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Effects of soil moisture regimes and time of nitrogen applications on seed yield, consumptive use, soil moisture depletion and water use efficiency of frenchbean crop (*Phaseolus vulgaris* L.)

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ABSTRACT

A field experiment was conducted during winter seasons of 2002-03 and 2003-04 at Main Pulses Research Station S.D.A.U., Sardarkrushinagar comprising of three levels of moisture regimes based on IW:CPE ratios (0.6, 0.8 and 1.0) and six levels of time of nitrogen applications. Seed yield increased with increase in levels of moisture regimes from 0.6 to 1.0 IW:CPE ratios. The mean consumptive use of water, water expense and water use efficiency were maximum with higher moisture regimes. Maximum soil water depletion was recorded from the upper soil profile at higher moisture regimes whereas, soil water extraction to a lower depth (61-90 cm) was higher at lower soil moisture regime (0.6). Split application of nitrogen *i.e.* half as basal and remaining half at branching stage recorded maximum water extraction, consumptive use of water, WUE and water expense efficiencies. Application of 100 kg N/ha in two equal split (half as basal and half at branching stage) further improved the seed yield than other mode of nitrogen applications.

Key words : French bean, Soil moisture regime, Water use efficiency, Water expense efficiency

INTRODUCTION

Frenchbean (*Phaseolus vulgaris* L.) is grown in the monsoon season as a rainfed crop in India. It has been introduced in middle gangatic plains as a winter seasons crop and is grown mostly for grain purpose. The introduction of a grain type frenchbean is gaining factors of the farming community because of its higher productivity, high remunerative value and market demand. Frenchbean having adventious roots has a shallow rooting depth and responds favourably to frequent irrigations (Maurer *et al.*, 1969). Frenchbean, being a shy nodulators responds to higher nitrogen for realizing higher yield potentials. Being a newly introduced crop in Gujarat, limited technology for the cultivation of frenchbean is available at present. Hence, an experiment was carried out to work out an optimum irrigation schedule and time of nitrogen application for frenchbean.

MATERIALS AND METHODS

A field experiment was conducted for two consecutive years (2002-03 and 2003-04) to assess the responses of frenchbean to three levels of moisture regimes and six levels of time of nitrogen application at Main Pulses Research Station, S.D. Agricultural University, Gujarat (24^0 19' north and 72^0 19' east). The soil was loamy sand having a soil pH 7.53, organic carbon (0.20 %), available nitrogen (145 kg ha^{-1}) and available phosphorus (53.1 kg ha^{-1}). Soil moisture at one third atmosphere pressure in 0-30, 30-60 and 60-90 cm soil layer was 6.74, 6.39 and 6.32 %, where as at 15 bar atmosphere pressure was 3.57, 3.32 and 3.04 %, respectively. The bulk density of the respective layers was 1.63, 1.65 and 1.65 g/cc. The soil physical constant were determined three days before sowing and were utilized for soil moisture through out the crop season.

Field experiment was laid out in split plot design with four replications. Total eighteen treatment combinations comprising of three levels of moisture regimes (0.6, 0.8 and 1.0 IW:CPE ratios) as main plot and six levels of time of nitrogen applications as a sub plot (*i.e.* 100% N as basal, 50 % N as basal + 50 % N at branching, 50 % N as basal + 25% N at branching + 25 % at flowering, 50% N as basal + 25 % N at branching + 25 % N at podding, 50% N as basal + 25 % N at flowering + 25 % N at podding, 25 % N at basal + 25 % N at branching + 25 % N at flowering + 25 % N at podding). The irrigation was applied when cumulative pan evaporation valued reached 83.3, 62.5, and 50.0 corresponding to 0.6, 0.8 and 1.0 IW:CPE ratios, respectively.

The crop was sown on 8^{th} November 2002 and 12^{th} November 2003. Seeds were sown at 30 x 10 cm spacing by opening the furrow and were placed 5-6 cm depth. A common dose of 40 kg phosphorus per ha (single super phosphate) was applied as a basal dose and nitrogen (urea) was applied as per treatments coincide with

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irrigations. All the cultural operations were carried out as and when required and the crop was harvested on 20th Feb 2003 and 26th Feb 2004.

Irrigations to each plot were applied by parshall flume having a throat width of 15 cm, installed at the head of the experiment plot under free flow conditions. The time required to irrigate the plot was calculated and water was applied across to a depth of 50 mm. Soil moisture depletion was calculated in 0-90 cm soil layers at an interval of 30 cm by the gravimetric method and moisture at the time of sowing and harvesting were also considered. Samples were taken before and after a day of irrigations and also from sowing and harvesting for calculating the soil moisture depletions. Water table depth was always bellow 20 meters from the upper surface layers and did not contribute in supplementing the water need. The total depth of depletion within 0-90 cm deep profile was considered as the actual water use by the crop. WUE was calculated by dividing the seed yield to its corresponding actual water use. The crop harvested from net plot was threshed and seed were cleaned and weighed for seed yield.

RESULTS AND DISCUSSION

The results obtained from the present investigation are summarized below :

Seed yield :

Seed yield of frenchbean was significantly improved with increasing levels of moisture from 0.6 to 1.0 IW:CPE ratios during both the years of investigations and in pooled data also (Table 1). Significantly the highest seed yield of frenchbean was recorded with a soil moisture levels of 1.0 IW:CPE ratio than that of 0.8 and 0.6 IW:CPE ratios. The lowest seed yield was registered at 0.6 moisture regimes. The response of 0.8 moisture regimes was found intermediate. On the basis of pooled results, scheduling of irrigations at higher moisture regimes (*i.e.* 1.0 IW:CPE) was recorded 66 and 28 per cent higher seed yield of frenchbean than that of lower moisture regimes (0.6 and 0.8 IW:CPE). An application of frequent irrigations at shorter interval under higher moisture regimes (*i.e.* 1.0 IW:CPE) did not show any visual stress on various physiological processes of the plant and also helped in proper utilizations of nutrients. Maintenance of adequate moisture of protoplasm might have reduced the viscosity and increased the permeability of both water and nutrients. Dahatonde *et al*. (1992) reported that scheduling of irrigations at 1.2 and 1.0 IW:CPE ratio recorded significantly higher seed yield of frenchbean than that recorded in lower moisture regimes *i.e.* 0.6 and 0.8 IW:CPE. The reduction in seed yield at lower frequencies of irrigations could be attributed to reduce the photosynthate activity by partial closure of stomata and decrease in supply of CO_2 under water stress. Gunton and Evenson (1980) also studied that moisture stress imposed on pre flowering and flowering stages of crop growth reduced seed yield up to 24 to 40 per cent.

Table 1 : Effect of soil moisture regimes and time of nitrogen applications on seed yield and water use efficiency

Treatments	Seed yield kg ha^{-1}			Water use efficiency kg ha^{-1}- mm			Water expense efficiency kg ha^{-1}-mm		
	2002-03	2003-04	Pooled	2002-03	2003-04	Pooled	2002-03	2003-04	Pooled
Main plot (Irrigation levels)									
I_1 0.6 IW:CPE	1309	900	1103	5.5	4.3	4.9	4.4	3.6	4.0
I_2 0.8 IW:CPE	1663	1198	1431	6.1	4.8	5.4	4.8	4.0	4.4
I_3 1.0 IW:CPE	2018	1638	1828	6.5	5.1	5.8	5.1	4.1	4.6
S.E.±									
C.D. (P=0.05)	161	117	89						
Sub-plot (Time of nitrogen applications)									
N_1 100 % N as Basal	1658	1248	1453	5.9	4.7	5.3	4.7	3.9	4.3
N_2 50 % N B+ 50 % N Br	1843	1363	1603	6.2	5.0	5.6	5.3	4.3	4.8
N_3 50 % N B +25 % N Br +25 %N Fl	1757	1314	1535	6.2	5.0	5.6	5.0	4.2	4.6
N_4 50 % N B +25 % N Br +25 % N Pd	1719	1252	1486	6.2	4.9	5.6	4.9	4.0	4.4
N_5 50 % N B +25 % N Fl +25 % N Pd	1513	1161	1337	5.9	4.6	5.3	4.3	3.7	4.0
N_6 25 % N B +25 % N Br +25 %N Fl + 25 % N Pd	1485	1134	1310	5.8	4.6	5.2	4.2	3.6	3.9
S.E.±									
C.D. (P=0.05)	141	112	89						
I x N Interactions									

NB: N = Nitrogen, B = Basal, Br = branching, Fl = flowering, Pd = podding

Seed yield increased significantly due to splitting of nitrogen up to branching stage (1843 and 1363 kg ha^{-1} in 2002-03 and 2003-04, respectively) (Table 1). The increase in seed yield due to application of nitrogen with 50 % N as basal + 50 % N at branching stage (N_2) may be due to increase in the number of pods per plant, number of seeds per pod and 100-seed weight. The splitting of nitrogen in four equal split *i.e.* 25 % N as basal + 25 % N at br + 25 % N at fl + 25 % N at pd stages (N_6) gave significantly the lowest seed yield during both the years of study and in pooled data. Moreover, application of nitrogen in two equal splits (*i.e.* half N as a basal and remaining half N at branching stage) recorded 22 per cent higher seed yield of frenchbean as compared to four equal split (*i.e.* 25 % N as basal + 25 % N at br + 25 % N at fl + 25 % N at pd stages (N_6)) This result corroborates the finding of Kushwaha (1994).

Soil moisture depletion :

A major part of soil moisture was extracted from 0-30 cm soil layer (Table 3). Scheduling of irrigation with 1.0 IW:CPE ratio utilized more water from 0-30 and 31-60 cm soil profile as compared to lower soil profile (61-90 cm). The lowest amount of water was extracted where irrigation was applied at 0.6 IW:CPE ratio. However, from 61-90 cm soil layer, relative water extraction was more in 0.6 IW:CPE ratio as compared to 0.8 and 1.0 IW:CPE ratios. An increase in moisture extraction from upper soil layer (0-30 cm) was due to the increase in the frequencies of irrigations resulting in higher evaporation from top soil layer since, moist conditions remained for longer period and higher root proliferation, mostly in upper soil layer. Thus, more water was used by the plant from the upper layer where as the root penetrates the deeper in search of water when crop experienced the moisture stress. Ravinandan and Prasad (1998) also reported similar results. Relatively higher amount of moisture was extracted from the first soil layer (0-30 cm) by the crop where nitrogen was applied with 50 % as basal and 50 % at branching (N_2). This was might be due to higher concentration of root in the upper soil layer owing to application of nitrogen in splits up to branching stage. As soil profile depth increase, the depletion of moisture were decreased with the nitrogen splitting.

Consumptive use of water (CU) :

Mean consumptive use of water was maximum by scheduling of irrigations at an IW:CPE ratio of 1.0 (315 mm) (Table 2) as compared to scheduling of irrigation at an IW:CPE ratio of 0.6 (223 mm). Frequent irrigation maintained wet surface for longer period, which consequently leads to higher loss of moisture due to evapotranspiration.

An application of half dose of nitrogen as basal and remaining half dose of nitrogen at branching stage (N_2) recorded maximum consumptive use of water and it might be due to higher leaf area index, plant height and higher dry matter production per plant. The lowest consumptive use of water with the application of 25 % N as basal + 25 % N at branching + 25 % N at flowering + 25 % N at podding stage (N_6) might be due to lower growth attributing characters.

Water use efficiencies and water expense efficiencies:

The water use efficiencies and water expense efficiencies were maximum with higher moisture regimes (*i.e.* 1.0 IW:CPE ratio) due to increasing in frequencies of irrigations which increased consumptive use of water

Table 2 : Number of irrigation, total quantity of water to be applied and consumptive use of water of French bean as influenced by soil moisture regimes and time of nitrogen applications

Treatments	Number of irrigations		Total quantity of water to be applied (mm)			Consumptive use of water (mm)		
	2002-03	2003-04	2002-03	2003-04	Mean	2002-03	2003-04	Mean
Main plot (Irrigation levels)								
I_1 0.6 IW:CPE	6	5	300	250	275	238	208	223
I_2 0.8 IW:CPE	7	6	350	300	325	274	251	263
I_3 1.0 IW:CPE	8	7	400	400	400	312	319	315
Sub-plot (Time of nitrogen applications)								
N_1 100 % N as Basal	-	-	-	-	-	280	263	272
N_2 50 % N B+ 50 % N Br	-	-	-	-	-	296	270	283
N_3 50 % N B +25 % N Br +25 %N Fl	-	-	-	-	-	284	266	278
N_4 50 % N B +25 % N Br +25 % N Pd	-	-	-	-	-	278	254	266
N_5 50 % N B +25 % N Fl +25 % N Pd	-	-	-	-	-	257	253	255
N_6 25 % N B +25 % N Br +25 %N Fl + 25 % N Pd	-	-	-	-	-	254	249	252

NB: N = Nitrogen, B = Basal, Br = branching, Fl = flowering, Pd = podding

Table 3 : Soil moisture depletion pattern (%) of frenchbean as influenced by soil moisture regimes and time of nitrogen applications

Treatments	Soil depth (cm)		
	0-30	31-60	61-90
Main plot (Irrigation levels)			
I_1 0.6 IW:CPE	60.82	29.63	9.50
I_2 0.8 IW:CPE	62.43	28.71	8.78
I_3 1.0 IW:CPE	64.28	27.55	8.18
Sub-plot (Time of nitrogen applications)			
N_1 100 % N as Basal	62.32	28.91	8.77
N_2 50 % N B+ 50 % N Br	63.72	27.53	8.75
N_3 50 % N B +25 % N Br +25 %N Fl	62.83	28.39	8.78
N_4 50 % N B +25 % N Br +25 % N Pd	62.24	29.10	8.49
N_5 50 % N B +25 % N Fl +25 % N Pd	62.37	28.45	9.18
N_6 25 % N B +25 % N Br +25 %N Fl + 25 % N Pd	61.56	29.49	8.95

NB: N = Nitrogen, B = Basal, Br = branching, Fl = flowering, Pd = podding

and seed yield of frenchbean proportionately. Therefore, water use efficiency was higher with higher moisture regimes. The water use efficiency was lowered at 0.6 IW:CPE ratio due to limited available water especially in upper soil depth as it dries out. Dahatonde and Nalamwar (1996) and Rama shanker *et al*. (1998) obtained the higher WUE and WEE by irrigating the crop with higher moisture regimes as compared to lower moisture regimes.

Splitting of nitrogen up to branching stages (*i.e*. 50 % N as basal + 50 % N at branching stage) resulted in higher WUE and WEE. The quantity of water applied was constant in all nitrogen treatments, whereas, seed yield was higher due to splitting of nitrogen in two equal splits than that of other mode of nitrogen applications

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