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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
Clusterbean (Cyamopsis tetragonoloba (L.) Taub.) growth indices, productivity, nutrient uptake, post-harvest soil nutrient status, and moisture extraction pattern were examined in a field experiment that took place in the summers of 2013 and 2014 at the Krishi Vigyan Kendra Farm of Junagadh Agricultural University on sandy loam soils. The experiment examined the effects of irrigation and fertility levels. The sixteen treatment combinations were examined using a split-plot design with three replications. The irrigation levels were 0.4, 0.6, 0.8, and 1.0 IW: CPE ratio, while the fertility levels were 00:00, 10:20, 20:40, and 30:60 kg N: P2O5/ha. In comparison to 0.4 IW: CPE, the combined results showed that 0.8 IW: CPE irrigation improved physiological growth parameters such as leaf area index (LAI), leaf: stem ratio, crop growth rate (CGR), relative growth rate (RGR), and net assimilation rate (NAR). Additionally, seed yield (1.33 t/ha), stover yield (2.84 t/ha), and harvest index (31.9%). At 1.0 IW: CPE, the total N intake by clusterbean was 87.8 kg/ha, P at 15.0 kg/ha, and K at 54.9 kg/ha, whereas at 0.4 IW: CPE, the maximum soil available N, P, and K levels were 195.6 kg/ha, 18.4 kg/ha, and 286.2 kg/ha, respectively. Under 1.0 IW: CPE, the maximum moisture extraction from the top soil profile was 43.78%, whereas under 0.4 IW: CPE, it was 11.4 %. The physiological growth parameters, including seed yield (1.32 t/ha), stover yield (2.78 t/ha), harvest index (32.2%), and total N, P, and K uptake by the crop (83.2%, 13.9 kg/ha, and 51.6 kg/ha, respectively) were all improved by applying 20:40 kg N:P2O5/ha, which was equivalent to 30:60 kg N:P2O5/ha. A significantly improved nutritional state after harvest was discovered with a ratio of 30:60 kg N:P2O5/ha (196.9, 18.3 and 274.1 kg N, P and K/ha respectively). Soil moisture depletion was highest in the control group (42.1%), lowest in the 30:60 kg N:P2O5/ha group (39.8%), and second lowest in the 20:40 kg N:P2O5/ha group (40.8%). But in the lowest 45-60 cm of soil, the pattern was the other way around. In order to increase clusterbean output and maintain soil health throughout the summer, an irrigation schedule of 0.8 IW: CPE and a fertilizer dosage of 20:40 kg N: P2O5/ha might be used.

Key words: Clusterbean, Fertility levels, Irrigation, Moisture extraction pattern, Nutrient uptake, Produc- tivity

Clusterbean is a significant legume crop grown in India that is resistant to drought. The high-quality gum found in the endosperm of this crop's seeds has given it a lot of attention recently. Clusterbean gum is in high demand on global markets because of its wide variety of applications in many different sectors, including those dealing with textiles, paper, explosives, mining, medicines, stamps, cosmetics, and food. Additionally, it is a crucial ingredient in poultry and live-stock feed. About 80% of the world's clusterbean seed comes from India, making it the biggest producer in the world. The states of Rajasthan, Gujarat, Haryana, Uttar Pradesh, and Punjab are known for their abundance of clusterbeans. Most of India's supply comes from the state of Rajasthan, which is a major producer. Clusterbean utilizes 5.35 million hectares of land in India, yielding 3.29 million tons at a productivity of 615 kg/ha (DES, 2016). India receives a substantial amount of foreign currency from its position as the top exporter of guar gum and seeds.

Clusterbean may have different water requirements according on the soil type and weather conditions. For this reason, when irrigation water is expensive and in short supply, water scheduling becomes crucial for harvesting a bumper crop of

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Indo-American Journal of Agricultural and Veterinary Sciences

summer clusterbeans. It is quite probable that agricultural output will be enhanced with irrigation scheduling informed by pan evaporation data.

from fifteen to twenty percent. In order to harvest the potential yield of field crops and make wise use of water, a more practical way is to employ the ratio of the fixed amount of irrigation water (IW) to the cumulative pan evaporation (CPE). Nitrogen is one of the many nutrients that determines the development of legumes, and it is also one of the most costly inputs. When applied to plants, it has the greatest and fastest impact on their development. The transformation of solar energy into chemical energy relies on phosphorus. Because of its central role in intensive agriculture and its role as the foundation of balanced fertilizer usage, low soil phosphorus concentration is worrisome. The production, content, and absorption of nitrogen and phosphorus by clusterbean were all significantly affected by these two nutrients (Sammauria et al., 2009). Clusterbean crops in Gujarat get 10–12 irrigations during the summer due to the irrigation intervals of 4-5 days. Using the IW: CPE technique, especially in summaries, helps decrease this need. There is a lack of data on this topic and nutrient control in the summer. Gaining maximum yield with little input of water and nutrients is an ideal situation. This is why we set out to investigate how different amounts of irrigation and fertility affected the summertime clusterbean crop in Gujarat's sandy loam soils in terms of yield, nutrient uptake, pattern of moisture extraction, and post-harvest soil nutrient status.

MATERIALS AND METHODS

In order to study the effect of irrigation and fertility levels on clusterbean, a field experiment was carried out at the Krishi Vigyan Kendra Farm of Junagadh Agricultural University in Nana Kandhasar, Surendranagar, Gujarat, during the summers of 2013 and 2014. The location was recorded as 22º45' N, 71º25' E, and the average elevation was 86.67 meters above sea level. The experimental location is in the agro-climatic North Saurashtra area of Gujarat. This area has hot, dry summers and a semi-arid, subtropical climate overall. The rainiest part of the year begins in the middle of June and continues all the way into September, with 500 mm of rain falling on average. Beginning in the middle of February and continuing until the middle of June, the summer season is in full swing. In the 2013 crop season, daily pan evaporation ranged from 4.8 to 11.7 mm/day, maximum temperature from 30.9 to 42.5 °C, and minimum temperature from 10.9 to 26.7 °C. In 2014, the temperature ranged from 27.6 to 43.0 °C, and daily pan evaporation was 5.2 to 12.2 mm/day. Unfortunately, the crop period did not get the off-season rains. A sandy loam including 78.3% sand, 8.4% silt, and 13.3% clay made up the experimental soil. It had a slightly alkaline response pH 7.95 and ECe.

33 microohms. Due to its low organic carbon content (4.0 g/kg) and accessible nitrogen level (195.5 kg/ha), medium phosphorus level (20.4 kg/ha), and high potassium level (287.8 kg/ha), it was moderately fertile.

One hundred and sixteen different treatment combinations 0.4, 0.6, 0.8, and 1.0 IW: CPE were used as primary plot treatments.

The split-plot design with three replications was used to examine four levels of fertility as sub-plot treatments: 00:00, 10:20, 20:40, and 30:60 kg N:P2O5/ha. When seeds were planted, diammonium phosphate and urea, according to the treatments, were drilled into the soil 5 cm below the seed.

On February 19th, 2013, and again on February 20th, 2014, the 'Gujarat guar-2' clusterbean variety was seeded with 20 kg seeds/ha at 45 cm row spacing. In order to promote improved germination and crop establishment, the crop was irrigated immediately after planting in both years, followed by a common irrigation one week later at a depth of 50 mm. Irrigation was then administered according to the treatment schedule, which was based on the ratio of irrigation water to cumulative pan evaporation (IW: CPE). A 7.5 cm neck size Parshall flume was erected in the main water channel at the field head to apply the measured amount of 50 mm irrigation water. It was irrigated3,5,7, and 9 times at a rate of 0.4.

with the exception of two common irrigations, 0.6, 0.8, and 1.0 IW: CPE, respectively. Both the 2013 and 2014 growing seasons recorded 690.9 and 660.9 mm of evapotranspiration, respectively.

To keep the plant-to-plant spacing inside the rows at 10 cm, the extra plants were trimmed off at 20 days after sowing (DAS). Two rounds of hand weeding were performed at 25 and 45 days after seeding (DAS), after which the pre-emergence herbicide pendimethalin 30 EC @ 0.5 kg/ha was applied. A leaf area meter was used to measure the dry-matter leaf area and area/plant for five representative plants (Systronics 211). The leaf-to-stem ratio and leaf area index (LAI) were determined at 60 days after seeding using a conventional equation. We used the method provided by Cheema et al. (1991) to determine the values of several agricultural growth indices, including crop growth rate (CGR), relative growth rate (RGR), and net assimilation rate (NAR) (1991). We used gravimetric data collected before and 48 hours after irrigation to calculate the soil moisture. The sum of the values for the depletion of accessible soil moisture up to a depth of 60 cm was used to determine the profile depletion (0–15, 15–30, 30-45, and 45–60 cm).

To get the Harvest Index (HI), the seed yield was divided by the biological yield. To get the stover yield, we subtracted the biological yield from the seed yield. Using a combination of colorimetry and the modified Kjeldahl technique, we were able to ascertain the nitrogen and phosphorus concentrations in the plant material examined.

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Vol. 11, Issue 3, 2023
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after tri-acid digestion, flame photometer. The product of the concentration of each nutrient and yield was used to determine the nutrient absorption by the crop. In both years, we took soil samples from each treatment at the beginning and end of clusterbean harvest, and we measured the available N, P, and K according to conventional techniques. The samples were taken from a depth of 0-15 cm. The data was statistically analyzed using the analysis of variance (ANOVA) approach for split-plot design at a significance level of 0.05.

RESULTS AND DISCUSSION

Measures of physiological development
The results showed that after 60 DAS, the ratio of leaves to stems and LAI were both improved with 1.0 IW: CPE (Table 1). A greater leaf-to-stem ratio and increased LAI are outcomes of physiological processes fostered by an adequate water supply. Srinivasulu et al. (2015) similarly found that chickpea LAI and the leaf-to-stem ratio increased with increasing irrigation levels. Crop growth indicators (CGR, RGR, and NAR) were significantly affected by fluctuations in irrigation levels. The CGR (7.02 g/m2/day), RGR (18.7 g/g/day × 10-3) and NAR (2.23 g/m2/day) were found to be significantly higher with an IW:CPE ratio of 0.8, and they were almost unchanged with a 1.0:CPE and 0.6:CPE ratio. At 60 DAS, greater CGR and RGR were attained by increased dry-matter production; meanwhile, higher NAR was attained through increased dry-matter production and LAI. When compared to the control and other treatments, 30:60 kg N:P2O5/ha produced the best leaf-to-stem ratio (0.28), and LAI (1.63).

per hectare of 20:40 kg N:P2O5 stayed the same. It is possible that the growth in leaf quantity, size, and succulency brought about by these treatments is responsible for the correlation between fertility levels and LAI and the leaf:stem ratio. According to the results, Srinivasulu et al. (2015) were right. At 45-60 DAS, the fertility level of 30:60 kg N:P2O5/ha showed, compared to the control, the greatest CGR (6.98 g/m2/day), RGR (18.3 g/g/day × 10-3) and NAR (2.19 g/m2/day). Due to their essential involvement in several biochemical and physiological processes, including as root formation, photosyn-thesis, and energy transfer, clusterbeans often exhibit improved physiological growth characteristics when fertilized at greater levels. These results are consistent with those of Rajput and Rajput (2017), who found that green gram crop growth indices were positively affected by important plant nutrients, particularly phosphorus.

Yield
In comparison to 0.4 and 0.6 IW: CPE, as well as 1.0 IW: CPE, the seed and stover yields from the 0.8 IW: CPE irrigation were much greater (Table 1). Seed yield increased by 26.67% and 12.71% with 0.8 IW: CPE compared to 0.4 and 0.6, respectively. Increased soil moisture and accelerated nutrient absorption may have contributed to the plant's optimal development, leading to better seed and stover yields with 0.8 and 1.0 IW: CPE, respectively. Srinivasulu et al. (2015) and Patel et al. (2014) observed an increase in stover and seed yields when 0.7 IW: CPE irrigation was used. 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

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Indo-American Journal of Agricultural and Veterinary Sciences

Rajanna et al. (2016) reported findings in clusterbean, while Sarkar et al. (2016) reported results in chickpea. For the remaining irrigation levels, the best harvest index was achieved at 0.8 IW: CPE. Due to changes in seed and stover yields as well as enhanced vegetative growth under frequent irrigations in 1.0 IW: CPE, the value of the harvest index might go up or down.

Fertility levels of 30:60 kg N:P2O5/ha significantly outperformed the control and maintained parity with 20:40 kg N:P2O5/ha, according to Table 1.

Produced at a fertility level of 30:60 kg N:P2O5/ha

most stover harvest relative to all lower fertility levels (Table 1). Under the 30:60 kg N:P2O5/ha treatment, seed and stalk yields increased by 28.06% and 21.64%, respectively, whereas under the 20:40 kg N:P2O5/ha treatment, they increased by 27.29% and 15.13%, above the control, respectively. This might be because the soil is more suitable for the crop's nutritional needs. Applying 20 kg N/ha improves french bean yield and profitability, according to Singh and Chaudhary (2016). The highest green gram yield was achieved by Stori et al. (2018) at the optimal phosphorus dosage. The maximum harvest index was maintained at 10:20 kg N:P2O5/ha and was restricted to 20:40 kg N:P2O5/ha. Clusterbean seed and stover yields, as well as increased vegetative development under greater fertility levels, are the factors that cause the harvest index value to alter. The harvest index dropped over a lower fertility level when the N:P2O5 ratio was 30:60 kg/ha. Sammauria et al. (2009) found similar outcomes, which are supported by these data.

Nutrient density and absorption

Results showed that at 0.8 IW: CPE, the total absorption of N, P, and K was statistically equivalent to those at 0.4 IW: CPE, while the maximum levels of N, P, and K content in seed and stover were seen at 1.0 IW: CPE. There is more nitrogen in the seed and stover when the moisture level is high because nutrients reach the root surface faster. When clusterbeans are watered early on in their development cycle, their root systems go deep into the soil, allowing them to draw nutrients from a greater volume of soil. This, in turn, raises the seed and stover P content. Due to shorter irrigation intervals, soil moisture is maintained for the majority of the crop season in areas with higher IW: CPE levels. This allows for better availability of K in the soil solution, leading to higher K content. 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) IW: CPE, clusterbean nutrient absorption was significantly greater than at 0.4 and 0.6 IW: CPE, respectively. The absorption of N, P, and K were enhanced by 43.9%, 38.2%, and 40.8 and 34.8%, respectively, above 0.4 IW: CPE, at irrigation levels 1.0 and 0.8 IW: CPE. As previously noted by Sarkar et al. (2016), this might be because there was an abundance of moisture in the soil, which increased the plant's capacity to absorb nutrients via transpiration. The increased biologi-cal yield and higher N, P, and K content in the seed and stover may have contributed to higher total N, P, and K absorption by the crop under 0.8 and 1.0 IW: CPE treatments compared to 0.4 IW: CPE. These results are in line with what Patel et al. (2011) found in clusterbean and what Srinivasulu et al. (2015) found in chickpea.

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

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Vol. 11, Issue 3, 2023

Indo-American Journal of Agricultural and Veterinary Sciences

With 30 : 60 kg N : P2O5/ha, there was a notable increase in the amount of nitrogen, phosphorus, and potassium in the seed and soil, as well as in the total amount of nitrogen, phosphorus, and potassium taken in by the crop, compared to the control. An better nutritional environment in the rhizosphere and the plant system may be responsible for the rise in N, P, and K content, which in turn may lead to greater translocation of nutrients in plant parts. The fertility levels are 30:60 kg N:P2O5/ha and 20:40 kg N:P2O5/ha, respectively.

improved nutrient uptake by 46.5%, 35.3%, and 28.9% above control, as well as by 26.6% and 21.9%, respectively. Fertilizer treatment probably had a role in the dramatic rise in nutrient content (Table 2) as well as growth and yield characteristics, leading to greater seed and stover yields (Table 1) and, therefore, more overall absorption of N, P, and K by the crop. Researchers 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 all found that fertilizer increased overall absorption of N, P, and K.

The condition of soil nutrients after harvest

Soil accessible P and K were both enhanced by varying degrees of irrigation following crop harvest, whereas available N was unaffected by these changes (Table 3). The available N did, however, drop numerically as irrigation frequency increased. After crop harvest, soils irrigated at 0.4 IW: CPE had the maximum accessible P (18.4 kg/ha) and K (286.2 kg/ha), which was comparable to soils irrigated at 0.6 IW: CPE. It might be because there is a shortage of moisture-

ture, which hindered the plant's ability to absorb nutrients from the soil. This means that a greater amount of accessible soil P and K is sitting unused in the soil. The available P and K values were significantly lowest under 1.0 IW: CPE. This could be because these treatments increased seed and stover yields, which in turn depleted the soil of more usable P and K. These findings corroborate those of Patel et al. (2011), Bana et al. (2016), and Singh et al. (2017). After crop harvest, soil accessible N and P levels rose sharply, while available K levels were unaffected. The fertility level of 30:60 kg N:P2O5/ha significantly outperformed 20:40 kg N:P2O5/ha in terms of accessible nitrogen (196.9 kg/ha) and phosphorus (18.3 kg/ha) in the soil after crop harvest. Soil N and P availability may be greater at higher fertility levels because more fertilizer is applied to the soil, and nutrient absorption may not have kept up with the increased availability. The highest value of available K was recorded under control, and its numerical drop was noticed as irrigation frequency increased. Soil potassium availability decreased as a consequence of increased plant K absorption at increasing fertility levels. Increased fertilizer dosages considerably improved soil fertility after harvest, according to Singh et al. (2017).

Pattern for extracting moisture

Between 0 and 30 centimeters below the surface, soil moisture extraction was at its highest, while between 45 and 60 centimeters below the surface, it was at its lowest. (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

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Vol. 11, Issue 3, 2023

Indo-American Journal of Agricultural and Veterinary Sciences

3). At 0.4, 0.6, 0.8, and 1.0 IW, the crop retrieved 68.6%, 71.9, 74.7, and 76.0% of the moisture from the top 0-30 cm and 0-45 cm depths, respectively. At 88.6, 90.7, 92.4, and 93.0% of the moisture, respectively, were CPE treatments. This proved that clusterbean roots could only grow up to a depth of 45 cm. The crop that required fewer irrigations was able to draw more water from the soil's deeper layers. The roots may have been forced to travel deeper into the soil in search of water in order to ensure adequate growth and development since there was insufficient moisture in the top layers of the soil profile. The presence of roots at deeper depths of the soil profile may explain why moisture extraction rose with increasing irrigation frequency in the first 0-30 cm depth and subsequently increased in the deeper soil layer (45-60 cm depth) with decreasing irrigation frequency. A combination of factors, including increased surface evaporation, shallow root density, and the availability of irrigation water, may explain the elevated surface layer water intake. Srinivasulu et al. (2015) for chickpea and Sarkar et al. (2017) for broad bean both find same outcomes.

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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