	43.62	43.60
CD (P = 0.05)	0.16	0.20	0.08	0.08	0.33	0.71	0.05	0.06	0.08	1.00	NS	NS

NS=not significant

**Table 3. Nutrient uptake in pea as affected by moisture stress, phosphorus, sulphur and zinc**

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)		S(kg/ha)		Zn(g/ha)	
	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94
<i>Moisture stress</i>										
At vegetative stage	75.81	97.44	8.88	11.58	32.47	42.00	9.17	10.92	74.82	93.21
At flowering stage	62.49	88.60	7.30	10.55	27.61	39.26	7.49	10.19	64.30	89.28
At pod-filling stage	71.62	94.10	8.48	11.32	31.35	41.27	8.92	11.28	76.39	98.70
No stress	90.36	114.94	10.58	13.63	38.53	48.95	11.94	14.69	95.61	117.81
CD (P = 0.05)	5.81	5.26	0.80	1.05	4.27	4.46	1.18	1.36	6.87	6.61
<i>Phosphorus (P - kg/ha)</i>										
0	59.30	79.18	6.79	9.21	25.63	34.40	8.97	11.36	54.84	69.80
13.1	78.17	102.42	9.20	12.28	33.79	44.47	9.52	11.96	80.81	102.18
26.2	87.74	114.71	10.45	13.82	38.05	49.74	9.65	11.99	97.69	127.27
CD (P = 0.05)	4.93	4.51	0.69	0.88	3.71	3.83	NS	NS	5.91	5.80
<i>Sulphur and zinc (kg/ha)</i>										
No S and no Zn	68.13	89.06	8.13	10.87	29.47	38.59	5.46	6.82	54.48	62.14
40 S	76.21	100.43	8.92	11.93	32.81	43.43	10.58	13.22	66.33	79.01
40 S+ 5 Zn	80.87	106.82	9.38	12.49	35.19	46.59	12.10	15.27	112.53	158.10
CD (P = 0.05)	4.56	5.63	0.42	0.42	1.80	1.83	1.70	2.27	6.50	7.33

NS = not significant

affected with moisture stress at flowering stage, this treatment recorded the lowest WUE. Moisture stress treatments failed to affect the post-harvest nutrient status of soil.

#### **Effect of phosphorus**

Application of 26.2 kg P/ha resulted in marked increase in vine length, dry matter/plant and leaf-area index (Table 1). Phosphorus enhances the activity of *Rhizobia* and thus increases N-fixation in the root nodules, thereby improving plant growth and development.

The number of pods/plant, number of grains/pod and 1,000-grain weight were substantially improved by the application of phosphorus (Table 2). The stimulatory effect of P on pea growth might lead to increase in

all the yield attributes. These results are in accordance with the findings of Yadav *et al.* (1990). Grain yield and harvest index were favourably affected by application of P, which might be due to improvement in growth and yield attributes with P application. The crop responded favourably with increasing levels of P up to 26.2 kg/ha, indicating higher needs of P by the crop. However, in terms of agronomic efficiency, the lower rate (13.1 kg/ha) of P produced 30.96 kg grain/kg of P as against 23.30 kg grain/kg of P with 26.2 kg P/ha. The apparent recovery of applied P was also higher with 13.1 kg P/ha (21.24%) than 26.2 kg P/ha (16.03%). This could be attributed to the greater fixation of applied P in soil when used in higher amounts. Goswami and

**Table 4.** Seasonal consumptive water use and water-use efficiency as affected by moisture stress, phosphorus, sulphur and zinc

Treatment	Consumptive water use (mm)		Water-use efficiency (kg grain/ha-mm)	
	1992-93	1993-94	1992-93	1993-94
<i>Moisture stress</i>				
At vegetative stage	248.9	210.2	6.34	9.84
At flowering stage	245.1	207.8	5.15	8.81
At pod-filling stage	244.2	206.3	6.04	9.56
No stress	275.8	247.7	6.68	9.63
<i>Phosphorus (P-kg/ha)</i>				
0	250.3	216.4	4.96	7.82
13.1	254.7	218.1	6.28	9.79
26.2	255.5	219.5	6.94	10.77
<i>Sulphur and zinc (kg/ha)</i>				
No S no Zn	251.4	216.3	5.60	8.48
40 S	254.1	218.4	6.12	9.32
40 S + 5 Zn	255.0	219.3	6.45	10.63

NS = not significant

Kamath (1984) also observed that rapid reversion of added soluble P fertilizers is a common phenomenon in almost all soils, resulting in low recovery of 15-20%. Application of phosphorus resulted in proportionately greater increase in grain yield to that of straw yield which consequently led to higher harvest index.

The uptake of nutrients increased with increasing levels of P up to 26.2 kg/ha, except in case of S where application of P did not affect the uptake of this nutrient. The increase in N, P and Zn content in grain and straw (data not reported here) by P application due to greater availability of these nutrients with extended root system, coupled

with increased grain and straw yields resulted in higher uptake of these nutrients (Table 3). The P fertilizer did not affect the K content but its uptake was higher with P application because of higher grain and straw yields. Further, S content in grain and straw though remained unaffected by P fertilizer but showed a decreasing trend with P application. This decrease in S content in grain and straw thus neutralized for the increase in yields, and resulted in no effect of P on S uptake.

Application of P resulted in higher CU of water over no P (Table 4). This might be ascribed to better root and canopy growth by P supply. The WUE also improved by P

**Table 5.** Soil nutrient status after harvest of pea as affected by moisture stress, phosphorus, sulphur and zinc (mean of 2 seasons)

Treatment	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available S (kg/ha)	Available zinc (ppm)
<i>Moisture stress</i>					
At vegetative stage	0.44	194.8	11.34	10.61	0.55
At flowering stage	0.45	196.3	11.74	11.02	0.57
At pod-filling stage	0.45	196.4	11.41	10.68	0.57
No stress	0.46	196.8	10.41	10.54	0.53
CD (P = 0.05)	NS	NS	NS	NS	NS
<i>Phosphorus (P-kg/ha)</i>					
0	0.42	192.0	8.94	11.00	0.57
13.1	0.46	196.7	11.30	10.61	0.55
26.2	0.47	199.6	13.42	10.53	0.54
CD (P = 0.05)	NS	3.1	0.98	NS	NS
<i>Sulphur and zinc (kg/ha)</i>					
No S no Zn	0.44	195.2	11.55	8.52	0.52
40 S	0.45	196.3	11.14	11.65	0.54
40 S + 5 Zn	0.46	196.7	10.98	11.97	0.61
CD (P = 0.05)	NS	NS	NS	NS	NS

NS = not significant

application. The crop receiving P showed relatively greater water extraction from deeper layers probably because of deeper penetration of roots with P availability as was also observed earlier by Lenka (1966).

Application of P showed a favourable effect on the post-harvest soil-available N and P but no effect on soil-available S and Zn (Table 5). The increase in available N could be attributed to greater BNF with adequate P supply. The status of soil P improved firstly due to direct application of P to soil, and secondly through organic acids released by legume roots capable of solubilizing soil P (Thind *et al.*, 1979).

#### **Effect of sulphur and zinc**

Combined application of 40 kg S and 5 kg Zn/ha recorded longer vines, higher leaf-area index and dry-matter accumulation in both the seasons when compared with 40 kg S and no S and no Zn (Table 1). Though there was improvement in growth attributes with sulphur application, it was more pronounced with combined application of S and Zn. This might be due to greater availability of S and Zn to the crop. Gupta *et al.* (1983) and Islam *et al.* (1989) also observed the increase in growth attributes such as plant height and dry-matter accumulation with Zn.

Yield attributes like number of pods/plant, number of grains/pod and 1,000-grain weight were substantially improved due to combined application of S and Zn (Table 2). Sulphur application in legumes in general and pea in particular has invariably resulted in increased pod production/plant (Jain *et al.*, 1984). Grain and straw yields were favourably affected by combined application of S and Zn. The improvement in growth and

yield attributes with S and Zn fertilizers as discussed earlier led to higher biomass production, whereas the improvement in yield attributes alone resulted in higher grain yield. Application of S + Zn fertilizers resulted in proportionately similar increase in grain and biological yields leading to no difference in harvest index when compared to control. These results are in conformity with those of Jain *et al.* (1984). Over the seasons, 40 kg S and 5 kg Zn/ha recorded agronomic efficiency of 4.52 and 21.1 kg grain/kg of nutrient respectively. The apparent recovery of Zn (1.25%) was lower than S (14.4%). This could be attributed to the need of crop and Zn adsorption with clay complex (Jain *et al.*, 1984).

Application of 40 kg S/ha markedly increased the uptake of N, P, K, S and Zn by the crop (Table 3). Addition of 5 kg Zn/ha with S further increased the uptake of these nutrients except that of S. Although S application with and without Zn increased N content in grain and S content in grain and straw but the uptake of other nutrients also increased owing to the higher dry-matter production. Zn application increased Zn content in grain and straw only. The increase in the N content in grain by S application could be attributed to increased root activity and BNF. The increase in S and Zn content in grain and straw was probably due to easy and greater availability of these nutrients with extended root system as a result of external supply of S and Zn. Singh *et al.* (1987) also observed similar behaviour with Zn application.

Application of S and its combination with Zn recorded higher CU and WUE over control (Table 4). The WUE was higher

mainly because of higher grain yields in these treatments since the differences in CU were not much conspicuous. Sulphur and zinc application showed a positive effect on post-harvest soil-available S and Zn only (Table 5). This could be ascribed to the left-over of unutilized portion of the fertilizers containing these nutrients in the soil.

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