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Effect of irrigation management and planting methods on yield and water use efficiency of French bean (*Phaseolus vulgaris* L.) under stored rain water resource

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Abstract

A field experiment was conducted on a silty clay loam (Typic Hapludalph) soil under rainfed conditions to evaluate the effect of irrigation and planting methods on French bean (*P. vulgaris*) under stored rain water resource for two consecutive rabi seasons during 2003 and 2004. The treatment plan included three irrigation frequencies at 1.2, 1.0 and 0.8 IW/CPE (Irrigation water/Cumulative Pan Evaporation) and three planting methods viz. ridge, furrow and level. The results indicated highest yield of French bean (7.95 Mg/ ha and 8.50 Mg/ ha during 2003 and 2004, respectively) at IW/CPE of 1.2 and furrow planting. The water use efficiency of the crop was higher under furrow method of planting i.e. 31.0 kg/ha/mm at irrigation of 1.0 IW/CPE ratio during first and 33.5 kg/ha/mm at irrigation of 0.8 IW/CPE ratio during second year.

Key words: Irrigation, planting methods, yield, water use efficiency, French bean, stored rain water.

Introduction

In Himachal Pradesh, about 84 per cent of the net cropped area is rain fed. Due to uneven and erratic rains, the yields of both *rabi* and *kharif* crops were low. Under rainfed conditions only cereal or pulse based cropping sequence are followed which fetch very meager net returns. The cost: benefit ratio can be widened if vegetable or cash crops based cropping systems are adopted. Vegetables are more prone to water stress among all the agricultural crops. So, vegetable production is the major sufferer of erratic and uneven rainfall in rainfed areas. Therefore, for the cultivation of vegetable crops assured irrigation is very much required. Adoption of more productive irrigation schedule is necessary to get good yield levels as water stress at any stage can reduce their yield threshold. This problem can be mitigated if rain water is stored in polylined water harvesting tanks and its productivity improved through alternative methods of planting and judicious use of stored water. Acharya *et al.* (1998) and Acharya and Kapur (2000) have highlighted the importance of shifting from conventional maize-wheat cropping sequences to vegetable based cropping systems if water is stored and recycled from water harvesting tanks and used for irrigating the vegetables.

French bean (*P. vulgaris*) is one of the most important legume vegetables. Amongst the 150 species of *Phaseolus*, it is the most widely cultivated form. It is cultivated throughout the world for tender pods and dry beans, and also grown on a large scale for processing. In India, vegetable type French bean occupies an area of about 1,50,000 hectares with an annual production and productivity of 4,20,000 tonnes and 2,800 kg ha^{-1}, respectively (Anonymous, 2002). In Himachal Pradesh, it covers an area of 2,444 ha with an annual production of 27,202 tonnes (Anonymous, 2004). This crop is gaining popularity in the state as an off season vegetable, because it is a quick growing crop and fetches premium prices in the metropolitan markets especially during summer and autumn- winter season. However, these periods coincide with the period of water deficit as during these periods evaporation exceeds rainfall resulting into limited cultivation of crops. Therefore, this crop can be successfully grown in rainfed areas by harvesting rainwater in polylined tanks and increasing its productivity by adopting effective irrigation schedules and manipulating methods of planting. Therefore, this work attempts to develop more effective irrigation scheduling and methods of planting for French bean under stored rain water resource.

Material and Methods

A field experiment was conducted in the experimental farm of the department of Soil Science, CSKHPKV, Palampur (Latitude 32°6' N and Longitude 76°3' E, altitude 1290.8 m above mean sea level) of Kangra district of Himachal Pradesh. The location has sub humid climate with mean annual rainfall of 2500 mm; Maximum and minimum temperature of the experimental site is 28.0°C and 8.2°C, respectively.

The soil of the experiment site was silty clay loam, Typic Hapludalf. The bulk density ranged from 1.23 Mg m^{-3} in 0-0.15 m soil layer to 1.35 Mg m^{-3} in 0.30-0.45 m layer. The steady state infiltration rate was 0.23 x 10^{-5} m sec^{-1}. The soil was acidic (pH 5.4) with 9.2 g kg^{-1} organic carbon, 285.3, 14.8 and 188.2 kg ha^{-1}, available N, P_2O_5 and K_2O, respectively, in 0.15 m soil layer. The field experiment was laid out with all possible combinations of three levels of irrigation at IW/CPE (Irrigation Water/Cumulative Pan Evaporation) of 1.2 (I_1) , 1.0 (I_2) and 0.8 (I_3) and three methods of planting i.e. ridge (P_1), furrow (P_2) and level (P_3), in randomized block design and replicated thrice. The experiment was conducted during 2003 and 2004. Before sowing, ploughing was done with power tiller and farm yard manure was incorporated @ 20t ha^{-1} 15 days before transplanting the crop. After land levelling, ridges and furrows were made as per layout plan. Half-dose of N and full-dose of phosphorus and potassium (50N: 43.48 P: 42.5K kg ha^{-1}) was added as a basal treatment and the rest (half dose of nitrogen) was added one month after transplanting. The sowing was done on 1st April and 9th April in first and second season, respectively. Irrigation was given as per treatments. During first year of the experiment drenching with chlorpyrifos @ 2.5ml/litre was done to control termites during early stages of crop.

The changes in the soil water content during the crop growth were determined at 0-0.15, 0.15-0.30 and 0.30-0.45 m layers. Soil water contents were monitored by gravimetric method at weekly intervals and before and after each rainfall. The seasonal water use (Et) was computed from the seasonal moisture depletion from 0.45m profile (CS_{45}), effective rainfall (ER) and irrigation water applied (I), (as per treatment), all in cm from the equation

$$Et = CS_{45} + ER + I$$

Where, CS_{45}

$$= \sum_{i=0}^{45} \frac{\{(\%\ \text{moisture before start of expt} - \%\ \text{moisture after expt}) \times \text{bulk density} \times \text{depth}_i\}}{100}$$

Crop yield (Mg ha^{-1}) was recorded as marketable terminal head (without wrapper leaves) and secondary sprouts. Water use efficiency (kg ha^{-1} mm^{-1}) was computed from curd yield produced per unit crop water use in Et.

Statistical analysis

The data was analyzed statistically using standard statistical procedures. Analysis of variance (ANOVA) was carried out using Randomized Block Design (Cochran and Cox, 1963).

Results and Discussion

Soil moisture content

Soil water content determined at flowering stage of French bean one day after irrigation(Table 1) revealed that at all the three irrigation levels, soil water content remained higher under furrow method of planting showing that furrow planting conserved and maintained higher soil water content compared to ridge and flat methods. The soil water content was higher in the surface layer and it decreased with the increase in soil depth. Soil water content was higher under higher frequency of irrigation at their respective planting methods.

Table 1. Depth wise soil moisture content (m^3 m^{-3}) in French bean at flowering stage during 2003 and 2004

Treatment	2003			2004		
	0-0.15 m	0.15-0.30 m	0.30-0.45 m	0-0.15 m	0.15-0.30 m	0.30-0.45 m
I_1P_1	16.41	16.00	14.20	21.56	17.11	16.02
I_1P_2	21.46	19.21	16.06	24.89	20.88	19.65
I_1P_3	19.04	17.20	13.90	23.61	18.42	17.82
I_2P_1	17.41	15.21	13.41	18.61	16.21	15.66
I_2P_2	20.26	17.41	16.43	22.82	20.11	18.84
I_2P_3	18.42	16.41	15.11	20.76	18.20	16.60
I_3P_1	16.41	13.20	12.90	16.45	14.30	13.80
I_3P_2	18.41	18.21	15.10	20.56	17.89	14.23
I_3P_3	18.01	16.10	14.20	17.21	15.41	14.11

Total water use

Table 2 presents the data on crop water use of French bean during 2003 and 2004, respectively. The number of irrigations (4.0 cm each) varied from 7 to 11 during the first and from 5 to 8 during the second cropping season. Crop water use was maximum (275 mm and 324 mm) during first and second year under I_1P_3 treatment where irrigation was given at IW/CPE

Table 2. Yield, crop water use and water use efficiency of French bean during 2003 and 2004

Treatment	2003			2004		
	Yield (Mg ha^{-1})	Crop water use (mm)	Water use efficiency (kg mm^{-1} ha^{-1})	Yield (Mg ha^{-1})	Crop water use (mm)	Water use efficiency (kg mm^{-1} ha^{-1})
I_1P_1	6.74	273	24.7	8.25	320	25.8
I_1P_2	7.95	273	29.2	8.50	317	26.8
I_1P_3	6.80	275	24.7	8.08	324	24.9
I_2P_1	5.40	233	23.2	6.77	270	25.1
I_2P_2	7.16	231	31.0	8.24	267	30.8
I_2P_3	4.11	232	17.6	6.58	271	24.3
I_3P_1	4.44	207	21.4	6.07	227	26.7
I_3P_2	6.34	207	30.6	7.58	226	33.5
I_3P_3	3.17	208	15.3	5.32	229	23.2
CD (P=0.05)	1.13			0.29		

of 1.2 and planting in level plots was done. This may be because the frequency of irrigation was more under IW/CPE of 1.2 and level planting which contributed more to profile moisture use due to more evaporative surface available for evaporation. Minimum crop water use was observed when water was applied at IW/CPE of 0.8 and furrow planting was done because the frequency of irrigation was less and furrow planting conserved moisture by exposing less surface to evaporation. In general, there was an increase in crop water use with increase in frequency of irrigation. Gupta *et al.*, 1997 and Kalyan *et al.*, 1996 in their study employed four irrigation schedules to French bean at 0.25, 0.50, 0.75 and 1.0 IW/CPE and found that water use by French bean increased with increasing irrigation while water use efficiency decreased with increasing irrigation level.

Yield

In both the years of study, crop yield was higher under furrow irrigation over other methods at their respective level of irrigation. Highest pod yield (7.95 Mg ha^{-1} and 8.50 Mg ha^{-1}, respectively) was obtained from I_1P_2 treatment where irrigation was given at IW/CPE of 1.2 and furrow planting was done (Table 2). It was also found that this was at par with I_2P_2 treatment where irrigation was given at IW/CPE of 1.0 and furrow planting was done. The yields were higher under furrow planting may be because in this method of planting less area was exposed to atmosphere and the evaporation was also low, this conserved more water in the soil and thus increased the availability of water to the plants maintaining better soil-water-plant relationships. Tomar (2001) studied the response of French bean to irrigation scheduling. He reported that scheduling irrigation at the branching and pod development stages was significantly better than two irrigations at branching and pod development stage and at par with IW/CPE ratios of 0.5 and 0.7 in terms of seed yield In French bean the yields increased with increasing rate of irrigation up to a plateau of 0.75 IW/CPE, (Singh et al., 1999). Hegde and Srinivas (1987), studied the effects of irrigation on yield and water use of French bean plants, irrigated when soil matric potential at 15 cm depth reached -25, -45, -65 or -85 kPa. They reported that highest green pod yield (155.7-169.7 q ha^{-1}) was obtained from irrigating at -45 kPa.

Water use efficiency

Perusal of data from table 2 revealed that the water use efficiency of the crop was higher under furrow method of planting i.e. 31.1 kg ha^{-1}mm^{-1} at irrigation of 0.8 IW/CPE ratio during first and 33.5 Kg ha^{-1} mm^{-1} at irrigation of 0.8 IW/CPE ratio during second year., because frequency of irrigation was less under this ratio least amount of water was applied under this treatment (Table 2). Hedge and Srinivas (1987) also reported that in French bean highest WUE was obtained from irrigating at -45 kPa. The

other treatments were -25, -65 and -85 kPa. Hedge and Srinivas (1990) in another study reported that the dry matter production, green pod yield, nutrient uptake and water use efficiency were significantly higher when the crop was irrigated at -45 kPa matric potential than at -65 or -85 kPa matric potential. Increasing soil moisture stress increased canopy temperature and adversely affected plant water relations. There was a Quadratic relationship between pod yield and evapotranspiration with the yield maximizing Et ranging between 268 and 299 mm. Ravi and Prasad, 1998 in their study on French bean with six levels of irrigation and three levels of nitrogen found that the water use efficiency was maximum with one irrigation.

Soil moisture depletion from 0-60 cm layers was higher with 2-3 irrigations whereas in lower profile (60-90 cm) the relative depletion was more with one irrigation. It was observed that furrow method of planting at all the irrigation levels improved WUE mainly because moisture content in the soil throughout the growing season remained higher (table 1), the yields were higher and crop water use was lower in comparison to ridge and level planting. Prabhakar and Srinivas (1995) and Bhagavantagoudra and Rokhade (2002) reported that alternatively alternate furrow method was found promising in least consumptive use and thus gave higher water use efficiency.

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