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Research Paper

Influence of irrigation and fertility levels on seed and gum yields, water-use, economics and quality of clusterbean (*Cyamopsis tetragonoloba*) in Gujarat

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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, Nana Kandhasar, Surendranagar, Gujarat, on sandy loam soils to assess the impact of irrigation and fertility levels on growth, yield, water-use, economics and quality of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. Sixteen treatment combinations of 4 irrigation levels [0.4, 0.6, 0.8 and 1.0 irrigation water: cumulative pan evaporation ratio (IW: CPE) 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 three replications. The pooled results indicated that irrigation at 0.8 IW: CPE being at par with 1.0 IW: CPE enhanced growth parameters and yield attributes and thereby seed yield (1.33 t/ha), stover yield (2.84 t/ha) and harvest index (31.9%) with the highest net returns (₹53,895/ha) and benefit: cost ratio of 2.29 over 0.4 IW: CPE. The maximum consumptive use of water was noticed under 1.0 IW: CPE, while the maximum water-use efficiency (WUE) (4.90 kg/ha-mm) and water-expense efficiency (WEE) (4.19 kg/ha-mm) were recorded under 0.4 IW: CPE. Significantly higher protein content (24.3%), protein yield (325 kg/ha), gum content (29.3%) and gum yield (391 kg/ha) were recorded under 0.8 IW: CPE over 0.4 and 0.6 IW: CPE. Application of 20:40 kg N:P_2O_5/ha being at par with 30:60 kg N:P_2O_5/ha also improved growth parameters, yield attributes, seed yield, stover yield, harvest index with the highest net returns (₹52,967/ha) and benefit: cost ratio of 2.24 along with consumptive use of water, WUE, WEE, protein content, protein yield, gum content and gum yield than control. Therefore, irrigation at 0.8 IW: CPE and fertilizer dose of 20:40 kg N:P_2O_5/ha could be applied for higher yield and monetary returns from clusterbean (gumguar) along with appreciable saving of water and fertilizer in summer season.

Key words : Clusterbean, Fertility levels, Gum yield, Irrigation, Protein content, Water-use efficiency

Clusterbean commonly known as *guar* 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 market. It is principally used as a feed for livestock and poultry. India is the largest producer of seed and clusterbean gum in the world with 80% share to total production. In India, clusterbean occupies an area of 5.15 million ha mainly in the states of Rajasthan, Gujarat, Haryana, Uttar Pradesh and Punjab producing 2.46 million tonnes with productivity of 478 kg/ha (DES, 2013). Rajasthan is a leading producer of it accounting for about 70% of all India's output. India is the leading exporter of guar seeds and gum and earn significant foreign-exchange.

Water need of clusterbean may vary with the climatic conditions and type of soil. Hence, scheduling of irrigation at an appropriate time and in right amount is one of the most important factors for realizing high yield of summer clusterbean, especially under scarce and costly irrigation water. Scientific scheduling of irrigation is a technique for determining the quantity of irrigation water, which also aims at optimizing crop yield with maximum water-use efficiency (WUE) and ensures minimum deterioration of the soil and crop. Scheduling of irrigation based on data of pan evaporation is likely to increase agricultural production 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 po-

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tential 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 P is the backbone of balanced fertilizer use and it occupies a key place in intensive agriculture. Phosphorus also showed significant influence on yield, protein, gum content and uptake of P by clusterbean (Bhadoria *et al*., 1997). Keeping these points in view, an attempt was made to study the influence of irrigation and fertility levels on growth, yield, water-use, economics and quality of clusterbean in summer season under Saurashtra region 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 under Gujarat plains and hills zone of India. The climate of this region is semi-arid and sub-tropical 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. July and August are the peak months of rainfall. Partial failures of monsoon once in three to four years are common occurrence in this region. Summer season commences in the second fortnight of February and ends in the middle of June. April and May are the hottest months of summer with the mean maximum temperature ranging from 36ºC to 44ºC. During crop season of the year 2013, the minimum temperature ranged from 15ºC 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 temperature ranged from 27.6ºC to 43.0ºC and daily pan evaporation ranged from 5.2 to 12.2 mm/day. The weather parameters, viz. mean relative humidity, wind velocity and sunshine hours were normal during both the years of experiment period. The off season rainfall was not received during the crop period. In general, the weather conditions were congenial during crop season of both the years. The experimental site had an even topography with a gentle slope and good drainage. The experimental soil was sandy loam (78.29% sand, 8.41% silt and 13.30% 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 (44.3 kg/ha) and high in available potassium (287.8 kg/ha). The soil moisture content at field capacity and permanent wilting point in the upper 30 cm were 15.58 and 6.09% respectively. Besides, initial bulk densities of the soil were 1.41, 1.44, 1.47 and 1.49 Mg/m^3 in 0–15, 15–30, 30–45 and 45–60 cm depth respectively.

The sixteen treatment combinations consisted of four levels of irrigation (0.4, 0.6, 0.8 and 1.0 IW: CPE) as a main-plots treatments and four levels of fertility (00:00, 10:20, 20:40 and 30:60 kg N:P_2O_5/ha) as sub-plots treatments were evaluated using split-plot design with 3 replications. The field plots of size 5.0 m × 3.6 m were separated from each other by using 1 m buffer rows. The quantity of fertilizer was drilled in the soils at 5 cm below the seed according to fertilizer treatments as a basal dose in form of diammonium phosphate and urea. 'Gujarat guar 2' variety was selected for the present investigation, as it is more popular in this region. It has attractive seed colour and good shape. It produces about 30% gum from its seeds. The seeds were sown keeping 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. Thereafter, irrigation was given as per treatment schedule based on irrigation water: cumulative pan evaporation ratio (IW: CPE). The excess plants were thinned out at 20 days after sowing (DAS) keeping within row distance at 10 cm for maintaining uniform plant stand. The required cultural practices and plant protection measures were followed as per recommended package. Weeds were managed by pre-emergence herbicide pendimethalin 30 EC @ 0.5 kg/ha on next day of the sowing followed by two weeding at 25 and 45 DAS and an intercultural operation with hand hoe at 25 DAS.

The quantity of irrigation water applied in each experimental plot was measured with a 7.5 cm throat size Parshall flume installed in the main water channel near the field head. The cumulative pan evaporation (CPE) values were calculated from daily pan evaporation measured with the help of USWB Class 'A' open pan evaporimeter installed at the meteorological observatory of the farm. Irrigations were applied as per treatment on the basis of IW : CPE approach using 50 mm depth of irrigation water. Time for applying the measured quantity of irrigation water to each plot was calculated using the standard equation.

The soil moisture studies were started from sowing of crop and continued up to its maturity. The soil moisture content of all the treatments was determined on same day just before irrigation and 48 hours after irrigation at 0–15, 15–30, 30–45 and 45–60 cm soil depth. The data obtained on moisture percentage in each depth were used for calculating seasonal consumptive use of water for clusterbean. The depth of water table was more than twenty meters below the surface throughout the period of experimentation. The consumptive-use of water (CUW) was determined by using the formula as described by Mishra and Ahmed (1987). Water-use efficiency (WUE) was calculated by dividing per hectare seed yield of clusterbean obtained under various treatment with the total consumptive use of water of the respective treatment and water-expense efficiency (WEE) by dividing per hectare seed yield of clusterbean obtained under various treatment with the total quantity of irrigation water applied to the respective treatment. The total number of irrigations required were 3, 5, 7 and 9 in 0.4, 0.6, 0.8 and 1.0 IW : CPE, respectively excluding the common 2 irrigations provided each for sowing and better establishment during both the years of experiment. The evapotranspiration observed during growing seasons of 2013 and 2014 were 690.9 and 660.9 mm respectively. The crop was harvested on 20 and 21 May during 2013 and 2014, respectively.

The plant height and branches/plant were recorded from five selected plant at harvest from each plot. Penultimate rows of each plot were used for recording observations, viz. number and dry weight of root nodules/plant, dry matter accumulation and leaf area index (LAI) at 60 DAS. For dry-matter accumulation, plant material first air dried, then chopped and oven dried at 70ºC for 72 hrs to a constant weight. For LAI, 5 representative plants were selected in penultimate rows, leaf area of all the leaves was calculated with the help of leaf area meter (Systronics 211). Days to 50% flowering was recorded with 50% plants were found by manual counting of plant row by row at flowering stage. The yield attributes, viz. pods/plant, seeds/pod, pod length, 1,000-seed weight and shelling per cent were recorded at the time of harvesting. The crop was harvested manually with the help of sickle when seed almost matured and stover had turned yellow. The sun dried bundles were threshed and winnowed and seed so obtained were weighed and data on seed and stover yields were recorded. Harvest Index (HI) was calculated by dividing the seed yield with biological yield. The per cent protein content in seed of each plot was worked out by multiplying the nitrogen content in seed with conversion factor 6.25 (AOAC, 1960). For estimation of gum content the procedure given by Das *et al.* (1977) was used. Protein yield and gum yield were calculated by multiplying the protein content and gum content, respectively with seed yield. The economics of the treatments was carried out on the basis of prevailing market prices of inputs and outputs. Gross returns were calculated based on the seed and stover yields of the crop and their prevailing market prices during the respective crop seasons. Net returns were calculated by subtracting cost of cultivation from gross returns. The benefit: cost ratio was calculated by dividing the net returns with cost of cultivation. 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

Growth parameters

Significantly higher plant height at 60 days after sowing (DAS) and at harvest and branches/plant was recorded at an IW: CPE of 1.0 over IW: CPE of 0.4 and 0.6, but it was found at par with IW: CPE of 0.8 (Table 1). The increase in the plant height and branches/plant might be due to optimum supply of soil moisture surrounding the root zone, which cause favourable improvement in the uptake and translocation of the nutrients and ultimately linked with the plant growth and development in terms of plant height. Increased plant height and branches/plant with increasing level of irrigation was also reported by Patel *et al.* (2011). Application of irrigation at an IW: CPE of 1.0 recorded significantly higher number of root nodules and dry weight/plant over IW: CPE of 0.4 and 0.6 but remained at par with 0.8 IW: CPE, owing to early establishment of effective *Rhizobium* host symbiosis due to early irrigation. Improved growth in terms of leaf area index (LAI) and dry-matter accumulation at 60 DAS was attained with higher IW: CPE of 1.0 and 0.8. As water is not a limiting factor, plant can absorb more nutrients from soil, which encourages physiological processes such as cell division and cell expansion. Hence leaves/plant increased and ultimately it reflected in higher LAI. The dry-matter is a cumulative effect of all growth parameters like plant height, number of branches, LAI etc. which were significantly more in 1.0 and 0.8 IW: CPE, the resultant dry matter also more. Similar increase in dry matter accumulation with higher level of irrigation was also reported by Shrinivasulu *et al.* (2015) in chickpea. Higher level of irrigation recorded significantly more days to 50% flowering than lower level of irrigation, could be owing to maintaining its progeny with the available resources.

Fertility levels had also significant effect on plant height, number of branches at harvest and LAI. The higher plant height and leaf area index were recorded under 30:60 kg $N:P_2O_5$/ha and remained at par with 20:40 kg $N:P_2O_5$/ha, while the highest branches/plant was recorded under 20:40 kg $N:P_2O_5$/ha and remained at par with 30:60 and 10:20 kg $N:P_2O_5$/ha (Table 1). The increase in these components seems to have been brought about by increase in amount of growth substances and naturally occurring phyto hormones with increased nitrogen supply. Probably

Table 1. Effect of irrigation and fertility levels on growth parameters, yield attributes and yield of summer clusterbean (pooled data of 2 years)

Treatment	Plant height (cm)	Branches plant	Root nodules/ plant	Dry weight of root nodules/ plant (mg)	Dry-matter accum-ulation/ plant (g)	Leaf-area index at 60 DAS	Days to 50% flowering	Pods/ plant	Seeds/ pod	Pod length (cm)	1,000 seed weight (g)	Shelling (%)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
Irrigation levels (IW: CPE ratio)															
I_1, 0.4	52.1	6.13	19.16	69.02	8.8	1.46	42.1	47.7	6.3	5.36	30.3	52.9	1.05	2.36	30.8
I_2, 0.6	56.1	6.33	21.09	76.08	10.2	1.56	43.9	52.2	6.4	5.65	31.0	54.2	1.18	2.57	31.4
I_3, 0.8	58.6	6.74	22.09	79.74	11.1	1.62	46.6	56.8	6.8	5.95	31.6	56.4	1.33	2.84	31.9
I_4, 1.0	61.2	7.00	22.67	82.08	11.3	1.64	47.9	58.4	7.0	6.00	31.7	58.6	1.34	2.97	31.2
SEm±	0.9	0.10	0.44	1.57	0.2	0.02	0.5	0.8	0.1	0.10	0.2	0.9	0.03	0.06	0.1
CD (P=0.05)	2.8	0.30	1.35	4.84	0.6	0.06	1.5	2.6	0.3	0.30	0.6	2.8	0.08	0.18	0.2
Fertility levels ($N:P_2O_5$ kg/ha)															
F_1, 00:00	52.50	6.27	19.59	70.84	9.03	1.47	44.0	46.8	6.4	5.44	30.6	53.4	1.04	2.41	30.1
F_2, 10:20	56.58	6.52	21.15	76.36	10.25	1.55	44.7	54.1	6.6	5.72	31.1	54.9	1.22	2.62	31.8
F_3, 20:40	58.79	6.78	21.98	79.28	10.93	1.62	45.8	56.9	6.7	5.90	31.4	56.6	1.32	2.78	32.2
F_4, 30:60	60.10	6.64	22.30	80.44	11.12	1.63	46.1	57.4	6.7	5.89	31.5	57.2	1.33	2.93	31.2
SEm±	0.67	0.07	0.30	1.03	0.14	0.02	0.4	0.6	0.1	0.06	0.1	0.7	0.02	0.04	0.2
CD (P=0.05)	1.92	0.21	0.86	2.94	0.41	0.05	1.2	1.8	0.2	0.18	0.3	1.9	0.06	0.12	1.0

IW: CPE, Irrigation water: Cumulative pan evaporation; DAS, days after sowing

the increase in auxin supply with higher levels of nitrogen brought about increase in the branches/plant. Anuradha *et al.* (2017) observed that increased availability of nitrogen on poor soil might have increased cell numbers and cell size leading to better growth in terms of plant height and branches/plant. The number and dry weight of root nodules/plant were significantly increased with increase the level of fertility over control. The increase in number of root nodules/plant might be owing to better root development with increasing level of fertility. Phosphorus plays a key role in the symbiotic N-fixation process by increasing top and root growth and decreasing the time needed for developing nodules to become active (Gangwar and Dubey, 2012). Application of fertilizer at 30:60 kg $N:P_2O_5$/ha recorded significantly higher dry matter/plant at 60 DAS and remained at par with 20:40 kg $N:P_2O_5$/ha. Nitrogen is a constituent of chlorophyll, it harnesses solar energy and fixes atmospheric CO_2 as carbohydrates and amino acids. Thus, nitrogen application increased dry matter production (Meena, 2013). Higher level of fertilizer recorded the maximum days to 50% flowering whereas, the least days to 50% flowering was registered under control treatment.

Yield attributes

Increasing frequency of irrigation from 0.4 to 0.8 IW: CPE significantly increased the yield attributing characters, viz. pods/plant, seeds/pod and pod length, 1,000-seed weight and shelling per cent (Table 1) but remained at par with IW: CPE of 1.0. The higher pods/plant observed under 0.8 and IW: CPE of 1.0 might be due to increase in number of irrigations applied at shorter intervals. This situation avoids moisture stress and provided a favorable condition for moisture and nutrient availability to the crop. Similar findings were reported by Patel (2009) in frenchbean. Significantly the highest number of seeds/pod, pod length, 1,000-seed weight and shelling per cent was recorded with IW: CPE of 1.0 and remained at par with 0.8 IW: CPE. The availability of adequate moisture with 0.8 and 1.0 IW: CPE might be resulted in better translocation and partitioning of these photosynthates from source to sink and increased the seeds/pod, pod length and thus 1,000-seed weight. Patel *et al.* (2014) also observed increased in yield attributes with higher irrigation over lower one in clusterbean.

Significantly higher values of yield attributes, viz. pods/plant, 1,000-seed weight and shelling per cent were registered under 30:60 kg $N:P_2O_5$/ha, which remained statistically at par with 20:40 kg $N:P_2O_5$/ha, while seeds/pod and pod length were registered higher under 20:40 kg N:P_2O_5/ha, which remained statistically at par with 30:60 kg N:P_2O_5/ ha and 10:20 kg N:P_2O_5/ha (Table 1). Better growth under 20:40 and 30:60 kg N:P_2O_5/ha might have produced and converted more photosynthates into numerous metabolites needed for such yield attributes. Chhipa *et al*. (2012) found that the increase in 1,000-seed weight for higher fertility level is due to the better filling of seeds, which resulted in bold sized seeds and consequently higher 1,000-seed weight. Chavan *et al.* (2015) reported increased in yield attributes with 25:50:50 kg N:P_2O_5: K_2O/ha over control in clusterbean.

Yield

The result with respect to seeds and stover yields indicated that irrigation level had appreciably influenced the seed and stover yields of clusterbean. 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 IW: CPE of 1.0. The increase in seed yield under 0.8 IW: CPE over 0.4 and 0.6 was 26.67 and 12.71%, while that of stover was 20.34 and 10.51% 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 nutrients uptake, which helped the plant to put optimum growth. Increase in seed and stover yields with an application of irrigation at 0.7 IW: CPE was also reported by Patel *et al*. (2014) and Shrinivasulu *et al.* (2015). Significantly 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 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. The fertility level 30:60 kg N:P_2O_5/ha produced significantly 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 the 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 beneficial for enhancing productivity and profitability of frenchbean. Significantly 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).

Soil moisture studies

Consumptive-use of water (CUW) increased with increase in IW: CPE from 0.4 to 1.0 (Table 2). The extent of increase in CUW by 1.0 and 0.8 IW: CPE over 0.4 IW: CPE was to the tune of 47.47 and 38.48% respectively. This increase in CUW with more number of irrigations might be due to more availability of water for evapotrans-

Table 2. Effect of irrigation and fertility levels on water-use, economics and quality of summer clusterbean (pooled data of 2 years)

Treatments	Total water applied (mm)	Consumptive use of water (mm)	Water-use efficiency (kg/ha-mm)	Water-expense efficiency (kg/ha-mm)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio	Protein content (%)	Protein yield (kg/ha)	Gum content (%)	Gum yield (kg/ha)
Irrigation levels (IW: CPE ratio)											
I_1, 0.4	250	214	4.90	4.19	61.2	39.9	1.90	22.2	233	26.5	278
I_2, 0.6	350	255	4.64	3.37	68.8	46.2	2.08	23.1	273	28.2	333
I_3, 0.8	450	296	4.50	2.96	77.8	53.9	2.29	24.3	325	29.3	391
I_4, 1.0	550	315	4.26	2.44	78.6	53.4	2.15	24.7	332	30.6	412
SEm±	-	5	0.13	0.07	1.6	1.6	0.07	0.3	6	0.33	9
CD (P=0.05)	-	15	0.41	0.22	4.9	4.9	0.22	0.8	17	1.01	27
Fertility levels (N:P_2O_5 kg/ha)											
F_1, 00–00	400	255	4.12	2.75	60.7	39.6	1.91	21.7	226	27.7	289
F_2, 10–20	400	268	4.61	3.24	71.1	48.4	2.17	23.5	287	28.2	345
F_3, 20–40	400	278	4.78	3.48	76.9	53.0	2.24	24.3	322	28.8	383
F_4, 30–60	400	279	4.79	3.50	77.5	52.4	2.10	24.8	330	29.8	398
SEm±	-	3	0.07	0.05	1.1	1.1	0.05	0.2	5	0.15	6
CD (P=0.05)	-	8	0.21	0.14	3.2	3.2	0.14	0.6	14	0.43	17

IW: CPE, Irrigation water: Cumulative pan evaporation; DAS, days after sowing piration. Unlike CUW the water-use efficiency (WUE) and water-expense efficiency (WEE) decreased with increasing number of irrigations from 0.4 to 1.0 IW: CPE. Crop irrigated at an IW: CPE of 1.0 reduced the WUE and WEE by 15.0 and 71.7% over 0.4 IW: CPE, respectively. Frequent wetting of the upper surface layer exposed to the hot atmosphere in 1.0 IW: CPE created a higher vapour pressure gradient between the crop canopy and atmosphere, which might have caused relatively larger loss of water from the soil surface which resulted in lower WUE and WEE. The higher WUE and WEE under lower IW: CPE might be due to lesser water loss in evapotranspiration under limited water supply condition. Similar results have been reported by Patel *et al.* (2011).

Application of higher quantity of fertilizer increased the CUW, WUE and WEE markedly (Table 2). The maximum CUW, WUE and WEE were recorded with higher fertility level 30:60 kg N: P_2O_5/ha over 00:00 and 10:20 kg N:P_2O_5/ha, which remained statistically at par with 20:40 kg N: P_2O_5/ha. The extent of increase in CUW by 30:60 and 20:40 kg N:P_2O_5/ha over 00:00 kg N:P_2O_5/ha was to the tune of 9.67 and 9.09% respectively. The increased CUW under higher level of fertility is mainly due to significant improvement in growth parameters, which demand more water in transpiration process. Crop fertilized at 30–60 kg N:P_2O_5/ha increased WUE and WEE to an extent of 16.3 and 27.3% over control respectively. Patel *et al.* (2014) found that under adequate nutrient availability, every drop of water utilized properly because of better crop canopy and higher rate of photosynthesis, which resulted in high seed yield.

Economics

The results pertaining to the cost: benefit analysis of the crop as influenced by irrigation levels indicated that application of irrigation at 0.8 IW: CPE recorded the highest net returns (₹53,895/ha) with the maximum benefit: cost ratio of 2.29, whereas irrigating at an IW: CPE of 1.0 recorded the highest gross returns. The higher net returns/ha under 0.8 IW: CPE could be attributed to significantly higher seed yield as compared to 0.4 IW: CPE and saving of extra cost of irrigation as compared to 1.0 IW: CPE. Fertility level 20:40 kg N:P_2O_5/ha recorded the highest net returns of ₹52967/ha with the highest benefit: cost ratio of 2.24, while the highest gross returns was observed with 30:60 kg N:P_2O_5/ha. The higher net gain/ha under 20:40 kg N:P_2O_5/ha could be attributed to significantly higher seed yield as compared to control and saving of extra cost of fertilizer as compared to 30:60 kg N:P_2O_5/ha. The results are in concurrence with those reported by Patel *et al*. (2014).

Quality parameters

Significantly the highest protein content, protein yield, gum content and gum yield were recorded under IW: CPE of 1.0 and except gum content these were at par with 0.8 IW: CPE (Table 2). Application of irrigation at an IW: CPE of 1.0 and 0.8, increased protein yield by 42.5 and 39.5% and gum yield by 48.2 and 40.6% respectively over 0.4 IW: CPE. The lower value of gum content in 0.4 IW: CPE could be owing to moisture stress condition, which leads to decrease in the activity of glutamine and glutamate synthesis and increase in the proline content, which ultimately reduce the gum synthesis in guar seeds. The significant increase in seed yield and gum content was directly responsible for higher gum yield. Patel *et al.* (2011) also recorded higher protein and gum yield with increasing level of irrigation.

Significantly the highest protein content, protein yield, gum content and gum yield were recorded with 30:60 kg N:P_2O_5/ha, which remained at par with 20:40 kg N:P_2O_5/ha except gum content. Fertility levels 30:60 kg N:P_2O_5/ha and 20:40 kg N:P_2O_5/ha increased protein yield by 46.0 and 42.5% and gum yield by 37.7 and 32.5% respectively over control. Chhipa *et al.* (2012) reported that higher level of fertility increased protein content of clusterbean. Gum content might be increased due to fat and carbohydrate synthesis in seeds by the increasing levels of phosphorus, which enhanced the biosynthesis of phospholipids and nucleic acids. A remarkable increase in seed yield and gum content with higher fertility levels over control was directly responsible for higher gum yield. Rathore *et al.* (2007) reported that application of 20 kg N and 40 kg P_2O_5 produced 59.3% higher gum yield over control.

Based on the study it is concluded that summer clusterbean sown in sandy loam soils of Gujarat region with 0.8 IW: CPE recorded the higher seed yield and gained the highest net returns and benefit: cost ratio over all the irrigation treatments. Fertility level 20:40 kg N:P_2O_5/ha seems to be optimum for getting higher seed yield and monetary returns. Therefore, irrigation at 0.8 IW: CPE and fertilizer dose of 20:40 kg N:P_2O_5/ha could be applied for higher yield and economical realization from clusterbean along with appreciable saving of water and fertilizer in summer season.

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