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Research Paper

Productivity, nutrient uptake, soil fertility and moisture extraction pattern of summer clusterbean (*Cyamopsis tetragonoloba*) as influenced by irrigation and fertility levels

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ABSTRACT

A field experiment was conducted during the summer seasons of 2013 and 2014 at Krishi Vigyan Kendra Farm of Junagadh Agricultural University on sandy loam soils to assess the impact of irrigation and fertility levels on growth indices, productivity, nutrient uptake, post-harvest soil nutrient status and moisture extraction pattern of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. Sixteen treatment combinations of 4 irrigation levels (0.4, 0.6, 0.8 and 1.0 IW: CPE ratio) and 4 fertility levels (00 : 00, 10 : 20, 20 : 40 and 30 : 60 kg N : P_2O_5/ha) were tested using split-plot design with 3 replications. The pooled results indicated that irrigation at 0.8 IW: CPE, being at par with 1.0 IW: CPE, enhanced physiological growth parameters, viz. leaf area index (LAI) leaf: stem ratio, crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR), seed yield (1.33 t/ha), stover yield (2.84 t/ha) and harvest index (31.9%) over 0.4 IW: CPE. The maximum N, P and K content in seed and stover and total N (87.8 kg/ha), P (15.0 kg/ha) and K (54.9 kg/ha) uptake by clusterbean were recorded under 1.0 IW: CPE, while the maximum soil available N (195.6 kg/ha), P (18.4 kg/ha and K (286.2 kg/ha) persisted under 0.4 IW: CPE. Maximum moisture extraction from the upper soil profile was recorded under 1.0 IW: CPE (43.78%), whereas moisture extraction to a lower depth was higher with 0.4 IW: CPE (11.45%). Application of 20 : 40 kg N : P_2O_5/ha being at par with 30 : 60 kg N : P_2O_5/ha also improved physiological growth parameters, seed yield (1.32 t/ha), stover yield (2.78 t/ha), harvest index (32.2%) with the N, P and K content in seed and stover and total N (83.2 kg/ha), P (13.9 kg/ha) and K (51.6 kg/ha) uptake by crop over control. Significantly higher post-harvest nutrient status was recorded with 30 : 60 kg N : P_2O_5/ha (196.9, 18.3 and 274.1 kg N, P and K/ha respectively). The maximum soil moisture depletion (42.1%) was registered from top soil layer (0–15 cm) in control, while the least with 30 : 60 kg N : P_2O_5/ha (39.8%) followed by 20 : 40 kg N : P_2O_5/ha (40.8%). However, the reverse trend was observed in bottom soil layer (45–60 cm). Thus, irrigation at 0.8 IW: CPE and fertilizer dose of 20 : 40 kg N : P_2O_5/ha could be applied for higher yield from clusterbean along with sustaining soil health in summer season.

Key words : Clusterbean, Fertility levels, Irrigation, Moisture extraction pattern, Nutrient uptake, Productivity

Clusterbean is an important drought resistant leguminous crop of India. In the recent years, this crop has assumed great significance due to the presence of a good quality of gum in the endosperm of its seed. Due to diversified uses of clusterbean gum in textile, paper, explosive and mining industries, pharmaceuticals, stamps, cosmetic goods and food stuffs, it has ever increasing demand in the international markets. It is also an important feed for livestock and poultry. India is the largest producer of clusterbean seed in the world, which constitutes about 80% of the total production. Rajasthan, Gujarat, Haryana, Uttar Pradesh and Punjab are the major clusterbean growing states of India. Rajasthan is a leading producer of it, accounting for about 70% of India's output. In India, clusterbean occupies an area of 5.35 million hectares producing 3.29 million tonnes with productivity of 615 kg/ha (DES, 2016). India is the leading exporter of guar seeds and gum and earns significant foreign-exchange.

Water need of clusterbean may vary with the climatic conditions and type of soil. Hence, scheduling of irrigation is one of the most important factors for realizing high yield of summer clusterbean, especially under scarce and costly irrigation water. Scheduling of irrigation based on data of pan evaporation is likely to increase agricultural produc-

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tion at least by 15 to 20%. A more practicable approach based on the ratio of fixed quantity of irrigation water (IW) to the cumulative pan evaporation (CPE), becomes useful for judicious utilization of water and to harvest potential yield of field crops. Among different nutrients, nitrogen is one of the decisive as well as expensive input which governs the legumes production. It has the quickest and the most pronounced effect on plant growth. Phosphorus is the key element in the process of conversion of solar energy into chemical energy. Low phosphorus content in the soil is alarming because it is the backbone of balanced fertilizer use and it occupies a key place in intensive agriculture. Nitrogen and phosphorus also showed significant influence on yield and content and uptake of N and P by clusterbean (Sammauria *et al*., 2009). In Gujarat, the clusterbean is irrigated at 4–5 days intervals thereby providing 10–12 irrigations in summer. This requirement can be reduced by using IW: CPE method particularly in summers. The information regarding this aspect as well as nutrient management in summer is scarce. It is highly desirable to obtain potential yield using the least possible amount of water and quantity of nutrient. Keeping these points in view, an attempt was made to study the effect of irrigation and fertility levels on productivity, nutrient uptake, moisture extraction pattern and post-harvest soil nutrient status of clusterbean in summers on sandy loam soils of Gujarat.

MATERIALS AND METHODS

A field experiment was conducted at Krishi Vigyan Kendra Farm of Junagadh Agricultural University, Nana Kandhasar (22º45' N, 71º25' E, 86.67 m above the mean sea level), Surendranagar, Gujarat during summer seasons of 2013 and 2014 to study the effect of irrigation and fertility levels on clusterbean. The site of experiment is situated in the North Saurashtra agro-climatic region of Gujarat. The climate of this region is semi-arid and subtropical with fairly dry and hot summer. The rainy season commences in the second fortnight of June and ends in September, with an average annual rainfall of 500 mm. Summer season commences in the second fortnight of February and ends in the middle of June. During crop season of the year 2013, the minimum temperature ranged from 15.0ºC to 27.2ºC, maximum temperature ranged from 30.9ºC to 42.5ºC and daily pan evaporation ranged from 4.8 to 11.7 mm/day, while in the year 2014, the minimum temperature ranged from 10.9ºC to 26.7ºC, maximum from 27.6ºC to 43.0ºC and daily pan evaporation from 5.2 to 12.2 mm/day. The off-season rainfall was not received during crop period. The experimental soil was sandy loam (78.3% sand, 8.4% silt and 13.3% clay) in texture and slightly alkaline in reaction with *p*H 7.95 and ECe 0.33 dS/m. It was moderately fertile being low in organic carbon (4.0 g/kg) and available nitrogen (195.5 kg/ha), medium in available phosphorus (20.4 kg/ha) and high in available potassium (287.8 kg/ha).

The 16 treatment combinations 4 levels of irrigation (0.4, 0.6, 0.8 and 1.0 IW: CPE) as a main plot treatments and 4 levels of fertility (00:00, 10:20, 20:40 and 30:60 kg N:P_2O_5/ha) as sub-plot treatments were evaluated using split-plot design with three replications. As per treatments fertilizers were drilled in the soils 5 cm below the seed at the time of sowing in form of diammonium phosphate and urea.

'Gujarat guar-2' variety of clusterbean was sown at 45 cm row spacing using 20 kg seeds/ha on 19 and 20 February during 2013 and 2014 respectively. The crop was irrigated immediately after sowing during both the years followed by a common irrigation of 50 mm depth one week after sowing for better germination and establishment of the crop. Thereafter, irrigation was given as per treatment schedule based on irrigation water : cumulative pan evaporation ratio (IW: CPE). The measured quantity of 50 mm irrigation water was applied with a 7.5 cm throat size Parshall flume installed in the main water channel near the field head. Crop received 3, 5, 7 and 9 irrigations at 0.4, 0.6, 0.8 and 1.0 IW: CPE respectively excluding 2 common irrigations. The evapotranspiration observed during growing seasons of 2013 and 2014 were 690.9 and 660.9 mm, respectively.

The excess plants were thinned out at 20 days after sowing (DAS) to maintain 10 cm plant to plant within the row spacing. Weeds were managed by application of pre-emergence herbicide pendimethalin 30 EC @ 0.5 kg/ha followed by 2 hand-weeding at 25 and 45 DAS. For dry-matter leaf area and area/plant, 5 representative plants were selected and leaf area of all the leaves was measured with the help of leaf area meter (Systronics 211). Leaf area index (LAI) and leaf:stem ratio at 60 DAS were calculated by standard equation. The values of different crop growth indices, viz. crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were calculated with the help of the formula given by Cheema *et al.* (1991). Soil moisture was determined by gravimetric method taking data before and 48 h after irrigation. Profile depletion was calculated by adding the value of depletion of available soil moisture up to depth of 60 cm (0–15, 15–30, 30–45 and 45–60 cm).

Harvest Index (HI) was calculated by dividing the seed yield with biological yield. The stover yield was obtained by subtracting the seed yield from the biological yield. Nitrogen content in plant material was determined using modified Kjeldahl method, whereas phosphorus and potassium content were determined colorimetrically and by flame photometer after tri-acid digestion. Nutrient uptake by the crop was obtained as the product of concentration of respective nutrient and yield. Soil samples were drawn at initial and after harvest of clusterbean during both the years from a depth of 0–15 cm from each treatment and soil available N, P and K were analyzed using standard procedures. The statistical analysis of data was done using analysis of variance (ANOVA) technique for split-plot design at 0.05 probability level.

RESULTS AND DISCUSSION

Physiological growth parameters

Improved growth in terms of LAI and leaf:stem ratio at 60 DAS were attained with 1.0 IW: CPE (Table 1). Adequate water supply, encourages physiological processes, resulting in higher LAI and leaf:stem ratio. Similar increase in LAI and leaf:stem ratio with higher level of irrigation was also reported by Srinivasulu *et al.* (2015) in chickpea. Different irrigation levels had significant influence on crop growth indices viz. CGR, RGR and NAR. Significantly the highest CGR (7.02 g/m^2/day), RGR (18.7 g/g/day × 10^{-3}) and NAR (2.23 g/m^2/day) were recorded with 0.8 IW : CPE and remained at par with 1.0 IW : CPE and 0.6 IW : CPE ratio. Increased dry matter production at 60 DAS resulted in higher CGR and RGR, while increased dry-matter production and LAI at 60 DAS resulted in higher NAR.

The highest LAI (1.63) and leaf : stem ratio (0.28) were recorded under 30 : 60 kg N : P_2O_5/ha over control and remained at par with 20 : 40 kg N : P_2O_5/ha. The increase in LAI and leaf : stem ratio with increasing fertility levels might be due to increase in number, size and succulency of leaves with these treatments. The findings confirm the observations of Srinivasulu *et al.* (2015). Fertility level 30 : 60 kg N : P_2O_5/ha recorded significantly the highest CGR (6.98 g/m^2/day), RGR (18.3 g/g/day × 10^{-3}) and NAR (2.19 g/m^2/day) at 45–60 DAS over control. The overall improvement in the physiological growth parameters of clusterbean achieved at higher level of fertility could be ascribed to their pivotal role in several physiological and bio-chemical processes, viz. root development, photosynthesis and energy transfer. These observations are in line with the findings of Rajput and Rajput (2017), who reported that major plant nutrients mainly phosphorus had a positive effect on crop growth indices in green gram.

Yield

The irrigation at 0.8 IW: CPE produced significantly higher seed and stover yields as compared to 0.4 and 0.6 IW: CPE and remained at par with 1.0 IW: CPE (Table 1). The increase in seed yield under 0.8 IW: CPE over 0.4 and 0.6 was 26.67% and 12.71%, respectively. The higher seed and stover yields with 0.8 and 1.0 IW: CPE could be attributed to increased soil moisture coupled with accelerated nutrient uptake, which helped the plant to gain optimum growth. Increase in seed and stover yields with an application of irrigation at 0.7 IW: CPE was reported by Patel *et al*. (2014) and Srinivasulu *et al*. (2015). Similar

Table 1. Effect of irrigation and fertility levels on physiological growth parameters, seed yield, stover yield and harvest index (HI) of summer clusterbean (pooled data of 2 years)

Treatment	Physiological growth parameters					Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
	LAI at 60 DAS	Leaf: stem ratio at 60 DAS	CGR at 45–60 DAS (g/m^2/day)	RGR at 45–60 DAS (g/g/day × 10^{-3})	NAR at 45–60 DAS (g/m^2/day)			
Irrigation levels (IW: CPE ratio)								
I_1, 0.4	1.46	0.21	4.64	14.6	1.64	1.05	2.36	30.8
I_2, 0.6	1.56	0.24	6.39	18.2	2.12	1.18	2.57	31.4
I_3, 0.8	1.62	0.26	7.02	18.7	2.23	1.33	2.84	31.9
I_4, 1.0	1.64	0.27	7.02	18.1	2.20	1.34	2.97	31.2
SEm±	0.02	0.01	0.21	0.4	0.07	0.03	0.06	0.1
CD (P=0.05)	0.06	0.02	0.65	1.4	0.21	0.08	0.18	0.2
Fertility levels (N:P_2O_5 kg/ha)								
F_1, 00:00	1.47	0.20	5.11	15.9	1.78	1.04	2.41	30.1
F_2, 10:20	1.55	0.24	6.19	17.3	2.06	1.22	2.62	31.8
F_3, 20:40	1.62	0.27	6.80	18.1	2.15	1.32	2.78	32.2
F_4, 30:60	1.63	0.28	6.98	18.3	2.19	1.33	2.93	31.2
SEm±	0.02	0.02	0.18	0.4	0.06	0.02	0.04	0.2
CD (P=0.05)	0.05	0.05	0.50	1.2	0.17	0.06	0.12	1.0

IW: CPE, Irrigation water: Cumulative pan evaporation; DAS, days after sowing; CGR, crop growth rate; RGR, relative growth rate; NAR, net assimilation rate results were also reported by Rajanna *et al.* (2016) in clusterbean and Sarkar *et al.* (2016) in chickpea. The highest harvest index was recorded with 0.8 IW: CPE over rest of the irrigation levels. The change in value of harvest index is due to corresponding increase or decrease in both seed and stover yields of clusterbean and the increased vegetative growth under frequent irrigations in 1.0 IW: CPE.

The fertility level 30 : 60 kg N : P_2O_5/ha produced significantly the highest seed yield as compared to control and remained at par with 20 : 40 kg N : P_2O_5/ha (Table 1). The fertility level 30 : 60 kg N : P_2O_5/ha produced the highest stover yield as compared to all the lower level of fertility (Table 1). The extent of increase in seed and stover yields under 30 : 60 kg N : P_2O_5/ha was 28.06% and 21.64% and in treatment 20 : 40 kg N : P_2O_5/ha it was 27.29% and 15.13% respectively over control. This might be due to better nutritional status in the soil for the crop. Singh and Chaudhary (2016) also reported that application of 20 kg N/ha is beneficial for enhancing productivity and profitability of french bean. Stori *et al.* (2018) observed that optimum dose of phosphorus recorded maximum green gram yield. The maximum harvest index was recorded under 20 : 40 kg N : P_2O_5/ha and remained at par with 10 : 20 kg N : P_2O_5/ha. The change in value of harvest index is due to corresponding increase or decrease in both seed and stover yields of clusterbean and the increased vegetative growth under higher fertility level 30 : 60 kg N : P_2O_5/ha resulted into decrease in the harvest index over lower fertility level. These findings are corroborating with the results of Sammauria *et al*. (2009).

Nutrient content and uptake

The highest values of N, P and K content in seed and stover and total N, P and K uptake were recorded under 1.0 IW: CPE over 0.4 IW: CPE and remained statistically at par with 0.8 IW: CPE (Table 2). When moisture content is high, the rate at which the nutrients reach to the root surface is higher, which in turn contributes to higher N content in the seed and stover. Clusterbean receiving irrigation at early growth stage established its root system deep into the soil for better extraction of nutrients from larger volume of the soil, which ultimately increases the P content in the seed and stover. In higher IW: CPE level owing to shorter interval of irrigation, soil moisture is maintained during most of the crop season which facilitates greater availability of K in soil solution resulting in higher K content. Clusterbean irrigated at an IW: CPE registered significantly higher nutrient uptake at 1.0 (87.8, 15.0 and 54.9 kg NPK/ha) and 0.8 (84.3, 14.3 and 52.7 kg NPK/ha) when compared to the 0.4 and 0.6 IW: CPE. Irrigation levels 1.0 and 0.8 IW: CPE increased N, P and K uptake by 43.9 and 38.2%, 40.8 and 34.8% and 32.5 and 27.0% respectively over 0.4 IW: CPE. This might be owing to availability of sufficient soil moisture that enhanced availability of nutrient to plant through high transpiration, as also reported by Sarkar *et al.* (2016). The higher N, P and K content in seed and stover coupled with greater biological yield might have resulted in more total N, P and K uptake by crop under 0.8 and 1.0 IW: CPE treatments over 0.4 IW: CPE. These findings are in agreement with those of Srinivasulu *et al.* (2015) in chickpea and Patel *et al.* (2011) in clusterbean.

Table 2. Effect of irrigation and fertility levels on nutrient content and their total uptake of summer clusterbean (pooled data of 2 years)

Treatment	Nutrient content (%)						Total nutrient uptake (kg/ha)		
	Nitrogen (N)		Phosphorus (P)		Potassium (K)		N	P	K
	Seed	Stover	Seed	Stover	Seed	Stover			
Irrigation levels (IW: CPE ratio)									
I_1, 0.4	3.55	1.00	0.528	0.215	1.407	1.132	61.0	10.7	41.4
I_2, 0.6	3.70	1.07	0.544	0.220	1.427	1.152	71.5	12.1	46.6
I_3, 0.8	3.89	1.13	0.580	0.230	1.455	1.171	84.3	14.3	52.7
I_4, 1.0	3.94	1.16	0.594	0.234	1.466	1.186	87.8	15.0	54.9
SEm±	0.04	0.02	0.006	0.002	0.010	0.008	1.5	0.3	1.2
CD (P=0.05)	0.13	0.05	0.019	0.007	0.030	0.025	4.7	0.8	3.6
Fertility levels (N : P_2O_5 kg/ha)									
F_1, 00:00	3.48	0.97	0.538	0.215	1.413	1.145	59.6	10.8	42.3
F_2, 10:20	3.76	1.08	0.556	0.221	1.437	1.162	74.4	12.6	48.0
F_3, 20:40	3.88	1.14	0.570	0.229	1.450	1.166	83.2	13.9	51.6
F_4, 30:60	3.96	1.17	0.582	0.234	1.455	1.168	87.3	14.6	53.6
SEm±	0.03	0.01	0.004	0.002	0.008	0.006	1.3	0.24	0.7
CD (P=0.05)	0.10	0.04	0.013	0.006	0.023	0.017	3.7	0.68	2.0

IW: CPE, Irrigation water: Cumulative pan evaporation

Significantly higher N, P and K content in seed and stover and total N, P and K uptake by crop were recorded with 30 : 60 kg N : P_2O_5/ha (87.3, 14.6 and 53.6 kg/ha respectively) over control. The increase in N, P and K content might be due to improved nutritional environment in the rhizosphere as well as in the plant system leading to enhanced translocation of nutrients in plant parts. Fertility levels 30 : 60 kg N : P_2O_5/ha and 20 : 40 kg N : P_2O_5/ha increased N, P and K uptake by 46.5 and 38.2%, 35.3 and 28.9%, and 26.6 and 21.9%, respectively over control. This increase could be attributed to influence of fertilizer application on remarkable increase in nutrient content (Table 2) and growth and yield attributes, which resulted in higher seed and stover yields (Table 1) and consecutively more total uptake of N, P and K by the crop. Pandey and Tiwari (2017) in pigeon pea-based intercropping system, Hiremath *et al.* (2016) in maize–chickpea system and Sammauria *et al.* (2009) in clusterbean also reported higher total uptake of N, P and K with the application of fertilizer.

Post-harvest soil nutrients status

The available P and K in soil after harvest of the crop were significantly increased by irrigation levels, while available N remained unaffected owing to different irrigation levels (Table 3). However, numerical decrease in available N was observed with the increase in irrigation frequency. Irrigating at 0.4 IW: CPE recorded significantly the highest available P (18.4 kg/ha) and K (286.2 kg/ha) in soil after harvest of the crop and remained at par with 0.6 IW: CPE ratio. It might be due to less availability of moisture, which reduced uptake of nutrient from soil by the plant. Due to this reason, nutrients remain unused in soil and so, available soil P and K were more. Significantly the lowest values for available P and K were recorded under 1.0 IW: CPE. It might be owing to higher seed and stover yields under these treatments, which removed greater amount of available P and K from soil. These results are in agreement with the results of Bana *et al*. (2016), Singh *et al.* (2017) and Patel *et al*. (2011).

The available N and P in soil after harvest of the crop increased significantly, while available K remained unaffected. Fertility level 30 : 60 kg N : P_2O_5/ha recorded significantly the highest available N (196.9 kg/ha) and P (18.3 kg/ha) in soil after harvest of the crop and remained at par with 20 : 40 kg N : P_2O_5/ha. The higher availability, of N and P in soil at higher fertility level might be due to application of higher dose of fertilizer in soil and uptake of nutrient might not have substantiated the availability, resulting in higher available N and P in soil. The numerical decrease in available K was observed with the increase in irrigation frequency and the maximum value of available K was recorded under control. Under the higher fertility level, uptake of K by the plant is more, which resulted in the reduction in the availability of K in soil. Singh *et al*. (2017) reported significant improvement in post-harvest soil fertility in elevated doses of fertilizer.

Moisture extraction pattern

Soil moisture extraction was recorded maximum between 0–30 cm soil depths and decreased with increase in depth of soil, being minimum at 45–60 cm depth (Table

Table 3. Effect of irrigation and fertility levels on available soil nutrients status after harvest and depth-wise moisture extraction pattern of summer clusterbean (pooled/mean data of 2 years)

Treatment	Soil available nutrients (kg/ha)			Depth-wise moisture extraction pattern (%)			
	N	P	K	0–15 cm	15–30 cm	30–45 cm	45–60 cm
Irrigation levels (IW: CPE ratio)							
I_1, 0.4	195.6	18.4	286.2	39.6 (39.6)	29.1 (68.7)	19.9 (88.6)	11.4 (100.0)
I_2, 0.6	191.5	17.8	278.2	41.5 (41.5)	30.4 (71.9)	18.8 (90.7)	09.3 (100.0)
I_3, 0.8	187.8	17.3	272.6	42.6 (42.6)	31.9 (74.5)	17.9 (92.4)	07.6 (100.0)
I_4, 1.0	187.1	17.2	271.4	43.8 (43.8)	32.2 (76.0)	17.0 (93.0)	07.0 (100.0)
SEm±	2.8	0.2	3.1	–	–	–	–
CD (P=0.05)	NS	0.6	9.5	–	–	–	–
Fertility levels (N:P_2O_5 kg/ha)							
F_1, 00:00	181.5	16.9	281.3	42.1 (42.1)	32.0 (74.1)	18.0 (92.1)	07.9 (100.0)
F_2, 10:20	188.3	17.3	278.2	41.8 (41.8)	31.0 (72.8)	19.2 (92.0)	08.0 (100.0)
F_3, 20:40	195.2	18.1	274.8	40.8 (40.8)	30.0 (70.8)	19.5 (90.3)	09.7 (100.0)
F_4, 30:60	196.9	18.3	274.1	39.8 (39.8)	28.5 (68.3)	20.6 (88.9)	11.1 (100.0)
SEm±	1.6	0.1	2.7	–	–	–	–
CD (P=0.05)	4.6	0.4	NS	–	–	–	–
Initial status	195.5	20.4	287.8	–	–	–	–

IW: CPE, Irrigation water: Cumulative pan evaporation; Data in parentheses indicates cumulative moisture extraction per cent up to that depth

3). Moisture extracted by the crop from top 0–30 cm and 0–45 cm depth in 0.4, 0.6, 0.8 and 1.0 IW: CPE treatments were 68.6, 71.9, 74.7 and 76.0% and 88.6, 90.7, 92.4 and 93.0%, respectively. This confirmed that the active root depth of clusterbean was confined up to 45 cm depth. The crop with less number of irrigations extracted more soil moisture from the deeper layers. It might be owing to scarce soil moisture in the upper layers of soil profile and it compelled the roots to go deeper into soil layer for utilization of water for their proper growth and development. Moisture extraction increased with increase in frequency of irrigation in first 0–30 cm depth and it progressively increased in deeper soil layer (45–60 cm depth) with decreased frequency of irrigation, which might be due to presence of root at deeper depth of soil profile. The higher amount of water uptake from surface layer might be due to increased surface evaporation, shallow root density and higher water uptake due to availability of irrigation water. The results are in complete agreement with Srinivasulu *et al*. (2015) in chickpea and Sarkar *et al*. (2017) in broad bean.

About 68.32% soil moisture was extracted from the top 30 cm of soil depth under 30 : 60 kg N : P_2O_5/ha, while it was 74% under control. This indicated that fertility levels had prominent effect on soil moisture extraction pattern. The crop with higher fertility level extracted more soil moisture from the deeper layers. It might be due to significant improvement in growth and yield attributes and ultimately higher seed and stover yields, which demand more water in transpiration process, resulting in deeper root growth for search of soil moisture. Moisture extraction decreased with increase in fertility levels in first 0-30 cm depth and it progressively decreased in deeper soil layer (45–60 cm depth) with decreased fertility levels, which might be due to presence of root at deeper depth of soil profile in higher level of fertility. Kumar *et al.* (2015) in maize + soybean intercropping system and Sarkar *et al.* (2017) in broad bean also reported higher soil moisture extraction from deeper soil layer under higher fertilizer application.

Based on the 2-years study, it can be inferred that clusterbean receiving irrigation at 0.8 IW: CPE with 5 cm irrigation water maintained its superiority throughout the growth period of the crop in various aspects. Among various fertilizer levels, fertilizer dose of 20 : 40 kg N : P_2O_5/ha could be applied for higher yield from cluster bean along with sustaining soil health in summers. Higher fertility level extracted more water from lower depth of rhizosphere than lower fertility levels, while lower irrigation levels extracted more water from upper depth over higher irrigation levels.

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