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Research Paper

Performance of clusterbean (*Cyamopsis tetragonoloba*) under variable irrigation schedules and crop-establishment techniques

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2013 and 2014 at Hisar, Haryana to study performance of cluserbean [*Cyamopsis tetragonoloba* (L.) Taub.] under different irrigation schedules and crop-establishment techniques. Four crop-establishment techniques, viz. conventional tillage (CT), minimum tillage (MT), zero tillage (ZT) and furrow-irrigated raised bed system (FIRBS), in main plots were assessed under 3 irrigation schedules, viz. irrigation at irrigation water: cumulative pan evaporation (IW: CPE) at 0.8, 0.7 and 0.6 in sub-plots using strip-plot design with 3 replications. Clusterbean planted under FIRBS showed significantly taller plants, more number of branches, relative growth rate (RGR), crop-growth rate (CGR), pooled yield parameters and pooled seed yield (0.69 t/ha) than CT, MT and ZT. The FIRBS recorded the highest water-use efficiency (WUE) and irrigation water productivity (IWP) than the others. Irrigation applied at an IW: CPE of 0.80 had pronounced effect on plant height, pod dry matter, CGR, pooled yield parameters and pooled seed yields (0.60 t/ha) compared to IW: CPE of 0.70 and IW: CPE of 0.60.

Key words : Clusterbean, Crop-establishment techniques, Economics, Irrigation, Water productivity, Yield

Indian agriculture is facing primarily triple threats, viz. land degradation, dwindling water and land resources and climate change. Under semi-arid conditions, water is the scarcest input which has considerable affects on the efficiency of other natural, applied inputs and individual factor productivity (Cossani *et al*., 2009). To meet the requirement of ever-increasing population coupled with scarcity and gradual decrease in the share of water for agriculture, the only option available is to produce more food per unit of available water. About 48% of the water consumed by the agricultural crops is lost through non-process beneficial evapotranspiration (ET) (Khan *et al*., 2008) and minimizing these losses through efficient technologies will greatly enhance the water productivity. Agronomic practices like zero tillage, minimum tillage and furrow-irrigated raised bed (FIRB) planting are found to be the potential RCTs which can play a major role to save the scarce natural resources like water (Hari *et al*., 2010).

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Clusterbean is an important legume cash crop, grown in semi-arid and arid regions of Rajasthan, Haryana and Gujarat during rainy (*kharif*) season. India contributes 80% to the global production of guar seed where it is cultivated on an area of 3.40 m ha, with a very low productivity of 580 kg/ha (NRAA, 2014). This crop is a source to replenish nutrient, especially nitrogen of the low-fertility soils and can withstand moisture stress. Thus, it becomes imperative to sustain the productivity of agricultural systems concomitant with friendly environment and efficient utilization of production resources.

Since the behaviour of water distribution in the root-zone soil and its use by the crops and thereby the irrigation schedule under different crop-establishment techniques is likely to be different than the normal tillage practices. Hence present study was taken up to study growth, yield parameters and yield along with economics of clusterbean as influenced by crop-establishment techniques and irrigation schedules.

MATERIALS AND METHODS

The field experiment was conducted at Agronomy Research Farm, CCS Haryana Agricultural University Hisar (29° 10' N and 75° 46' E) during the rainy (*kharif*) seasons of 2013 and 2014. Treatments consisted of 4 crop-establishment techniques, viz. conventional tillage (CT), minimum tillage (MT), zero tillage (ZT) and furrow-irrigated raised bed system (FIRBS), in main plots and 3 irrigation schedules, viz. irrigation at irrigation water: cumulative pan evaporation (IW: CPE) of 0.8, 0.7 and 0.6 in subplots. It was laid out in strip-plot design with 3 replications in a 50 m^2 each gross plot size. The soil was slightly alkaline (*p*H 8.0), medium in organic carbon (0.58%). The available N, P and K were 133.6, 24.6 and 276.5 kg/ha respectively. It contained 20.5% water at -0.03 MPa (FC) and 6.1% at -1.5 MPa (PWP). A total of 662 and 212 mm rainfall was received during the respective 2 crop seasons (Table 1).

In CT, 2 harrowing + 2 ploughings followed by planking, while in MT, 1 harrowing + 1 ploughing followed by planking was done and sowing was done with seed-cum-fertilizer drill. In ZT, no tillage operations were done and the sowing was done with seed-cum-fertilizer zero till drill. The row spacing kept was 45 cm in the above techniques. Under FIRBS, beds were made with bed planter in such a way that 2 rows of clusterbean were planted at 30-cm-row spacing on top of the beds. The spacing between the bottoms of furrows was 70 cm and the bed width was 45 cm as shown in Fig. 1.

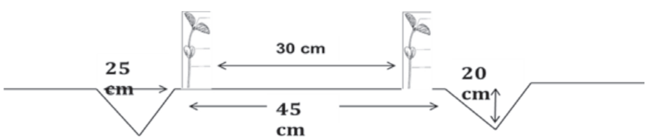

Fig. 1. Two rows of clusterbean on bed planting

After a pre-sown irrigation, clusterbean cv. HG 2-20 was planted on 12 June during 2013 and on 21 June 2014 using seed rate of 10 kg/ha. The recommended dose of 50 kg N, 25 kg P and 25 kg K per ha was applied through diammonium phosphate, urea and muriate of potash, half dose N, full P and full K at sowing and rest N was applied at 35 DAS through broadcasting during both the seasons. The other cultural practices followed were as per recommendations. The crop was harvested on 26 and 30 September in the respective 2 crop seasons.

Surface irrigations were applied in individual plots and the depth was measured with current meter. The IW: CPE ratios were calculated based on depth of irrigation water and the cumulative pan evaporation during the particular period. During *kharif* 2013, the rainfall was well distributed and therefore irrigation was not applied according to the various irrigation scheduling (IW: CPE) treatments. During *kharif* 2014, Four post-sown irrigations each in IW: CPE of 0.80 and IW: CPE of 0.70, while in IW: CPE of 0.60 three post-sown irrigations were applied. Date and depth (cm) of irrigation water applied in clusterbean during respective seasons is given in Table 2.

Observations on growth parameters, viz. plant height, branches/plant, dry matter and yield parameters and yields, were recorded at maturity from 3 random plants from each net plot (8.4 m × 4.5 m = 37.8 m^2).

Relative growth rate (RGR) for 61–90 days period was calculated as per the formula given by Blackman (1919).

$$\text{RGR} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \text{ g/g/day}$$

where, w_1 and w_2 are dry weights of plant at time t_1 and t_2 respectively. Log_e, natural logarithm.

Crop growth rate (CGR) for 61–90 days period was calculated as:

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \text{ g/m}^2\text{/day}$$

where, W_1 and W_2 are dry weights of plant at time t_1 and t_2 respectively.

The period-wise total water use/ consumptive use by clusterbean crop was computed from different sources, i.e. depletion from soil, rainfall, contribution from shallow ground water and post-sown irrigations in both the years. The profile-moisture status of the active root zone was measured by gravimetrically method and the moisture per cent was computed on dry-weight basis. The moisture in entire root zone (cm) was computed by the following formulae:

$$M = \sum_{i=1}^{n} \frac{Mi \times Dbi \times Di}{100}$$

where M = amount of moisture in 0–90 cm in soil profile in cm. n and i = n number of soil layers, where i is equal to 1 layer, M = moisture per cent of ith layer, Dbi= bulk density of ith layer (gcm^{-3}), Di = depth of ith layer of soil in cm.

Groundwater contribution (The flux density of the soil water from groundwater table to root zone) was estimated using Darcy's law for steady-state conditions as proposed by Giesel *et al.* (1972) as under:

$$q = K\theta \,(dh/dz \text{ -1})$$

where q = water flux density, Kθ = capillary conductivity, h = soil-water suction at the bottom of the crop root zone, z = depth of water table from the bottom of the root zone.

The saturated hydraulic conductivity of the different soil layers, i.e. 0–30, 30–60, 60–90 and 90–120 cm was taken as 20.2, 18.5, 14.0 and 12.0 respectively.

Water-use efficiency of different treatments was computed by dividing the economic yield (kg/ha) by total amount of water used (cm) from respective plots (Michael *et al*., 1977).

$$\text{WUE} = \frac{\text{Economic (grain/seed) yield (kg/ha)}}{\text{Total consumptive use of water (cm)}} = \text{kg/ha-cm}$$

Irrigation water productivity (IWP) of different treatments was computed by dividing the economic yield (kg/ha) by irrigation water applied (cm) from respective plots. It is expressed in kg m^{-3} (kg/ha-cm/100).

$$\text{IWP} = \frac{\text{Economic (grain/seed) yield (kg/ha)}}{\text{Irrigation water applied (cm)}} = \text{kg/m}^3$$

The experiment was conducted on the same layout during both the years. Economic analysis of the data was done based on the prevailing cost of inputs/operations and price of the marketable produce during both the crop seasons. The data recorded for different parameters were analyzed through analysis of variance (ANOVA) technique for a strip plot design. The result are presented at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Crop-establishment techniques

Growth parameters: The clusterbean plants under FIRBS at maturity produced significantly higher pooled plant height, more number of branches with higher pod dry weight and total dry-matter than the other crop-establishment techniques (Table 3). However, CT also resulted in noticeably higher pooled number of branches, pod dry weight and total dry-matter than ZT and MT. Better growth conditions under FIRBS provided higher light interception, optimum moisture regimes and increased nutrient supply. Total dry weight, which includes pod was substantially higher in bed (FIRBS) planting can be ascribed to additive effect of more plant height and number of branches under favourable light, moisture and nutrient conditions than the other tillage practices. Contrastingly (Horn *et al*., 1996) harvested more dry matter at harvesting in ZT than CT in clusterbean.

The relative growth rate (RGR) of 2 crop seasons did not differ significantly under various crop-establishment techniques with varying irrigation schedules (Table 3). Significantly higher pooled crop growth rate (CGR) for 61–90 days period was observed under FIRBS than ZT and MT, but was at par with CT. Considerably, higher CGR observed under bed (FIRBS) planting than the other crop-establishment techniques, might be owing to higher dry matter production and its partitioning in different parts.

Yield attributes: Clusterbean planting under FIRBS had significantly higher yield parameters such as clusters/plant, pods/cluster, pod length with higher grains/pod, higher pod yield and 1000-seed weight as compared to the other crop-establishment techniques except the number of clusters/plant and grains/pod where the difference between FIRBS and CT was at par with each other (Table 4). Better yield-attributing parameters of clusterbean as mentioned above under FIRBS (beds) might be owing to more favourable conditions for growth of root and nodules (Sewhag *et al.,* 2008) leading to vigorous vegetative growth through more dry-matter accumulation and translocating it to the reproductive parts.

Seed and biological yield: The bed-planted clusterbean (FIRBS) produced significantly higher seed yield and biological yield than the other crop-establishment techniques, but the difference between FIRBS and CT under biological yields was not distinct (Table 4). Under FIRBS, higher seed and biological yield of clusterbean is primarily assigned to better growth and yield parameters. Over flat sowing, the availability of mineral nutrients under FIRBS was better and enhanced growth and reproductive parts of mungbean (Fraz *et al*., 2006). Under FIRBS, improvement in yield of pigeonpea by 22%, clusterbean by 8% and greengram by 15% (Dhindwal *et al.,* 2006), of clusterbean by 15% (Sewhag *et al.,* 2008) have been reported as compared with flat-sown crops. However, zero-tilled clusterbean recorded significantly lower seed and biological yields than MT, CT and FIRBS. This might be due to lower germination rates observed under zero tilled plots because of more weed menace could lead to lower growth and yield parameters which ultimately reflects on overall

Table 1. Pan evaporation, rainfall and water-table depth during clusterbean crop seasons

Crop period	Pan evaporation (mm)		Rainfall (mm)		Water-table depth (cm)	
	2013	2014	2013	2014	2013	2014
Initial (sowing to 30 DAS)	196	235	215	45	142	165
Growth (31 to 70 DAS)	195	235	330	54	56	172
Development and maturity (71 DAS to maturity)	172	152	117	83	68	176
Total	563	622	662	212	-	-

DAS, Days after sowing

Table 2. Date and depth (cm) of irrigation water applied in clusterbean during 2014

Date	Depth of irrigation applied (cm) during 2014													
	IW/CPE = 0.80				Date	IW/CPE = 0.70				Date	IW: CPE = 0.60			
	FIRB	CT	MT	ZT		FIRB	CT	MT	ZT		FIRB	CT	MT	ZT
05 July 2014	5.23	6.24	6.02	5.91	07 July 2014	5.54	6.26	6.09	5.94	09 July 2014	5.59	6.49	6.22	6.11
14 July 2014	5.28	6.18	5.96	5.76	16 July 2014	5.48	6.19	5.96	5.79	23 July 2014	5.68	6.57	6.13	6.06
27 July 2014	5.33	6.22	5.85	5.82	17 Aug 2014	5.41	6.25	5.91	5.88	24 Aug 2014	5.53	6.53	6.15	5.92
24 Aug 2014	5.34	6.16	5.87	5.61	31 Aug 2014	5.34	6.17	6.04	5.95					
Total	21.18	24.8	23.7	23.1	Total	21.77	24.87	24.0	23.56	Total	16.8	19.59	18.5	18.09

IW: CPE, irrigation water: cumulative pan evaporation; FIRB, furrow-irrigated raised bed; CT, conventional tillage; MT, minimum tillage; ZT, zero tillage

yield of clusterbean.

Total water use/consumptive use of water: During 2013 crop season, since no irrigation was applied to clusterbean and contribution of rainfall was more, i.e. 51 cm towards ET followed by soil-moisture depletion and groundwater contribution (Table 5). While during 2014 season, rainfall contribution was more towards ET followed by irrigation water. The share of soil-moisture depletion (SMD) was the highest and of groundwater contribution (GWC) was the lowest towards total water use under FIRBS compared to the other crop-establishment techniques (Table 5). Their relative contribution under FIRBS was a 15.0% SMD, 9.7% GWC, 36.7% irrigation water and 38.5% rainfall. The contribution of the corresponding components under the other crop-establishment techniques varied from 12.7 to 13.2%, 10.8 to 11.8%, 38.4 to 39.1% and 36.4 to 37.9%, respectively. The total water use was the highest with CT followed by MT, ZT and the lowest under FIRBS. The total water used was around 5.6, 4.7 and 1.8% lower under FIRBS over that of CT, MT and ZT respectively. Under ZT it was also increased by 3.9 and 3.0% over that of CT and MT. Under FIRBS, the water is applied only up to shoulder of the furrows, covering the entire with less amount of irrigation water (Khatri *et al*., 2001). The more amount of applied water moves horizontally than vertically, reducing the chance of deep percolation beyond root zone. Under ZT, plant residues acted as mulch minimizing the evaporation from soil surface and hence lower ET and water use. In conventional tilled crop, the irrigation water is spread over the entire area enhancing evaporation from the soil surface and thus higher ET and water use.

Water-use efficiency and irrigation water productivity (IWP) : Water-use efficiency (WUE) was more under bed-planted clusterbean, than that under the other crop-establishment techniques during 2013 and 2014 crop seasons (Table 5). Since, no irrigation was given in clusterbean during 2013, the IWP could not be calculated. During 2014, the IWP was found to be highest under FIRBS, followed by CT and the lower under MT and ZT. This could be attributed to relatively higher economic yield and lower irrigation water application. FIRBS-planted *kharif* pulses had higher total water productivity of clusterbean by 18%, of pigeonpea by 34% and of greengram by 25% (Dhindwal *et al*., 2006).

Economics: The cultivation cost of 2 years was the highest with FIRBS and the lowest with ZT (Table 6). Net returns of the 2 crop seasons were significantly higher with FIRBS planting, followed by CT, MT and ZT. The improvement in net returns under FIRBS could be owing to higher seed and biological yields in the respective crop seasons. The net returns with CT were also significantly higher than MT and ZT, but the difference between the later 2 techniques was not pronounced. The ZT clusterbean gave the lowest net returns could be due to the negative net returns recorded during 2014 crop season because of lower seed and biological yields obtained due to more disease incidence and weeds in the respective tillage plots. Mean benefit: cost of 2 clusterbean was significantly higher with FIRBS than the other crop-establishment techniques, but was at par with CT. Higher net returns and benefit cost of clusterbean under FIRBS was largely owing to improved grain yields.

Irrigation schedules

Growth parameters: Noticeable difference in number of branches/plant, pod dry weight and total dry-matter production was not observed with varying moisture regimes at maturity (Table 3); this could be due to no irrigation was applied on account of well-distributed and sufficient rainfall received during the 2013 crop season. However, irrigation applied at an IW: CPE of 0.80 (I_1) resulted in significantly higher plant height of clusterbean compared to IW: CPE of 0.60 (I_3). The difference between the irrigation-scheduling treatments of IW: CPE of 0.80 and IW: CPE of 0.70 was not marked. High values of growth parameters at higher moisture regimes might be due to application of more irrigations at timely and early growth stages encourages better growth and development.

Irrigation schedules did not differ significantly on the RGR and CGR of clusterbean. However, it was higher with IW: CPE of 0.80, followed by IW: CPE of 0.60 and IW: CPE of 0.70. Application of irrigation at IW: CPE of 0.80 resulted in highest CGR might be owing to increase in moisture regimes resulted in higher photosynthetic activity per unit area and more dry-matter production lead to increase in growth indices.

Yield attributes: Various moisture regimes had no marked influence on clusters/plant, pods/cluster and 1,000-seed weight. However, irrigation applied at IW: CPE of 0.80 (I_1) resulted in significantly higher number of grains/pod and pod yield/plant compared to the other irrigation schedules. The difference between latter 2 moisture regimes (I_2 and I_3) was not pronounced. Since no irrigation could be applied during 2013 crop season owing to sufficient and well-distributed rainfall, the yield parameters did not differ significantly under various irrigation schedules. During 2014, all the yield-attributing parameters were the highest with irrigation at IW: CPE of 0.80 than IW: CPE of 0.60, but it was at par with IW: CPE of 0.70. This might be attributed to its beneficial effect on pods/plant and seeds/pod. The better development of yield attributes at higher moisture regimes might be owing to increase in cell turgidity, better opening of stomata and finally helping in translocation of photosynthates to sink (Sewhag *et al.*, 2008).

Seed and biological yield: Seed and biological yields were significantly higher with irrigation at an IW: CPE of 0.80 than the other irrigation schedules (Table 4). Increased seed and biological yields observed with irrigation at an IW: CPE of 0.80 might be attributed to the beneficial effect of better moisture regimes on pods/plant and seeds/pod. The higher biological yield under higher moisture regimes occurred primarily owing to moisture availability

Table 3. Effect of crop-establishment techniques and irrigation scheduling on growth parameters of clusterbean (pooled data of 2 years)

Treatment	Plant height (cm) at 90 DAS	Branches/ plant at maturity	Pod dry matter/m² at maturity (g)	Total dry-matter production/m² at maturity (g)	Relative growth rate (g/g/day) at 61–90 days period	Crop-growth rate (g/m²/day) at 61–90 days period
Crop-establishment techniques						
FIRBS	92.8	12.1	186.8	368.8	0.038	8.90
CT	88.0	11.1	173.8	339.0	0.040	8.38
MT	83.3	9.8	149.2	302.4	0.039	7.64
ZT	76.7	9.3	141.8	286.9	0.041	7.40
SEm±	0.8	0.2	2.7	5.8	0.001	0.14
CD (P=0.05)	2.3	0.6	8.8	20.0	NS	0.48
Irrigation schedules						
I_1	86.5	10.7	164.9	327.9	0.039	8.13
I_2	85.6	10.6	162.5	323.8	0.039	8.08
I_3	83.4	10.4	161.3	321.1	0.040	8.04
SEm±	0.6	0.1	1.7	4.1	0.001	0.09
CD (P=0.05)	1.9	NS	NS	NS	NS	NS

FIRB, Furrow-irrigated raised bed; CT, conventional tillage; MT, minimum tillage, ZT, zero tillage; I_1, IW: CPE=0.80; I_2, IW: CPE=0.70; I_3, IW: CPE=0.60

for higher dry-matter production and number of branches. Thus, adequate irrigations favoured both source and the sink. Irrigation at 150 mm CPE resulted in higher grain yield of clusterbean (Dhindwal *et al.*, 2006) and of greengram (Idnani and Gautam, 2008) and decreased with decrease in moisture regimes to 200 mm and 250 mm CPE.

Total water use/consumptive use of water: The total water use of clusterbean was almost equal under varying irrigation schedules during 2013 crop season, because no irrigation water applied. During 2014, the share of SMD and GWC was the lowest towards total water use under an IW: CPE of 0.80 (I_1) as compared to other irrigation schedules (Table 5). The contribution of SMD, GWC, irrigation water and rainfall under I_1 was 11.7, 10.2, 40.8 and 37.3% respectively. The corresponding values under IW: CPE of 0.70 (I_2) were 12.6, 10.8, 40.4 and 36.3% and 16.1, 12.1, 33.3 and 38.6% under IW: CPE of 0.60 (I_3). Highest amount of water was used under I_2 followed by I_1 and minimum under I_3. The total water used was 6.0% and 2.7% lower under I_3 and I_1 compared to I_2. The lesser amount of total water use with irrigation applied at IW: CPE of 0.60 was principally due to less frequent irrigation water application.

Water-use efficiency (WUE) and irrigation water productivity (IWP): During 2013 season the WUE was found

Table 4. Yield parameters, seed yield and biological yields of clusterbean under various crop-establishment techniques and irrigation schedules (pooled data of 2 years)

Treatment	Clusters/ plant	Pods/ cluster	Pod length (cm)	Grains/ pod	Pod yield/ plant (g)	1,000-seed weight (g)	Seed yield (t/ha)	Biological yield (t/ha)
Crop establishment techniques								
FIRBS	5.4	6.0	5.3	7.4	6.2	23.0	0.69	3.18
CT	5.3	5.6	5.2	7.4	5.5	22.4	0.63	3.12
MT	5.0	5.4	5.1	7.3	4.6	20.9	0.54	2.68
ZT	4.8	5.1	4.9	7.1	4.1	20.9	0.49	2.58
SEm±	0.07	0.10	0.02	0.03	0.12	0.12	0.01	0.06
CD (P=0.05)	0.25	0.36	0.05	0.10	0.43	0.41	0.05	0.18
Irrigation schedules								
I_1	5.2	5.6	5.1	7.4	5.2	22.0	0.60	2.93
I_2	5.1	5.6	5.1	7.3	5.1	21.7	0.58	2.89
I_3	5.0	5.4	5.1	7.2	5.0	21.7	0.57	2.84
SEm±	0.04	0.05	0.02	0.02	0.07	0.12	0.01	0.02
CD (P=0.05)	NS	NS	NS	0.08	0.21	NS	0.02	0.07

FIRB, Furrow-irrigated raised bed; CT, Conventional tillage; MT, Minimum tillage; ZT, Zero tillage; I_1, IW: CPE=0.80; I_2, IW: CPE=0.70; I_3, IW : CPE=0.60; IW, Irrigation water; CPE, Cumulative pan evaporation

Table 5. Water use, water-use efficiency (kg/ha-cm) and irrigation water productivity (kg/m^3) of clusterbean as influenced by crop-establishment techniques and irrigation schedules

Treatment	Consumptive use of water (cm)										Water-use efficiency		Irrigation water productivity
	2013					2014							
	Rainfall	IW	GWC	SMD	Total	Rainfall	IW	GWC	SMD	Total	2013	2014	2014
Crop-establishment techniques													
FIRBS	51.0	0.0	1.1	5.4	57.5	21.2	20.2	5.4	8.3	55.1	15.7	8.6	0.23
CT	51.0	0.0	1.4	4.7	57.1	21.2	22.8	6.9	7.4	58.3	14.3	7.5	0.19
MT	51.0	0.0	1.2	4.5	56.7	21.2	22.2	6.8	7.6	57.8	12.1	6.6	0.17
ZT	51.0	0.0	1.3	4.1	56.4	21.2	21.6	6.1	7.1	56.0	11.2	6.3	0.16
Irrigation schedules													
I_1	51.0	0.0	1.2	4.6	56.8	21.2	23.2	5.8	6.7	56.9	13.4	7.6	0.19
I_2	51.0	0.0	1.3	4.7	57.0	21.2	23.6	6.3	7.4	58.5	13.4	6.9	0.17
I_3	51.0	0.0	1.2	4.7	56.9	21.2	18.3	6.6	8.8	54.9	13.2	7.1	0.21

IW, Irrigation water; GWC, Ground water contribution; SMD, Soil-moisture depletion; FIRB, Furrow-irrigated raised bed; CT, Conventional tillage; MT, Minimum tillage; ZT, Zero tillage; I_1, IW: CPE=0.80; I_2, IW: CPE=0.70; I_3, IW: CPE=0.60

Table 6. Economics of clusterbean as influenced by crop-establishment techniques and irrigation schedules (pooled data of 2013 and 2014)

Treatment	Cost of cultivation (₹ × 10^3/ha)	Gross returns (₹ × 10^3/ha)	Net returns (₹ × 10^3/ha)	Benefit: cost ratio
Crop-establishment technique				
FIRBS	24.3	36.0	11.7	1.49
CT	23.7	33.2	9.5	1.41
MT	22.2	28.7	6.5	1.30
ZT	21.2	26.4	5.3	1.26
SEm±	-	-	0.5	0.03
CD (P=0.05)	-	-	1.5	0.12
Irrigation schedules				
I_1	22.9	31.9	9.0	1.39
I_2	22.9	31.0	8.2	1.36
I_3	22.7	30.4	7.6	1.34
SEm±	-	-	0.3	0.03
CD (P=0.05)	-	-	0.9	NS

FIRB, Furrow–irrigated raised bed; CT, Conventional tillage; MT, Minimum tillage; ZT, Zero tillage; I_1, IW : CPE=0.80; I_2, IW : CPE=0.70; I_3, IW: CPE=0.60; IW, Irrigation water; CPE, Cumulative pan evaporation

to be similar under all the 3 irrigation schedules (Table 5). Since no irrigation water applied during the respective crop season the total water use was almost similar. During 2014, WUE was the highest with an IW: CPE of 0.80 (I_1), followed by IW: CPE of 0.60 and lowest with IW: CPE of 0.70. This was due to higher seed yield and lower total water use in the higher moisture regimes lead to the highest WUE. Higher WUE in lower moisture regimes was also due to proportionally more loss of water in evapotranspiration than increase in yield (Arya and Sharma, 1994).

Since no irrigation was applied in clusterbean during 2013, the IWP could not be calculated. During 2014, irrigation applied at an IW: CPE of 0.60 resulted in the highest IWP, followed by IW: CPE of 0.80 and lowest with IW: CPE of 0.70. The IWP was the highest with irrigation an IW: CPE of 0.60, this could be attributed to relatively higher economic yield and lower irrigation water application.

Economics: The cost of cultivation (COC), net returns and benefit: cost remained almost similar among the irrigation scheduling treatments (Table 6). This could be owing to no irrigation given during 2013 crop season and almost equal number of irrigations given during 2014 crop season because of sufficient rainfall received during respective crop seasons and hence almost similar seed yields of clusterbean was obtained. While, during 2014, COC for irrigation at an IW: CPE of 0.80 and IW: CPE of 0.70 of ₹22.9 ×10^3/ha was higher, where 4 irrigations were applied compared to IW: CPE of 0.60 (I_3) where only 3 irrigations were applied. However, the net returns and benefit cost, calculated for irrigation schedule of I_1 were significantly higher than I_2 and I_3. The difference between the later 2 irrigation schedules was not found to be substantial. The cost of cultivation increased with increase in moisture regimes from lower to higher, due to more expenditure on irrigation water. The gross and net returns as well as the benefit cost ratio improved with increase in each level of moisture regime from irrigation at IW: CPE of 0.60 to 0.80. Idnani and Gautam (2008) and Yadav and Singh (2014) obtained the highest net return and benefit: cost ratio with higher irrigation levels in greengram.

From the present investigation, it may be concluded that adoption of bed planting (FIRBS) with application of irrigation at an IW: CPE of 0.80 in clusterbean leads to increase in growth parameters along with yield parameters and seed and biological yields compared to conventional tillage and minimum tillage during both the years. Since varied weather conditions during both the crop seasons clusterbean performed well under beds than the other crop-establishment techniques. This clearly shows that clusterbean crop survived and performed better at high rainfall and also low rainfall conditions under FIRBS.

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