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Influence of Phosphorus on Dry matter Partitioning and Nutrient Allocation in Clusterbean under Water deficit

Shubhra Barwa[1], Balaram Pani[1] and Leena Shakya[2]*

[1]Bhaskaracharya College of Applied Sciences, University of Delhi, India.

[2]Department of Botany, Kirorimal College, University of Delhi, India.

Corresponding author: *Leena Shakya, Department of Botany, Kirorimal College, University of Delhi, India.

Abstract

Clusterbean (C. tetragonaloba L. Taub) locally called Guar cultivar HG-365 was supplied with three level of phosphorus (i.e. 15, 30 and 60 mg/kg) of the soil in two split doses at weekly intervals in the form of KH_2PO_4 one week after sowing of the crop. Water stress was created by withholding irrigation at different growth stages of the crop. Plants were sampled at permanent wilting point (PWP) with soil moisture content 3.5 (±0.5). Results show that dry weight of all the plant parts (leaf, stem, root and nodules) decreased under water deficit in clusterbean. Phosphorus treatment proved effective in improving leaf dry weight (25-100%) in control and stressed plants. Nitrogen content of the plant parts (leaf, stem, root, and seeds) was decreased significantly (17-22%) by the water deficit stress and improved approximately 12-18% with increasing level of phosphorus application. P content of the plant parts increased up to flowering stage and decreased at later growth stages. Significant decrease in the P content of the leaf (16-21%), stem (17-20%), and root (18-22%) was observed under water deficit stress conditions. phosphorus as a fertilizer improved P content of leaf by 17-18%, stem (13-15%), and root (14-20%) at all three growth stages. Potassium content decreased up to 37-56% due to water deficit stress in clusterbean and improved approximately 8-25% with the increasing level of phosphorus treatment compared to untreated control plants.

Keywords: Clusterbean, Phosphorus, water deficit, dry matter portioning

Introduction

Clusterbean (Cyamopsis tetragonoloba L. Taub) commonly known as Guar is one of the important self pollinated kharif crop. It has been grown in Indian subcontinent for thousands of year for forage and vegetables. Now it has emerged as new industrial crop because of the gum present in its endosperm which forms an important raw material for a wide range of industries like textiles, cosmetics, mining, and oil industry. Industrial importance of the crop has given a new dimension to its cultivation and created immense interest among the research workers, growers and industrialists.

The crop has the ability to recover from water stress (Kuhad and Sheoran, 1986). The ability of this crop to flower an fruit over an extended period of time partially alleviates yield restrictions caused by drought of short duration. Water stress causes reduction in plant growth, fresh and dry weights of the plant parts, nitrogen fixation and soluble proteins (Kuhad and Sheoran,1987; Shubhra , 2001).Dry matter reduction under water stress was reported in clusterbean (Shubhra, 2001), sunflower (Hall et al, 1985) and pigeonpea (Nandwal, 1989). Nodule dry weight decreased significantly due to water stress in clusterbean (Venkateshwarlu et al, 1984) and pigeonpea.(Nandwal,1989). Under water stress percentage nitrogen content accumulated more in leaves and stem whereas nodule content show six times decline in it (Kuhad and Sheoran, 1997). Phosphorus, an important plant nutrient plays a vital role in plant growth and development. Its application led to increase in plant length (Bhadoria and Tomar,1997), extensive root growth (Liang et al, 1996) and leaf area(Thomas et al, 1998). Dry weights of the plant parts also increased by phosphorus application in clusterbean (Shubhra, 2001), soybean (Daniel W. Israel, 1987), and wheat (Flavio and Thomas, 1998). Phosphorus application led to improved nitrogen accumulation in the leguminous crops. This response was higher on manured soil than on unmanured soil (Das et al, 2000). Potassium uptake was particularly high during early vegetative stage when leaf area expanded rapidly, resulting in maximum accumulation of the shoot potassium content. This reflects that the uptake of potassium is required during this period when newly formed cell volume in the process of enlargement needs an additional influx of the osmotic material. Water deficit led to maximum accumulation of potassium in stem though root and leaves show 2-3 times decline in it. Water deficit conditions adversely affect nutrient allocation as well as dry matter production in plants. The main objective of the present investigation was to assess the effect of water deficit conditions on translocation of essential nutrients (NPK) and the role played by phosphorus in combating the deleterious effect of stress in clusterbean.

Materials and methods

Seeds of clusterbean cultivar HG-365 were taken and surface sterilized with 1% sodium hypochlorite solution and then inoculated with mixed rhizobium culture. Seeds were sown under natural conditions in the screen house in earthen pots filled with 5 kg of dune sand. In each pot five seeds were sown and after germination only two healthy plants were retained. Irrigation was given as and when required. Water stress was created by withholding irrigation at different growth stages of the crop. Plants were sampled at permanent wilting point (PWP) with soil moisture content 3.5 (±0.5). Each pot was supplied with nitrogen free nutrient solution (Wilson and Reisenauer, 1963) at fortnightly intervals. Three level of phosphorus were supplied (i.e. 15, 30 and 60 mg/kg of the soil in two split doses at weekly intervals in the form of KH_2PO_4 one week after sowing of the crop. Equal concentration of potassium was maintained in control and phosphorus treated plants by adding K_2SO_4 and CH_3COOK in 1:1 ratio. Plant protection measures were taken by spraying 0.02% malathione at regular intervals. For each sampling three replicates were taken.

The plant of each treatment were removed from the pot and separated into their components i.e. leaf, stem, root and nodule. The components were weighed separately to determine the fresh weights. They were then wrapped in paper and allowed to dry under laboratory conditions for a day and then placed in an oven at 60°C till a constant weight is obtained. Mineral analysis (N P K content) of leaf, stem, roots and seeds were determined from oven dried material. For digestion 200 mg of well dried and grinded material was taken in 50 ml of flask to which 10 ml 9:1 H_2SO_4 (97%) and $HCLO_4$ (60%) were added. The flasks were heated on hot plate until dense white fumes were formed. Then heating was increased and material was digested for another 25-30 minutes till a colorless digest is formed. The digest was then cooled and diluted to 50 ml with distilled water for mineral analysis. Nitrogen content of the different plant parts was determined as per the method given by Linder et al, 1944. Phosphorus content was estimated by the vanado-molybdo phosphoric yellow color method given by Jackson, 1973. K content was estimated by flame photometer. Data was expressed as mg/g dry weight of the tissue for each of the three minerals estimated.

Results

Growth is one of the best indices for evaluating plant response to environmental stress. Dry weight of the plant parts (leaf, stem, root and nodules) decreased under water deficit in clusterbean (Table 1). Nodule maintained relatively higher dry weight than leaf stem and root under normal as well as stress conditions. Dry weights of different plant parts decreased approximately 20-25% by the water deficit stress. Phosphorus treatment proved effective in improving leaf dry weight (25-100%) in control and stressed plants (Table 1).Stem dry weight decreased approximately 17-25% under water deficit conditions. Decrease in the dry weight of stem was lesser at higher phosphorus treatment levels (P2 and P3 respectively) relative to untreated control plants (Table 1). P treatment improved stem dry weight (Approximately 89-100%) in control as well as stressed plants. Relative to other two stages maximum improvement in stem dry by P treatment was observed at the vegetative stage. Dry weight of the root decreased 21-24% due to water deficit in clusterbean (Table 1).Maximum decrease in the dry weight was seen at pod-filling stage under stress conditions. This may be attributed to translocation of the nutrients to potential sink organs. Root dry weight improved approximately 21-54% by phosphorus treatment irrespective of the growth stages (Table 1). Water deficit stress reduced the nodule dry weight approximately 20% as compared to control plants. Improvement in the dry weight of the nodule (up to 28-36%) was observed by phosphorus application in control and stressed plants at all the three growth stages (Table 1).

Table 1: Impact of water deficit and phosphorus application on dry matter accumulation in cluster bean.

Treatment	P content	Vegetative stage				Flowering stage				Pod-filling stage			
		leaf	stem	root	nodule	leaf	stem	root	nodule	leaf	stem	root	nodule
Control	P0	0.28	0.10	0.37	11.34	0.35	0.18	0.43	18.30	0.47	0.28	0.46	15.46
	P1	0.38	0.17	0.43	12.06	0.44	0.25	0.45	20.16	0.73	0.31	0.49	15.91
	P2	0.60	0.21	0.46	12.75	0.57	0.32	0.48	22.57	0.84	0.42	0.58	19.14
	P3	0.71	0.28	0.50	15.50	0.70	0.36	0.52	24.38	0.98	0.53	0.65	19.87
Stress	P0	0.21	0.08	0.29	9.07	0.26	0.14	0.34	14.65	0.35	0.21	0.35	12.35
	P1	0.28	0.13	0.34	9.86	0.35	0.20	0.36	16.53	0.59	0.24	0.38	13.20
	P2	0.46	0.17	0.38	10.81	0.43	0.26	0.39	19.18	0.68	0.35	0.46	16.27
	P3	0.55	0.22	0.41	13.17	0.54	0.29	0.43	20.96	0.81	0.44	0.54	16.36
CD at 5%	S	0.03	0.05	0.04	1.20	0.05	0.07	0.06	0.36	0.08	0.10	0.07	2.11
	P	0.10	0.10	0.07	1.50	0.12	0.14	0.09	1.68	0.16	0.14	0.15	2.28
	S*P	0.18	0.15	NS	1.57	0.20	0.17	NS	2.10	0.24	0.18	NS	NS

Table 2: Impact of water deficit and phosphorus application on Nitrogen content (mg/g dry wt.) in clusterbean.

Treatment	P content	Vegetative stage leaf	stem	root	seed	Flowering stage leaf	stem	root	seed	Pod-filling stage leaf	stem	root	seed
Control	P0	18.96	14.24	10.18	48.50	20.36	16.50	12.14	48.50	18.22	18.22	10.61	48.50
	P1	20.48	15.61	11.31	51.56	21.84	17.59	13.26	51.56	19.12	19.38	0.96	51.56
	P2	21.04	15.86	11.63	54.80	22.56	17.97	13.51	54.80	19.86	19.71	11.35	54.80
	P3	21.62	16.19	11.83	55.60	23.06	18.58	14.22	55.60	20.46	20.39	12.41	55.60
Stress	P0	15.28	11.32	8.10	47.79	15.90	13.36	9.71	43.56	14.64	15.10	8.48	44.40
	P1	16.86	12.63	8.97	50.27	17.20	14.67	10.87	47.79	15.50	16.20	8.97	48.31
	P2	17.52	12.87	9.48	52.62	17.82	14.86	11.21	50.71	16.36	16.58	9.46	52.30
	P3	17.64	13.10	9.78	53.81	18.52	15.24	11.94	51.60	17.26	17.34	10.43	52.77
CD at 5%	S	0.22	0.20	0.51	NS	0.26	0.24	0.66	3.12	0.19	0.31	0.70	3.40
	P	0.23	0.29	0.62	3.62	0.28	0.37	0.71	4.42	0.22	0.40	0.81	4.78
	S*P	0.31	NS	NS	3.69	0.30	NS	NS	3.72	0.26	NS	NS	4.10

Table 3: Impact of water deficit and phosphorus application on Phosphorus content (mg/g dry wt.) in clusterbean.

Treatment	P content	Vegetative stage leaf	stem	root	seed	Flowering stage leaf	stem	root	seed	Pod-filling stage leaf	stem	root	seed
Control	P0	2.82	3.26	3.50	5.40	3.51	4.10	4.70	5.40	3.35	3.41	3.66	5.40
	P1	2.93	3.41	3.78	5.58	3.68	4.31	4.92	5.58	3.47	3.46	3.81	5.58
	P2	3.12	3.59	3.95	5.73	3.87	4.52	5.26	5.73	3.76	3.61	4.03	5.73
	P3	3.32	3.78	4.02	6.01	4.17	4.76	5.45	6.01	3.97	3.87	4.20	6.01
Stress	P0	2.22	2.67	2.73	5.12	2.81	3.40	3.76	4.56	2.68	2.72	2.91	4.83
	P1	2.34	2.84	2.81	5.35	2.98	3.53	3.96	4.59	2.84	2.83	3.11	4.96
	P2	2.55	2.98	3.12	5.44	3.15	3.69	4.28	4.71	3.09	2.97	3.29	5.03
	P3	2.62	3.09	3.28	5.77	3.41	3.85	4.51	4.85	3.30	3.20	3.46	5.33
CD at 5%	S	0.16	0.16	0.26	0.40	0.20	0.70	0.20	0.40	0.25	0.81	.90	0.30
	P	0.37	0.23	0.37	0.50	0.29	0.11	0.29	0.60	0.23	0.76	0.30	0.50
	S*P	NS	NS	NS	0.70	NS	NS	NS	0.90	NS	NS	NS	0.80

Table 4: Impact of water deficit and phosphorus application on Potassium content (mg/g dry wt.) in clusterbean.

Treatment	P content	Vegetative stage leaf	stem	root	Flowering stage leaf	stem	root	Pod-filling stage leaf	stem	root
Control	P0	28.40	32.80	23.40	40.81	39.60	30.81	35.94	36.20	27.20
	P1	32.02	35.20	25.40	45.36	41.40	34.50	36.45	38.42	28.14
	P2	33.20	37.70	27.03	46.44	44.16	36.60	37.62	4046	30.40
	P3	34.25	38.40	29.30	48.50	47.80	46.12	38.86	43.30	33.80
Stress	P0	14.60	14.40	12.60	22.40	19.61	16.53	18.96	20.17	14.25
	P1	16.21	15.63	13.07	25.31	20.66	18.25	19.21	21.70	15.19
	P2	17.50	17.43	13.71	27.20	23.20	20.30	19.80	23.14	16.63
	P3	18.15	20.10	15.32	30.31	25.09	22.07	20.43	23.65	18.48
CD at 5%	S	0.96	0.36	0.40	1.79	0.53	0.42	0.40	0.15	0.49
	P	1.36	0.52	0.50	2.53	0.75	0.53	0.56	0.22	0.66
	S*P	NS	0.73	0.80	3.59	1.06	0.85	NS	0.31	0.91

Nutrient allocation

Nitrogen content of the plant parts (leaf, stem, root, and seeds) was decreased significantly (17-22%) by the water deficit stress and improved approximately 12-18% with increasing level of phosphorus application (Table 2). Highest nitrogen content was determined in the seeds followed by that of leaf stem and root. Highest decline in the N content was seen at the flowering stage compared to other two stages. Stem N content increased progressively with the age of the plant. Water deficit conditions decreased stem N content up to 14- 21% and increased with increasing level of P application, N content of the stem increased up to 12-16% with highest P level at all the three sampling stages (Table 2).Root N content declined up to 20% under water deficit. However, the decrease in N content was 3-4% less with the increasing level of Phosphorus application at all the three growth stages (Table 2). N content of the seeds 2-8% deficit conditions relative to control plants and improved significantly up to 14-18% with increasing level of phosphorus application in control as well as the plants stressed at different stages of growth (Table 2).

It is evident from Table 3, P content of the plant parts increased up to flowering stage and decreased at later growth stages. Significant decrease in the P content of the leaf (16-21%), stem (17-20%), and root (18-22%) was observed under water deficit stress conditions (Table 3) at all the three growth stages of the plant. Application of phosphorus as a fertilizer improved P content of leaf by 17-18%, stem (13-15%), and root (14-20%) at all three growth stages. P content of the seeds declined 4-19% due to water deficit stress compared to control plants. Seed phosphorus content increased up to 11% with the highest P treatment relative to untreated control. Highest decrease in seed P content (15-19%) was seen in the plants stressed at the flowering stage relative to other two stages of the plant (Table 3).

Potassium content of the plant parts (Leaf stem and root) increased up to flowering stage and declined at the later growth stages. K content of the stem was highest at vegetative and pod-filling stages however leaf reported highest K content at the flowering stage (Table 4).Potassium content decreased up to 37-56% due to water deficit stress in clusterbean and improved approximately 8-25% with the increasing level of phosphorus treatment compared to untreated control plants (Table 4).

Discussion

Growth is one of the best indices for evaluating plant responses to environment stress. Water deficit stress decreased stem height and plant dry matter appreciably. Hence the root shoot ratio improved under stress conditions. Dry weight of the different plant parts decreased significantly under water deficit conditions (Table 1).Root maintained markedly higher weight compared to leaves and stem under normal as well as stress conditions. The decline in these parameters under stress was due to reduced water supply from the rooting medium leading to loss of turgor and inhibition of assimilatory process. With the advancement in the age of the plant dry weights of the plant parts increased. This may be due to increase in number and the area of leaves and number of secondary branches that emerge on shoot and root. Leaf dry weight decreased significantly under water deficit conditions (Table 1).This may be due to enhanced abscission of leaves and conspicuous decline in leaf area (Flavio and Thomas, 1998) due to reduction in water content resulting in the inhibition of photosystem that contributed to decreased leaf weight. These changes due to water stress were long being recognized in clusterbean (Kuhad and Sheoran, 1986),Turner and Begg, 1981, chickpea (Gupta et al, 1995) fababean (Mwanamwenge et al, 1999) and in wheat (Nagarajan et al, 1999).Water deficit conditions also led to decrease in dry weight of nodules in clusterbean (Table 1).This may be attributed to dehydration, cessation of the meristamatic growth and shrinkage of nodule structure (Venkateshwarlu et al, 1984).Fertilizer application improved root as well as shoot growth which reflected in terms of increased nodule dry weight under normal as well as stress conditions. Similar effects due to phosphorus application have been reported in clusterbean (Shubhra et al, 2003) groundnut (Kulkarni et al, 1986) chickpea (Enania and Vyas, 1994) and wheat (Flavio and Thomas, 1998).

Water stress reduced the plant growth by disturbing the mineral nutrition of plants (Table 2-4). In addition to organic solutes, inorganic solutes/ ions play a role in osmotic adjustment after being sequestered into vacuoles or distribute themselves between vacuole and cytoplasm, thus subsequently helps in the maintenance of turgor for sufficient growth of plant. It also helps the plant to various physiological processes even at low water potential in clusterbean. In the present study N P and K content in different plant parts (Leaf, stem, root, nodules) increased with the advancement in the age of plant but decreased significantly under water restricted conditions (Table 2-4).The decrease in the nitrogen content of the leaves might be due to its utilization for resumed growth. Leaves maintained appreciably higher nitrogen content compared to stem and root (Table 2). The loss of very high nitrogen content of root may be due to their drying/shedding under stress conditions and decreased availability of nitrogen to plant parts. Application of phosphorus tends to improve the nitrogen content of the plant parts under control as well as stress conditions (Table 2).

Unlike nitrogen, phosphorus content of seeds was highest followed by root, stem and leaves. CO_2 pressure has been reported as an important factor governing phosphorus nutrition in plants (Table 3).The low phosphorus content of the leaves may be attributed to reduction in leaf number, leaf expansion and leaf area under stress conditions. Seeds reported the highest accumulation of phosphorus as they are potential sink organs in control as well as water deficit conditions (Table 3).

Potassium content of stem was higher than that of leaf and root at vegetative and pod-filling stage however leaf potassium content was maximum at the flowering stage (Table 4). Significant decline in K content was noted under water stress in different plant parts and percentage decrease was conspicuously higher in leaves relative to stem and roots (Table 4).The reduction in the nutrient uptake by the crop under water deficit conditions could be compensated by improving water use efficiency (Jain et al, 1990). Potassium content was especially high during early vegetative stage when leaf area was rapidly expanding and needs an additional influx of osmotic material under stress conditions. Potassium content was stored in leaves at early growth stages and thereafter in stem where all other organs show 2-3 times decline in it (Table 4).

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