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Productivity and P-use efficiency of clusterbean (*Cyamopsis tetragonoloba*) as influenced by bio-regulators and phosphorus

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ABSTRACT

A field experiment was conducted at Bikaner during 1999 and 2000 on sandy soil to study the effect of bio-regulators (thiourea and dimethylsulphoxide) and phosphorus on productivity and P-use efficiency of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. The study revealed that application of thiourea 5 kg/ha in the soil (split), thiourea 5 kg/ha + dimethylsulphoxide 2 kg/ha in the soil (split), foliar spray of 500 ppm thiourea and foliar spray of 500 ppm thiourea + 100 ppm dimethylsulphoxide proved effective in improving the growth and yield-attributing parameters over the control. The maximum seed yield of 1.988 tonnes/ha was obtained with thiourea 5 kg/ha ++ dimethylsulphoxide 2 kg/ha in the soil (split) along with 17.2 kg P/ha, which was on a par with yield obtained with application of 5 kg thiourea/ha in soil (spilt) and 8.6 kg P/ha, and foliar spray of 500 ppm/ha thiourea and 8.6 kg P/ha. Growth indices, viz. leaf-area index (LAI) and crop-growth rate (CGR) also improved with bio-regulators and phosphorus application. Application of phosphorus up to 17.2 kg P/ha significantly improved the LAI and CGR at 60 and 90 days after sowing (DAS), number of nodules/plant, pods/plant and pod length as well as P-use efficiency. The gum content increased significantly due to phosphorus application up to 8.6 kg P/ha. The maximum P recovery of 47.4 kg/ha was obtained with the application of 8.6 kg P/ha followed by 17.2 kg/ha (26.4 kg/ha). The highest P uptake by seed (10.72 kg/ha) was obtained with 5 kg thiourea/ha + dimethylsulphoxide 2 kg/ha in the soil (split). Soil and foliar applications of thiourea and dimethylsulphoxide recorded higher agronomic as well as physiological efficiency of the applied phosphorus.

Key words: Clusterbean, Dimethylsulphoxide, P-use efficiency, Phosphorus, Thiourea

Low productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] may be ascribed to many reasons, but inadequate and imbalanced fertilization is the major factor. In most of the clusterbean-growing areas, poor soil fertility is one of the severe constraints limiting expression of its potential productivity. In arid region phosphorus deficiency is usually the dominant factor leading to poor yield of legume crops due to poor nodulation. Thus phosphorus management has an important role to play for increasing the productivity of clusterbean. Besides P fertilization, a bio-technological approach for its improvement could be the use of bio-regulators to improve photosynthesis and photo-assimilate partitioning. Since clusterbean is largely a crop adapted to limited water environment, the use of bio-regulator would prove most rewarding by hastening the partitioning of dry matter for yield formation. The potential of regulating the translocation of assimilates by either plant-growth regulators or chemicals (bio-regulators) promises substantial opportunities for increasing the yield of crops (Girrford and Evans, 1981). Thiourea is a novel bio-regulator with considerable potential to improve crop productivity. Sahu and Solanki (1991) reported that it improves the dry-matter partitioning and grain yield of maize. The soil application of thiourea at 5 kg/ha increases the phosphorus-use efficiency in potato, bringing about a saving of 8.6 kg P/ha and increasing tuber yield by 15.2% (Sud *et al.*, 1991). The increase in grain yield of several field crops due to dimethylsulphoxide application has also been reported by various researchers. It was therefore presumed that thiourea and dimethylsulphoxide might improve the productivity of clusterbean either through improvement in phosphorus use efficiency or through improved dry-matter partitioning. In view of these observations, an experiment was conducted to study the effect of thiourea and dimethylsulphoxide on the productivity and P-use efficiency of clusterbean under arid environment of Bikaner region.

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MATERIALS AND METHODS

The field experiment was conducted at Agricultural Research Station, Bikaner (Rajasthan) during 1999 and

2000. The geographical co-ordinates of Bikaner are: $28^{0}01'$ N latitude, $73^{0}22'$ E longitude and 234.7 m above mean sea level. The soil was sandy, having low available N (107.0 kg/ha), available P (7.4 kg/ha) and high available K (167.7 kg/ha) with pH 8.4. The experiment consisted of 24 treatment combinations, viz. three levels of phosphorus (P @ 0, 8.6 and 17.2 kg /ha) and eight bio-regulators, viz. the control, thiourea 5 kg/ha in the soil (basal), thiourea 5 kg/ha in the soil (split), dimethylsulphoxide 2 kg/ha in the soil (split), thiourea 5 kg/ha + dimethylsulphoxide 2 kg/ha in the soil (split), thiourea 500 ppm foliar spray, dimethylsulphoxide 100 ppm foliar spray and thiourea 500 ppm + dimethylsulphoxide 100 ppm foliar spray. The experiment was laid out in randomized block design with four replications. Phosphorus was applied basal through diaammonium phosphate (DAP) as per treatment and thiourea @ 5 kg/ha and dimethylsulphoxide @ 2 kg/ha were mixed with soil and applied in furrow manually at a depth of 8-10 cm, followed by 3-4 cm soil layering. The remaining half doses of thiourea and dimethylsulphoxide were top-dressed at 45 days after sowing between the crop rows, followed by hoeing and light irrigation. Foliar spraying of thiourea and dimethylsulphoxide was done at pre-flowering (40 DAS) and pod-development stage (60 DAS). The crop was fertilized with N @ 20 kg/ha and K @ 16.6 kg/ha. Clusterbean variety 'RGC 986' was sown on 17 and 18 July during 1999 and 2000, respectively. The crop was grown under irrigated conditions. During crop-growth period, 34.0 and 166.3 mm rainfall was recorded in 1999 and 2000, respectively.

RESULTS AND DISCUSSION

Growth and yield

Soil and foliar application of thiourea and thiourea + dimethylsulphoxide brought about significant variations in the number of growth parameters in comparison with the control (Table 1). The maximum leaf-area index (LAI) and crop-growth rate (CGR) at 60 DAS, number of nodules/plant, pods/plant, pod length, test weight, seeds/pod, harvest index and gum content were recorded with the application of thiourea 5 kg + dimethylsulphoxide 2 kg/ha in the soil (split). However, the number of nodules/plant at 60 DAS significantly increased with soil application of thiourea at 5 kg/ha (split) and thiourea 5 kg + dimethylsulphoxide 2 kg/ha in the soil (split) only. It indicates that thiourea might have stimulated the photosynthetic carbon fixation mechanism and hence might have increased the canopy photosynthesis. Significant increases in LAI obtained with thiourea treatment provide ample support to such effects. Since thiourea shows cytokinin-like activity (Erez, 1978), which is responsible for delaying leaf senescence, thiourea might have resulted in the creation of larger photosynthetically active leaf surface during grain filling. By and large, soil application of thio-

Table 1. Effect of bio-regulators and phosphorus on growth and yield parameters, and gum content of clusterbean (pooled data of 2 years)

Treatment	LAI		CGR ($g/m^2/d$)		Nodules/ plant (60 DAS)	Pods/ plant	Pod length (cm)	Test weight (g)	Seeds/ pod	Straw yield (t/ha)	Harvest index (%)	Gum content (%)
	60 DAS	90 DAS	60 DAS	90 DAS								
Bio-regulator												
Control	4.48	2.66	17.6	7.2	4.9	53.8	5.2	29.1	6.8	4.08	27.21	27.08
TU 5 kg/ha in soil (basal)	4.63	3.39	17.8	9.9	5.1	54.3	5.1	29.7	6.9	4.17	28.01	27.61
TU 5 kg/ha in soil (split)	4.95	3.92	19.5	10.3	6.0	66.6	5.4	30.1	7.5	4.30	30.00	28.31
DMSO 2 kg/ha in soil (spilt)	4.45	3.27	17.6	10.3	5.2	57.5	5.2	29.8	7.2	4.12	28.39	27.15
TU 5 kg + DMSO 2 kg/ha in soil (split)	5.21	4.24	20.6	11.6	6.1	67.4	5.4	30.4	7.6	4.12	30.11	28.42
TU 500 ppm (spray)	4.80	4.33	18.9	11.2	5.3	65.0	5.4	30.1	7.4	4.13	29.26	28.16
DMSO 100 ppm (spray)	4.46	3.24	17.9	10.6	5.1	56.7	5.3	29.7	7.3	4.23	29.35	27.79
TU 500 ppm + DMSO 100 ppm (spray)	4.80	4.52	19.1	11.7	5.4	65.4	5.6	30.3	7.5	4.17	29.46	28.22
SEm ±	0.11	0.09	0.44	0.52	0.15	1.52	0.06	0.19	0.09	0.09	0.37	0.24
CD (P = 0.05)	0.32	0.25	1.21	1.43	0.41	4.21	0.19	0.53	0.27	NS	1.01	0.67
Phosphorus (kg/ha)												
0	3.80	2.89	15.9	8.4	4.2	52.0	5.1	29.5	6.9	3.72	27.27	26.77
8.6	4.80	3.87	19.1	10.9	5.8	63.5	5.3	30.0	7.4	4.38	29.02	28.29
17.2	5.47	4.33	20.9	11.7	6.2	66.9	5.5	30.2	7.5	4.39	30.63	28.68
SEm ±	0.07	0.06	0.27	0.32	0.09	0.93	0.04	0.12	0.06	0.05	0.22	0.15
CD (P = 0.05)	0.19	0.16	0.74	0.88	0.25	2.57	0.12	0.33	0.16	0.15	0.62	0.41

TU= thiourea; DMSO= dimethylsulphoxide, DAS= days after sowing urea 5 kg + dimethylsulphoxide 2 kg/ha (split) was on a par with soil application of thiourea at 5 kg/ha (split) in most of the parameters. This shows that addition of dimethylsulphoxide in thiourea has no additional advantage for improving the growth and yield parameters over split application of thiourea. Similar trends were observed for foliar spray as well. Basal application of thiourea did not show consistent effects. Obviously persistence of soil-applied thiourea appears to be more under split application in soil than when it was applied basal. The maximum gum content (28.42%) was recorded with thiourea 5 kg + dimethylsulphoxide 2 kg/ha in the soil (split).

Harvest index increased significantly due to application of thiourea 5 kg/ha (split), thiourea 5 kg + dimethylsulphoxide 2 kg/ha in soil (split) and all the foliar applications over the control. Eventually seed yield increased significantly under thiourea treatments, but straw yield did not. This indicates that thiourea and dimethylsulphoxide treatments in the present study improved the seed yield chiefly on account of improved assimilate partitioning and transport during grain development.

A significant interaction was recorded between bio-regulators and phosphorus levels for pooled seed yield (Table 2). The data reveal that soil and foliar applications of thiourea and dimethylsulphoxide increased the seed yield up to 8.6 kg P/ha. Soil application of 5 kg thiourea + 2 kg dimethylsulphoxide/ha (split) and 17.2 kg P/ha gave the highest seed yield (1.98 t/ha). However, this treatment was on a par with that of soil application of thiourea 5 kg/ha (split) with 8.6 kg P/ha and foliar spray of thiourea 500 ppm + dimethylsulphoxide 100 ppm with P 8.6 kg/ha. Meena and Sharma (2005) in pigeonpea, and Mehta *et al.* (2006) in mustard also reported improvement in their yield on application of thiourea.

An increase in the levels of P application up to 17.2 kg/ha significantly increased number of nodules at 60 DAS (Table 1). LAI and CGR also improved significantly due to application of phosphorus up to 17.2 kg/ha. Naagar (2001) also reported the beneficial effects of P on growth of clusterbean. Growth improvement under increased P application might have increased the metabolic processes in the plant, resulting in greater meristematic activity and apical growth, thereby improving the growth parameters and ultimately resulting in improved photosynthetic surface of the plant. This is evident from increase in LAI at 60 and 90 DAS due to P application.

Application of 17.2 kg P/ha significantly increased the pods/plant and pod length over the control and 8.6 kg P/ha. However, the number of seeds/pod and test weight significantly increased up to 8.6 kg P/ha. Straw yield and gum content responded up to 8.6 kg P/ha improvement in yield attributes due to increased P application. Shivran *et al.* (1996) and Naagar (2001) also reported improvement in yield attributes due to P application. The favourable effect of phosphate fertilization on yield attributes might be due to the fact that phosphorus plays a key role in the root development, energy transformation and various vitally important metabolic processes in the plant.

P-use efficiency

The data on P-use efficiency, viz. P uptake, P-harvest index, agronomic efficiency, physiological efficiency and P recovery, are presented in Tables 3 and 4. The highest P uptake by seed (10.72 kg/ha) was obtained with application of thiourea 5 kg + dimethylsulphoxide 2 kg/ha in the soil (split). However, it was on a par with thiourea 5 kg/ha in the soil (split). Application of thiourea 5 kg/ha in the soil (split), thiourea 5 kg + dimethylsulphoxide 2 kg/ha in the soil (split), foliar spray of thiourea 500 ppm and foliar spray of thiourea 500 ppm + dimethylsulphoxide 100 ppm significantly increased P-uptake by seed over control by

Table 2. Effect of bio-regulators on seed yield (t/ha) at different levels of phosphorus (pooled data of 2 years)

Treatment	P level (kg/ha)			
	0	8.6	17.2	Mean
Control	1.12	1.65	1.78	1.52
TU 5 kg/ha in soil (basal)	1.22	1.74	1.85	1.60
TU 5 kg/ha in soil (split)	1.58	1.92	1.93	1.81
DMSO 2 kg/ha in soil (spilt)	1.34	1.70	1.81	1.62
TU 5 kg + DMSO 2 kg/ha in soil (split)	1.57	1.91	1.98	1.82
TU 500 ppm (spray)	1.32	1.80	1.96	1.69
DMSO 100 ppm (spray)	1.44	1.71	1.87	1.69
TU 500 ppm + DMSO 100 ppm (spray)	1.47	1.83	1.89	1.73
Mean	1.38	1.78	1.88	
	Phosphorus	*Bio-regulator*	*Interaction*	
SEm ±	0.02	0.03	0.05	
CD (P=0.05)	0.05	0.09	0.15	

TU = thiourea, DMSO = dimethylsulphoxide

22.2, 23.9, 12.7 and 15.3%, respectively. The magnitude of increase in P uptake by seed was larger under soil-applied thiourea + dimethylsulphoxide compared with foliar sprays. Application of 5 kg thiourea/ha in the soil (split), thiourea 5 kg + dimethylsulphoxide 2 kg/ha in the soil (split), foliar spray of thiourea 500 ppm and thiourea 500 ppm + dimethylsulphoxide 100 ppm significantly increased the total P uptake by the crop over the control by 14.6, 15.2, 6.6 and 9.2% respectively. The highest total P uptake (24.38 kg/ha) was recorded under soil application of 5 kg thiourea + 2 kg dimethylsulphoxide/ha (split) followed by 5 kg thiourea/ha in soil (split). Sud *et al.* (1991) also reported that P uptake by potato increased with the application of thiourea 5 kg/ha in the soil. Application of thiourea 5 kg/ha in the soil (split), thiourea 5 kg + dimethylsulphoxide 2 kg in the soil (split), foliar sprays of 500 ppm thiourea, dimethylsulphoxide 100 ppm and thiourea 500 ppm + dimethylsulphoxide 100 ppm significantly increased the P-harvest index by 7.3, 7.9, 6.1, 5.7 and 5.7% respectively over the control. However, these treatments were at par. Soil-and-foliar applied treatments of thiourea and dimethylsulphoxide showed increasing trends in phosphorus recovery. Higher agronomic and physiological efficiencies were recorded due to soil-and foliar-applied thiourea and dimethylsulphoxide treatments over the control. The maximum agronomic efficiency of 30.4

Table 3. Effect of bioregulators and phosphorus on P uptake and P-harvest index of clusterbean (pooled of 2 years)

Treatment	P uptake (kg/ha)			P-harvest index (%)
	Seed	Straw	Total	
Bio-regulator				
Control	8.65	12.51	21.16	40.63
TU 5 kg/ha in soil (basal)	9.16	12.84	21.99	41.57
TU 5 kg/ha in soil (split)	10.57	13.89	24.26	43.58
DMSO 2 kg/ha in soil (spilt)	9.17	12.73	21.91	41.76
TU 5 kg + DMSO2 kg/ha in soil (split)	10.72	13.66	24.38	43.87
TU 500 ppm (spray)	9.75	12.81	22.56	43.09
DMSO 100 ppm (spray)	9.45	12.63	22.08	42.94
TU 500 ppm + DMSO 100 ppm (spray)	9.97	13.13	23.10	42.96
SEm ±	0.19	0.33	0.45	0.45
CD (P=0.05)	0.53	NS	1.26	1.26
Phosphorus (kg/ha)				
0	7.33	10.52	17.87	41.05
8.6	10.53	14.01	24.54	42.95
17.2	11.17	14.46	25.63	43.65
SEm ±	0.19	0.20	0.28	0.28
CD (P = 0.05)	0.33	0.56	0.77	0.77

TU= thiourea, DMSO= dimethylsulphoxide

Table 4. Effect of bio-regulators on agronomic efficiency, physiological efficiency, and P recovery at varying levels of phosphorus in clusterbean (pooled data of 2 years)

Treatment	Agronomic efficiency (kg grain/kg applied P)			Physiological efficiency (kg grain/kg uptake)			P recovery (%)		
	8.6 kg P/ha	17.2 kg P/ha	Mean	8.6 kg P/ha	17.2 kg P/ha	Mean	8.6 kg P/ha	17.2 kg P/ha	Mean
Bio-regulator									
Control	26.1	16.4	21.3	63.1	65.6	64.4	41.4	25.0	33.2
TU 5 kg/ha in soil (basal)	30.9	18.1	24.5	65.3	68.4	66.8	47.3	26.5	36.9
TU 5 kg/ha in soil (split)	39.6	20.1	29.9	74.6	77.8	71.2	53.1	29.6	38.9
DMSO 2 kg/ha in soil (spilt)	28.9	17.2	23.1	68.2	72.8	70.5	42.5	23.7	33.1
TU 5 kg + DMSO 2 kg/ha in soil (split)	39.3	21.5	30.4	68.9	74.9	71.9	57.0	28.7	42.8
TU 500 ppm (spray)	33.6	20.8	27.2	70.7	76.5	73.6	47.5	27.2	37.3
DMSO 100 ppm (spray)	29.4	18.7	24.1	72.1	74.4	73.3	40.8	25.2	32.9
TU 500 ppm + DMSO 100 ppm (spray)	35.5	19.1	27.3	71.9	74.7	73.3	49.3	25.5	37.9
Mean	32.9	18.9		68.4	73.1		47.4	26.4	

TU= thiourea, DMSO= dimethylsulphoxide

kg grain/kg applied P was recorded with the application of thiourea 5 kg + dimethylsulphoxide 2 kg/ha in the soil (split) which was 42.7% higher over the control. However, the maximum physiological efficiency of 73.6 kg/grain/kg uptake/ha was recorded with foliar spray of 500 ppm thiourea which was 14.3% higher than that of the control. Maximum P recovery (42.8%) was obtained with thiourea 5 kg + dimethylsulphoxide 2 kg/ha in the soil (split), followed by thiourea 5 kg/ha in the soil (split) (38.9%). The increase in P-use efficiency on soil application of thiourea might be due to direct effect of thiourea on soil phenomena like solubilizing of native P and P availability due to reduced P fixation

Uptake of P by seed, straw and total P uptake by the crop significantly increased with the application of phosphorus (Table 3). Application of P @ 8.6 and 17.2 kg/ha significantly increased the P uptake of seed by 43.6 and 52.4% and total P uptake of the crop by 37.3 and 43.4% respectively over the control. P-harvest index was significantly improved with the application of 8.6 and 17.2 kg P/ha over control. But P levels at 8.6 and 17.2 kg P/ha were at par. Agronomic efficiency of the crop decreased with the application of 17.2 kg P/ha compared with P 8.6 kg/ha (Table 4). However, physiological efficiency showed reverse trends. Application of 8.6 kg P/ha gave higher P recovery (47.4%) compared with 17.2 kg P/ha (26.4%). Decrease in agronomic efficiency and P recovery with increasing levels of P indicates that much of the applied P was nearly sufficient up to 8.6 kg P/ha, beyond which the absorbed P was less effective in grain production. Khiriya *et al.* (2001) also reported an decrease in agronomic efficiency and P recovery with increasing levels of P application in fenugreek.

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