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Leaf area index, productivity and water use pattern of summer clusterbean influenced by different irrigation scheduling and growth regulators

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Abstract
A field experiment was conducted during summer season of the year 2009 at Anand Gujarat to study the different irrigation scheduling and growth regulators" with sixteen treatment combinations consisting of four levels of irrigation schedules (IW: CPE ratios) viz., I_0 – Control- Critical growth stages, I_1 – 0.6 IW: CPE ratio, I_2 – 0.8 IW: CPE ratio, I_3 – 1.0 IW: CPE ratio as a main plot treatments and four plant growth regulators viz., GR_0 – Control- water spray, GR_1 – NAA @ 100 ppm at 30 and 60 DAS, GR_2 – GA_3 @ 40 ppm at 30 and 60 DAS, and GR_3 - AA @ 25 ppm at 30 and 60 DAS were relegated in sub plot as sub plot treatments tested under split plot design with four replications. The leaf area index was significantly influenced by irrigation scheduling and growth regulators. The leaf area index at 20, 40 DAS and at harvest (44.56, 93.90 and 175.64 respectively) were significantly higher when irrigation was applied at 1.0 IW: CPE ratio (I3) and when growth regulators study significantly affect the leaf area index at similar stages higher under treatment GR_1 (NAA @ 100 ppm at 30 and 60 DAS). The treatment combination I_3GR_1 (1.0 IW: CPE ratio along with application of NAA @ 100 ppm at 30 and 60 DAS) produced significantly the highest leaf area index at 40 DAS and at harvest 113.87 and 195.31. Lower leaf area index was observed under treatment combination I_0GR_0 (control- irrigation as per recommendation along with water spray). The maximum water use pattern was noticed under treatment I_3 (1.0 IW: CPE ratio) and minimum was also recorded with lower IW: CPE 1.0 ratio. When the growth regulators are application, Higher water use pattern were also recorded under treatment GR_1 (NAA @ 100 ppm at 30 and 60 DAS) and minimum with control as water spray. But the highest water expense efficiency (81.78 kg/ha-mm) was recorded under treatment I_0 (Control), followed by I_1 (0.6 IW: CPE ratio, 48.47 Kg/ha-mm) and I_2 (0.8 IW: CPE ratio, 37.16 kg/ha-mm). The lowest water expense efficiency (35.42 Kg/ha-mm) was observed under treatment I_3 (1.0 IW: CPE ratio).

Keywords: Interaction of leaf area index, productivity, water use pattern, Irrigation scheduling and growth regulators

Introduction
Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub. (Syn. *C. psoraliodes*)], all and bushy annual herb have a deep rooted system, is a resilient and drought resilient leguminous crop grown on sandy soils of arid and semi-arid regions (Gillete 1958) [7]. It has been established as a high-valued cash crop in the arid and semi-arid regions due to its drought hardiness and multitude of usage and has occupied a special place in the commercial scene because of its gum. It is cultivated mainly in the rainy season and major producing states in India are Rajasthan, Haryana, Gujarat, Punjab and to a limited extent in Uttar Pradesh and Madhya Pradesh (Deewan *et al.,* 2017) [4].

The various production factors viz. spacing, seed rate, sowing time, dose of fertilizers, methods and time of fertilizer application, irrigation, use of plant growth regulator etc. play an important role in the maximization of green pod of clusterbean production per unit area. Among the various factors of production, irrigation schedules (IW: CPE ratio) and use of different growth regulators play pivotal role in increasing the clusterbean production. Water is the basic input for increasing crop production. Agricultural Productivity cannot be maintained without assured supply of moisture to the plant, which is accomplished by irrigation. Climatologically approach based on the ratio between irrigation water and cumulative pan evaporation was found the most appropriative approach, as it integrates all the weather parameters giving them their natural weightage in given soil water plant continuum.

Scheduling of irrigation based on the data of the pan evaporation is likely to increase agricultural production at least to the tunes of 15-20 percent (Dastane, 1972) [3]. Among various strategies employed to increase crop yield, use of plant growth regulators have great promise due to modified crop growth by changing the rate or pattern of growth or both (Nickell, 1982) [12]. Plant growth regulators are known to influence the growth and development of plants and ultimately the yield and yield attributing characters. Senescence in the plant is complex phenomenon, which is influence by environmental condition and endogenous plant hormones. Senescence can be regulated by exogenous hormones application (Osborne *et al.* 1982) [13].
The use plant of growth regulators can improve the physiological efficiencies of plant and offer a sufficient role in increasing crop yield. Their use in many crops has been reported to delay senescence of leaves and to retard the abscission of reproductive organ (Fletcher and Adedipe, 1970) [6]. Further they also known to increase flowering, fruiting and grain filling (Ries *et al.* 1978) [19]. The application of gibberellins increase germination, stimulation of rooting, leaf expansion, leaves become broader and elongated, increase flowering and fruit setting, the most important effect of GA_3 (Gibbrellic Acid) is the stem elongation. Gibberellins have found great use in increase stalk length and production, breaking dormancy, inducing uniform crop emergence, producing staminate flowers, increase fruit size, quickening of maturity, improve quality. Application of NAA (Naphthalene acetic acid) is effective in weed control and used to induce the rooting of cutting of woody plants, to increase flowering and improve fruit-setting. Information regarding this aspect is scarce; hence, this experiment was conducted at Anand, Gujarat during summer season on clusterbean.

Methods and Material

A field experiment was conducted during summer season of the year 2009 at College Agronomy Farm, B. A. college of Agriculture, Anand Agricultural University, Anand Gujarat to study the "Interaction of Leaf Area Index, Productivity and Water Use Pattern of Summer Clusterbean influenced by Different Irrigation Scheduling and Growth Regulators". Sixteen treatment combinations consisting of four levels of irrigation schedules (IW: CPE ratios) viz., I_0 – Control-Critical growth stages, I_1 – 0.6 IW: CPE ratio, I_2 – 0.8 IW: CPE ratio, I_3 – 1.0 IW: CPE ratio as a main plot treatments and four plant growth regulators viz., GR_0 – Control- water spray, GR_1 – NAA @ 100 ppm at 30 and 60 DAS, GR_2 – GA3 @ 40 ppm at 30 and 60 DAS, and GR_3 - AA @ 25 ppm at 30 and 60 DAS were relegated in sub plot as sub plot treatments tested under split plot design with four replications. Each experimental unit had 2.70 m X 5.00 m gross plot and 1.50 m X 4.00 m net plot. The cluster bean crop variety "*Pusa Navbahar"* was sown with prior treatment with *Rhizobium* culture 'pv movable' @ 400 gm/20 kg seeds. It was dry sown at 30 cm row to row and 10 cm plant to plant distance. As sowing was performed under dry condition and the seeds were covered with the soil by manually. The crop was fertilized with 20 kg N and 40 kg P2O5 per hectare from DAP and urea as basal application. Soil physical constant viz. field capacity, permanent wilting point and bulk density were determined for experiment at site up to 60 cm depth. The values are presented in the Table-1. The weather conditions were favourable for normal crop growth of summer clusterbean during the crop season. The different irrigation treatments (IW: CPE ratios) were imposed after establishment of the crop with the help of 7.5 parshall flume. The application of different plant growth regulators were sprayed as per treatment. The periodical observations on leaf area index, productivity and water use pattern studied under summer Clusterbean in middle Gujarat conditions. The productivity at harvest in kg per hacter calculated on the basis of per plot. The leaf area indexes were recorded from the selected and tagged five plants in each plot at 20, 40 DAS and at harvest. The leaf area index was worked out by dividing the average leaf area per plant with land area i.e. spacing, using formula suggested by Hunt (1982) [9]. It is calculated as per the following formula.

$$\mathrm{LAI} = \frac{\text{Leaf area per plant (cm}^2)}{\text{Ground area per plant (cm}^2)}$$

Soil Moisture Studies: The soil moisture studies were started right from sowing of crop and continued up to its maturity. The soil moisture constant of all the treatments in one replication was determined on same day just before irrigation and 48 hours after irrigation at 0-15, 15-30 and 30-45 cm soil depth were recorded. Soil samples were taken with the help of screw auger from four different soil depths. The soil samples were taken around fixed spot selected at random in net plot area of each treatment from one replication. The samples were transferred immediately to aluminum boxes and covered with gunny bag to avoid moisture losses from the samples. The soil moisture extraction determined by oven dry method (Jackson, 1973) [10] and it was expressed in the percentage of total water used by Gregory *et al.* (1978) [8].

Consumptive use of water: The consumptive use of water under different treatments was computed by using the following formula as described by Mishra and Ahmad (1987) [11].

CU of water (mm) = ($E_0 \times 0.6$) + Profile soil moisture + Effective rainfall + Ground water contribution.
The depth of water table was more than three meters below the surface throughout the period of experimentation. Hence, the ground water contribution was considered as zero. The profile soil moisture (depletion) was worked out as under which is described by Patel (1993) [17],

$$d = \frac{\sum M_{1i} - M_{2i}}{100} \times \mathrm{Asi} \times \mathrm{Di}$$

Where, d = Moisture deficit in the root zone,
∑ = Summation of 'n' number of the root zone,
M_{1i} = Soil moisture in the i^{th} layer of profile after irrigation,
M_{2i} = Soil moisture in the i^{th} layer of profile on the day before next,
Asi = Apparent specific gravity of the layer (Bulk density of i^{th} layer),
Di = Depth of i^{th} layer,
E_0 = PE mm/day (from saturation to FC)

Water Use Efficiency (kg/ha-mm): The response of seed yield per unit of irrigation water used at varying level of irrigation was worked out by dividing per hectare seed yield of clusterbean crop obtained under various treatment with the total consumptive use of water (mm) of the respective treatment and it was recorded as water use efficiency (kg/ha mm) which was worked out by the followed formula which is described by Patel (1993) [17].

$$\text{WUE (Kg/ha-mm)} = \frac{\text{Green pod yield (kg/ha)}}{\text{Total consumptive use of water (mm)}}$$

Water expense efficiency (kg/ha-mm): The response of seed yield per unit of irrigation water used at varying level of irrigation was worked out by dividing per hectare green pod yield of clusterbean crop obtained under various treatments with the total quantity of water expense (Irrigation water, seasonal rainfall and profile water deplatation) in the respective IW: CPE ratios and it was calculated as Water expense efficiency as described by Patel (1993) [17].

$$\text{WEE} = \frac{\text{Green pod yield of clusterbean (kg/ha)}}{\text{Total quantity of irrigation water applied (mm)}}$$

Statistical Analysis: The data generated leaf area index and productivity of clusterbean were subjected to statistical analysis using "Analysis of variance technique". The value of table 'F' at

5% level of significance, where the treatment differences were found significant the value of CD was worked out to compare the treatment mean (Snedecor and Cochran, 1967) [21].

Results and Discussion

Leaf area index: Different irrigation schedules and growth regulators significantly influenced on the leaf area index at 20, 40 DAS and at harvest (table-2). The maximum leaf area index of 44.56, 93.90 and 175.64 were recorded at 20, 40 DAS and at harvest, respectively under the treatment I_3 (1.0 IW: CPE ratio) and it was remained at par with treatment I_2 (0.8 IW: CPE ratio). The probable reason for that due to maintenance of higher plant water status and more cooler crop canopy which resulted in to more absorption of photosynthetically active radiation and higher rate of net photosynthesis. Similar results were reported by Sawant *et al.* (1992) [20], Elamathi and Singh (2001) [5] and Prajapati *et al.* (2007) [18]. Among different plant growth regulator treatments GR_1 (NAA @ 100 ppm at 30 and 60 DAS) was recorded significantly the maximum leaf area index at 43.04, 88.03 and 171.80 at 20 and 40 DAS and at harvest, respectively followed by treatment GR_2 (GA_3 @ 40 ppm at 30 and 60 DAS) i.e. 42.32, 78.98 and 156.95 at 20 and 40 DAS and at harvest, respectively. The increase in leaf area index might be due to increased vegetative growth and assimilate production that favored larger reproductive growth. The accelerated vegetative growth resulted in an extensive photosynthetic apparatus and relative increase was recorded in LAI. Other reason for increasing LAI was stimulative action to improve vegetative growth and biochemical constituents like chlorophyll. The lower leaf area index was recorded 39.03, 78.37 and 150.21 at 20 and 40 DAS and at harvest, respectively under treatment GR_0 (control-water spray).These results are in conformity with those of in LAI reported by Bai *et al.* (1987) [2], Upadhyay (2002) [22], Prajapati *et al.* (2007) [18] and Patel (2008) [15].

Interaction of leaf area index: Leaf area index at 20 and 40 DAS and at harvest was significantly influenced due to irrigation scheduling and application of plant growth regulators (table-3, 4 & 5). Among the different treatment combinations, I_3GR_3 (1.0 IW: CPE ratio along with application of AA @ 25 ppm at 30 and 60 DAS) recorded significantly the highest (48.39) leaf area index at 20 and 40 DAS, treatment combinations, I_3GR_1 (1.0 IW: CPE ratio along with application of NAA @ 100 ppm at 30 and 60 DAS) recorded significantly the highest (113.87) leaf area index, and at harvest treatment combinations, I_3GR_1 (1.0 IW: CPE ratio along with application of NAA @ 100 ppm at 30 and 60 DAS) recorded significantly the highest (195.31) leaf area index. The increase in leaf area index at 20 and 40 DAS and at harvest was probably due to maintenance of higher plant water status and more cooler canopy which resulted in to more absorption of photosynthetically active radiation and higher rate of net photosynthesis and the accelerated vegetative growth resulted in an extensive photosynthetic apparatus. Lower leaf area index at 20 DAS (35.58) was observed under treatment combination I_0GR_2 (control along with GA_3 40 ppm at 30 and 60 DAS), lower leaf area index at 40 DAS (54.28) was observed under treatment combination I_0GR_0 (control along with control-water spray) and lower leaf area index at harvest (139.54) was observed under treatment combination I_1GR_3 (0.6 IW:CPE ratio along with GR_3 AA 25 ppm at 30 and 60 DAS) The result is in conformity with those of in LAI reported by Prajapati *et al.* (2007) [18] and Patel (2008) [15].

Productivity: The data pertaining to green pod and biological yields indicated that, significantly influenced due to different irrigation schedules. Among these treatments, treatment I_3 (1.0 IW: CPE ratio) recorded significantly the highest green pod and biological yield (19480 and 47297 kg/ha). The increase in green pod yield to treatments I_3 (1.0 IW: CPE ratio) was to the tune of 16.04, 12.90 and 4.61 per cent over treatments I_0 (control), I_1 (0.6 IW: CPE ratio) and I_2 (0.8 IW: CPE ratio). The increase in green pod and biological yield might be due to increase in irrigation frequency and consumptive use because of increased ratio. Thus, there was progressive increase in green pod and biological yields due to favourable moisture condition and better availability of soil moisture at higher frequency of irrigation throughout the growth period, which remarkabdly stimulated yield attributes and finally green pod and biological yield A remarkable reduction in green pod biological yield with limited water supply (i.e. I_0- control) was explained on the basis of internal water status in relation to different physiological processes taking place in plant. That is why it clearly indicated that crop required frequent water supply for optimum plant growth and high productivity during summer season. The results are in arrangement with Ahlawat *et al.* (1979) [1], Sawant *et al.* (1992) [20], Prajapati *et al.* (2007) [18] and Patel *et al.* (2005) [16]. The data regarding the green pod and biological yield indicated that, they were significantly influenced by different plant growth regulator treatments. Among them, treatment GR_1 (NAA @ 100 ppm at 30 and 60 DAS) recorded significantly the highest green pod and biological yield (18854 and 43892 kg/ha). The percent increase in green pod yield by treatment GR_1 (NAA @ 100 ppm at 30 and 60 DAS) was to the tune of 13.22 4.16 and 3.99 per cent over treatment GR_2 (GA_3 @ 40 ppm at 30 and 60 DAS), GR_3 (AA @ 25 ppm at 30 and 60 DAS) and GR_0 (control-water spray), respectively. The maximum green pod and biological yield was recorded due to making the plants photosynthetically more effective and also preventing flower shading, improving pod setting and consequently increasing the green pod and biological yield. The lower green pod yield was recorded under treatment GR_0 (control-water spray, 16360 kg/ha). The results are in agreement with the findings of Pandey *et al.* (2004) [14] Prajapati *et al.* (2007) [18] and Patel (2008) [15].

Consumptive use of water: The total quality of water applied were different irrigation treatments with the depth of water was 50 mm under different irrigation schedules (fig.1). The consumptive use of water was 176.70, 197.96, 311.51 and 383.10 mm under respective treatments. Thus, the consumptive use of water was increased with increase in irrigation water quantity. This might be due to higher number of irrigations with high quantity of water increased the consumption of water, due to better growth of crop and simultaneously the loss of water through evapotranspiration. Inadequate moisture supply to the crop under I0 (control) treatment resulted in lower consumptive use of water. These findings are analogous to those reported by Ahlawat *et al.* (1979) [1], Prajapati *et al.* (2007) [18] and Patel *et al.* (2005) [16]. The results indicated that mean consumptive use of water was influenced by application of different plant growth regulators (fig.2). The highest consumptive use of water (280.14 mm) recorded under treatment GR1 (NAA@ 100 ppm at 30 and 60 DAS). Treatment GR0 (control-water spray) recorded the lowest consumptive use of water (252.74 mm). In general, application of NAA @ 100 ppm at 30 and 60 DAS (GR1) increased consumptive use of water over other treatment. This might be due to increase in av. number of branches per plant by application of growth regulators as compared to control treatment. Second reason, application of NAA might have produced deeper root system which extracted the soil moisture from deeper layer of soil and in turn provided more water to shoot system for the process of transpiration. The increase in consumptive use of water might be due to higher seed yield which was incurred in plant growth regulators application as compared to control. The result is in conformity with those of in LAI reported by Prajapati *et al.* (2007) [18] and Patel (2008) [15].

Water Use Efficiency: Water use efficiency refers largely to the production of economics produce of crop per unit of water used by it throughout the life of a crop. Unlike consumptive use of water, the water use efficiency decreased with each successive increase in IW: CPE ratios (fig.1). The highest water use efficiency (93.07 Kg/ha-mm) was observed under irrigation scheduling at I_0 (control). The low WUE under treatment I_3 (1.0 IW: CPE) might be due to frequent irrigation and more losses through evapotranspiration. The second reason might be due to high WUE under treatment. I_0 would be less evapotranspiration ultimately less consumptive use of water and high WUE. The lowest water use efficiency (51.11 Kg/ha-mm) recorded under the treatment I_3 (1.0 IW: CPE ratio). Reduction in water use efficiency when more quantity of water was applied because, in higher moisture regimes more moisture is used for evaporation rather than for production, thereby reducing the water use efficiency. It might be also proportional to quantity of water used. The WUE decreased with higher IW: CPE ratios as frequent irrigation applied under these treatments increased moisture loss due to evapotranspiration in summer season. Higher WUE with I_0 (control) was stemmed from less water loss due to evapotranspiration under limited water supply. The reason for low WUE under treatment I_3 (1.0 IW: CPE ratio) might be due to an increase in frequency of irrigation resulted in higher soil moisture content and greater evapotranspiration. Frequent wetting of the upper surface layer exposed to the hot atmosphere in 1.0 IW: CPE ratio 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 than in other irrigation schedules which resulted in lower field and crop water use efficiency under treatment I_3 (1.0 IW: CPE ratio). Similar results are observed by Ahlawat *et al.* (1979) [1], Patel *et al.* (2005) [16] and Prajapati *et al.* (2007) [18]. Different plant growth regulators showed remarkable influence on water use efficiency (Kg/ha-mm). The data (fig.2) indicated that the highest water use efficiency of 79.36 Kg/ha-mm was observed under treatment GR_1 (NAA@ 100 ppm at 30 and 60 DAS), followed by GR_2 (GA_3 @ 40 ppm at 30 and 60 DAS, 74.04 Kg/ha-mm) and GR_3 (AA @ 25 ppm at 30 and 60 DAS, 73.31Kg/ha-mm). The lowest water use efficiency (68.15 Kg/ha-mm) was recorded under treatment GR_0 (control-water spray). The increase in water use efficiency might be due to higher seed yield which was incurred in plant growth regulators application as compared to control. The result is in conformity with those of in LAI reported by Prajapati *et al.* (2007) [18] and Patel (2008) [15].

Water Expense Efficiency: The highest water expense efficiency (81.78 kg/ha-mm) was recorded under treatment I_0 (Control), followed by I_1 (0.6 IW: CPE ratio, 48.47 Kg/ha-mm) and I_2 (0.8 IW: CPE ratio, 37.16 kg/ha-mm). The lowest water expense efficiency (35.42 Kg/ha-mm) was observed under treatment I_3 (1.0 IW: CPE ratio). It might be due to more irrigation applied under this under treatment and less water applied under I_0(Control).The reason might be due to that soil irrigation depth of water applied was increased on the contrary WEE was decreased might be due to lesser proportionately increase in green pod yield than water applied Higher WEE with lower ratio(0.6 IW: CPE ratio) and control irrigation treatment recorded due to lesser water loss in evapotranspiration under limited water supply condition (fig.1). The results are close conformity with reported by Prajapati *et al.* (2007) [18]. and Patel *et al.* (2005) [16]. Application of plant growth regulators influenced the water expense efficiency. The results (fig.2) indicated that treatment GR_1 (NAA @ 100 ppm at 30 and 60 DAS) resulted in higher WEE (55.02 Kg/ha-mm), followed by GR_2 (GR_3 @ 40 ppm at 30 and 60 DAS, 51.32 Kg/ha-mm). The lower water expense efficiency (46.70 Kg/ha-mm) was noticed under treatment GR_0 (control-water spray). The probable reason for increase in WEE might be due to the higher green pod yield recorded under GR_1 (NAA @ 100 ppm at 30 and 60 DAS). This finding is analogous to those reported by Prajapati *et al.* (2007) [18] and Patel (2008) [15].

Soil Moisture Extraction (%): Soil moisture extraction decreased progressively with depth of soil in all irrigation schedules (fig.3). Frequently irrigated clusterbean extracted more soil moisture (51 per cent) from upper layer (0-30 cm) under treatment I_3 than unfrequently irrigated clusterbean. This may due to the availability of more in the soil profile which increased the potential and a grater stomatal conductance. The mean moisture extraction from 0-15 cm depth was 31.65, 34.02, 35.54 and 33.21 per cent observed with treatments I_0 (control), I_1 (0.6 IW: CPE ratio), I_2 (0.8 IW: CPE ratio) and I_3 (1.0 IW: CPE ratio), respectively. Under the deeper soil layer (30-45 cm), the mean moisture extraction pattern was 22.96, 22.77, 23.24 and 21.27 per cent in treatments I_0 (control), I_1 (0.6 IW: CPE ratio), I_2 (0.8 IW: CPE ratio) and I_3 (1.0 IW: CPE ratio), respectively. The moisture extraction increased gradually with decrease in frequency of irrigation under treatment I_0 from deeper soil layer 60-90 cm. Under limited water supplied conditions moisture availability from upper layer was decreased due to prolonged irrigation cycles which compel the plant to extract more moisture from deeper layer of the soil. In short, irrigation from upper layer and on the other hand, moisture extraction increased gradually with decrease in frequency of irrigation in deeper soil layer. Another reason might be due to the soil moisture extraction pattern in control treatment (I_0) was relatively higher from the lower soil depth indicating higher activity of roots in the deeper soil layers under water stress. Moisture extraction increased with increase in frequency of irrigation in first 0-30 cm depth, perhaps due to increased in surface evaporation and water use. However, it progressively increased in deeper soil layer (30-45 cm depth) with decreased frequency of irrigation, which might be due to presence of root at deeper depth of soil profile. This finding is analogous to those reported by Prajapati *et al.* (2007) [18] and Patel (2008) [15]. Considering the mean moisture extraction from 0-15 cm depth was of root zone area, treatments GR_0 (control- water spray), GR_1 (NAA @ 100 ppm at 30 and 60 DAS), GR_2 (GA_3 @ 40 ppm at 30 and 60 DAS) and GR_3 (AA @ 25 ppm at 30 and 60 DAS) extracted 34.12, 30.98, 33.65 and 32.11 per cent mean moisture, respectively (fig.4). The highest moisture extracted under application of growth regulators might have produced higher vegetative plant growth such as number of branches and extensive root system which extracted more moisture from upper layer i.e. (0-15 cm) as compared to other treatments. While, in deeper zone (30-45 cm) extracted were 22.17, 24.01, 24.34 and 23.99 per cent under treatment GR_0 (control- water spray), GR_1 (NAA @ 100 ppm at 30 and 60 DAS), GR_2 (GA_3 @ 40 ppm at 30 and 60 DAS) and GR_3 (AA @ 25 ppm at 30 and 60 DAS), respectively.

Table 1: Physical constant the soil of experimental field

Depth (cm)	Physical properties of soil		
	F. C. %	P.W.P. %	B. D. g/cc
0-15	13.50	4.44	1.34
15-30	13.09	4.65	1.40
30-45	12.78	5.05	1.48
45-60	23.41	5.1	1.56
Procedure Followed	Actual field method (Dastane, 1972) [3]	Pressure plat apparatus method (Richard,1948)	Actual field method (Dastane, 1972) [3]

Table 2: Effect of different irrigation schedules (IW: CPE ratios) and plant growth regulators on leaf area index and yields of summer clusterbean

Treatment	Leaf Area Index			Green pod yield (Kg/ha)	Biological yield (Kg/ha)
	20 DAS	40 DAS	At harvest		
A.Irrigation schedules					
I_0 Control: (critical growth stages)	39.36	71.31	145.12	16355	38650
I_1 : 0.6 IW: CPE ratio	39.21	77.62	155.52	16966	41479
I_2 : 0.8 IW: CPE ratio	43.07	82.50	166.65	18581	44885
I_3 : 1.0 IW: CPE ratio	44.56	93.90	175.64	19480	47297
S Em ±	1.04	3.76	4.26	675.43	807.41
C D (P = 0.05)	3.34	12.04	13.63	2160.81	2583.03
B. Plant Growth regulators					
GR_0 : Control (Water spray)	39.03	78.37	150.21	16360	41416
GR_1 : NAA @ 100 ppm at 30 & 60 DAS	43.04	88.03	171.80	18854	43892
GR_2 : GA_3 @ 40 ppm at 30 & 60 DAS	41.81	79.94	163.97	18100	43671
GR_3 : AA @ 25 ppm at 30 & 60 DAS	42.32	78.98	156.95	18068	43551
S Em ±	0.97	2.34	2.91	518.21	660.49
C D (P = 0.05)	2.78	6.70	8.33	1486.31	1980.47

Table 3: Interaction effect of different irrigation schedules and plant growth regulators on leaf area index of summer clusterbean at 20 DAS

Interaction effect	Leaf Area Index at 20 DAS			
	Plant growth regulators (4 levels)			
Irrigation schedules (4 levels)	GR_0 Control (Water spray)	GR_1 (NAA 100 ppm at 30 & 60 DAS)	GR_2 (GA_3 40 ppm at 30 & 60 DAS)	GR_3 (Ascorbic acid 25 ppm at 30 & 60 DAS)
I_0 Control(Irrigation at critical growth stages)	35.92	46.90	35.58	39.03
I_1 (0.6 IW:CPE)	39.95	36.96	36.07	43.85
I_2 (0.8 IW:CPE)	44.53	41.63	48.14	38.00
I_3 (1.0 IW:CPE)	35.74	46.68	47.45	48.39
S.Em± C. D. at 5 %	1.94 5.56			

Table 4: Interaction effect of different irrigation schedules and plant growth regulators on leaf area index of summer clusterbean at 40DAS

Interaction effect	Leaf Area Index at 40 DAS			
	Plant growth regulators (4 levels)			
Irrigation schedules (4 levels)	GR_0 Control(Water spray)	GR_1 (NAA 100 ppm at 30 & 60 DAS)	GR_2 (GA_3 40 ppm at 30 & 60 DAS)	GR_3 (Ascorbic acid 25 ppm at 30 & 60 DAS)
I_0 Control (Irrigation at critical growth stages)	54.28	61.39	82.95	86.61
I_1 (0.6 IW:CPE)	65.09	97.51	85.02	62.85

I_2 (0.8 IW:CPE)	96.06	79.36	74.13	80.43
I_3 (1.0 IW:CPE)	98.04	113.87	77.65	86.04
S.Em±	4.67			
C. D. at 5 %	13.40			

Table 5: Interaction effect of different irrigation schedules and plant growth regulators on leaf area index of summer clusterbean at harvest

Interaction effect	**Leaf Area Index at harvest**			
	Plant growth regulators(4 levels)			
Irrigation schedules (4 levels)	GR_0 Control (Water spray)	GR_1 (NAA 100 ppm at 30 & 60 DAS)	GR_2 (GA_3 40 ppm at 30 & 60 DAS)	GR_3 (Ascorbic acid 25 ppm at 30 & 60 DAS)
I_0 Control(Irrigation at critical growth stages)	140.03	145.92	144.44	150.09
I_1 (0.6 IW:CPE)	157.19	158.01	167.33	139.54
I_2 (0.8 IW:CPE)	149.48	187.96	159.86	169.31
I_3 (1.0 IW:CPE)	154.14	195.31	184.25	168.88
S.Em±	5.81			
C. D. at 5 %	16.67			

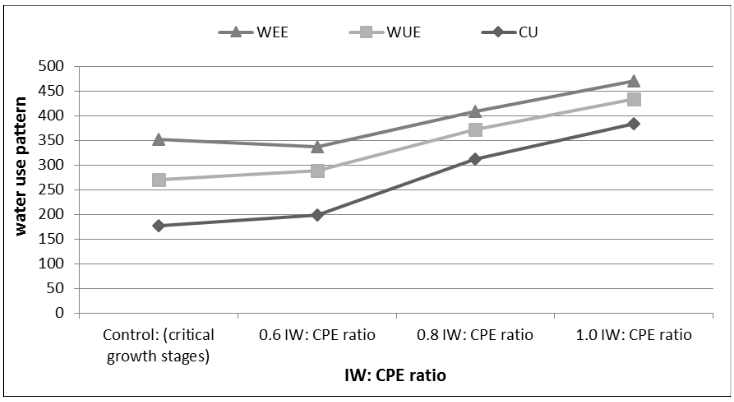

Fig 1: Effect of IW: CPE ratio on water Water expense efficiency (Kg/ha-mm) Water use efficiency (kg ha-mm) and Consumptive use of water (mm)

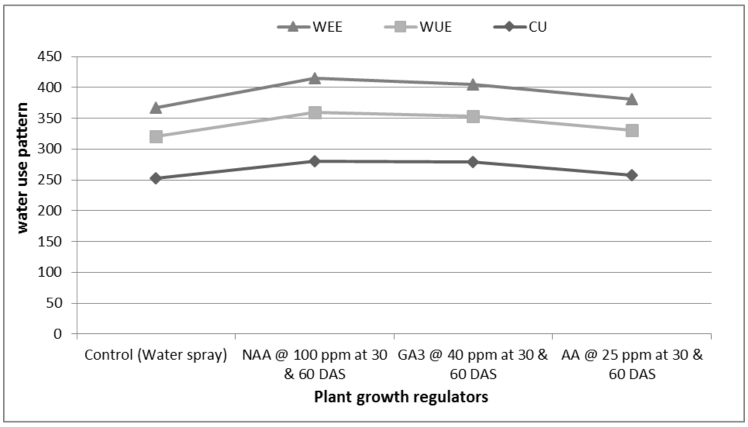

Fig 2: Effect of growth regulators on Water expense efficiency (Kg/ha-mm) Water use efficiency (kg ha-mm) and Consumptive use of water (mm)

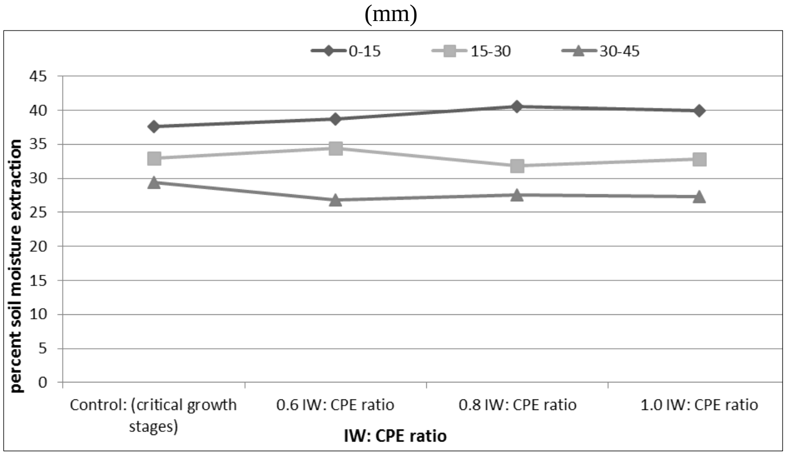

Fig 3: Effect of IW: CPE ratio on percent soil moisture extraction at different depth

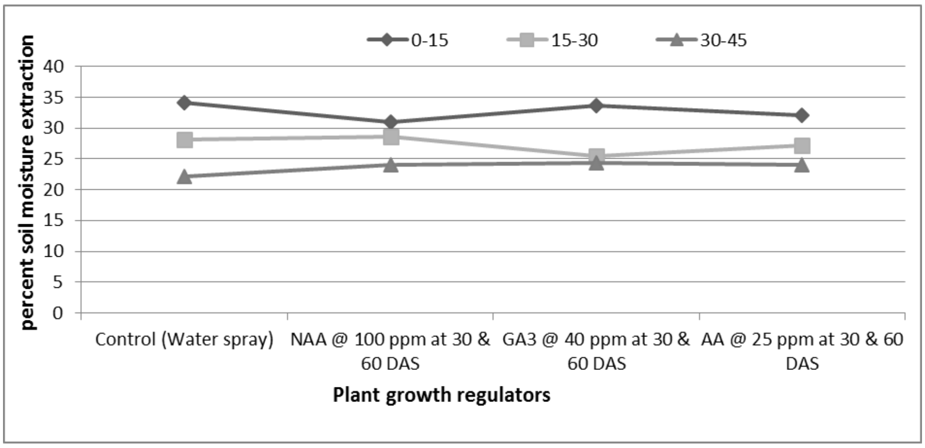

Fig 4: Effect of growth regulators on percent soil moisture extraction at different depth

Conclusion

For securing higher green pod yield, gross realization and net realization from summer clusterbean crop cv. "Pusa Navbhar" raised on loamy sand soils of middle Gujarat conditions, it is advisable to apply ten irrigations, including common light irrigation of 25 mm depth applied immediately after dry sowing, and the rest of irrigations, each of 50 mm depth to be scheduled an IW: CPE ratio of 1.0. The first irrigation should be applied at 12 days after sowing for uniform plant stand, second at 10 days after first irrigation and remaining irrigations at an interval of 5 to 8 days with an application of plant growth regulator NAA @ 100 ppm at 30 and 60 DAS.

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