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Effect of irrigation schedules on yield attributes, consumptive use of water, water-use efficciency and moisture-extraction pattern of Frenchbean (*Phaseolus vulgaris*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 1989–90 and 1990–91 to study the effect of 15 irrigation schedules on yield attributes, yield, consumptive use of water, water-use efficiency and moisture-extraction pattern of Frenchbean (*Phaseolus vulgaris* L.). Number of branches/plant, pods/plant, grain yield/plant and seed yield/ha were higher with irrigation at irrigation water : cumulative pan evaporation (IW : CPE) ratio of 6 and 2 irrigations at 25 and 100 days after sowing during first and second years respectively. The 1,000-grain weight was higher with 1 irrigation at 100 days after sowing. Four irrigations at 25, 50, 75 and 100 days after sowing during first year and 2 irrigations at 25 and 100 days after sowing during second year produced higher straw yield/ha. Consumptive use of water and moisture extraction were higher with 3 irrigations at 25, 50 and 75 days and at 25, 75 and 100 days after sowing during first year and with 3 irrigation given at 50, 75 and 100 days after sowing during second year. Water-use efficiency was higher (74.2 kg/ha cm) with irrigation at 0.6 IW : CPE ratio during first year and 2 irrigations at 25 and 100 days after sowing (67.0 kg/ha-cm) during the second year.

Frenchbean or *rajmash* (*Phaseolus vulgaris* L.) is highly sensitive to soil-water balance, and a slight stress may result in reduced yield. In arid regions on an average 25–40 cm water is usually applied to this crop, depending on soil, climate and length of growing season (Kay, 1979). However, optimum requirement of irrigation is to be worked out to get higher yield potential of the crop. Hence effort was yield made to find out optimum irrigation schedules to get higher yield and to determine consumptive use of water, water-use efficiency and moisture-extraction pattern under foot-hill (*tarai*) conditions of Pantnagar, Uttar Pradesh, in the present study.

MATERIALS AND METHODS

The field experiment was conducted with 'Uday' Frenchbean during winter season of 1989–90 and 1990–91 at the Crop Research Centre, Pantnagar, which is under *tarai* belt of Shiwalik range of Himalaya. The soil was silty clay-loam neutral in reaction, rich in organic carbon and in available phosphorus, and medium in available potassium; the top 0–60 cm soil had a bulk density 1.43 g/cm^3, permanent wilting point 5.5% and field capacity 20.9%, on oven-dry weight basis during first

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year, whereas during second year the soil was neutral in reaction, medium in organic carbon, available P, and available K; the top 0—60 cm soil had a bulk density of 1.35 g/cm^3, permanent wilting point 6.6% and field capacity 19.55% on oven-dry-weight basis. Total rainfall received during the entire crop seasons of 1989—90 and 1990—91 was 20.0 and 16.2 cm respectively. The cumulative pan evaporation (CPE) was 41.8 cm during 1989—90 and 56.7 cm during 1990—91 crop season. The treatments comprised 15 irrigation schedules based on days after sowing (DAS) and irrigation water : cumulative pan evaporation (IW : CPE) ratio. The experiment was were laid out in randomized block design, replicated 4 times. The treatments were as follows:

T_1, no irrigation; T_2, 1 irrigation at 25 days after sowing; T_3, 1 irrigation at 50 days; T_4, 1 irrigation at 75 days; T_5, 1 irrigation at 100 days; T_6, 2 irrigations at 25 and 75 days; T_7, 2 irrigations at 25 and 100 days; T_8, 2 irrigations at 50 and 100 days; T_9, 3 irrigations at 25, 50 and 75 days; T_{10}, 3 irrigations at 25, 75 and 100 days; T_{11}, 3 irrigations at 50, 75 and 100 days; T_{12}, 4 irrigations at at 25, 50, 75 and 100 days; T_{13}, irrigations at 0.4 IW : CPE ratio; T_{14}, irrigations at 0.6 IW : CPE ratio; and T_{15}, irrigation at 0.8 IW : CPE ratio.

Irrigation depth of 0.6 cm was kept while applying the irrigation treatment. Recommended cultural practices were adopted as per need of crop.

The soil moisture was determined at planting, just before and 2 days after irrigation and at harvest. Soil samples were drawn from 0—30 and 30—60 cm depths. The moisture (%) was calculated on oven-dry weight basis. Consumptive use was worked out from the loss in soil-profile moisture, effective rainfall and potential evapo-transpiration for 2 days following irrigations. The seasonal consumptive use of water was calculated as per procedure described by Dastane (1967). In present study contribution of groundwater was assumed to be negligible, since Frenchbean being a shallow-rooted crop was not able to extract water from prevailing water-table range (196—224 cm during 1989—90 and 212—234 cm during 1990—91.

RESULTS AND DISCUSSION

Yield attributes

Different yield attributes like number of primary branches/plant, pods/plant, seeds/pod, 1,000-seed weight and grain yield/plant differed significantly due to irrigation treatments. Higher number of primary branches, pods/plant and seed yield/plant might have led to a significantly higher seed yield/ha in treatment receiving 1 irrigation at 75 days and irrigation at 0.6 IW : CPE ratio. Lower number of pods/plant as well as lower 1,000-seed weight (Table 1) might be responsible for yield reduction with treatment having 4 irrigations at 25, 50, 75 and 100 days during first the year. During the second year besides higher number of branches/plant, pods/plant and seed yield/plant, seeds/pod also contributed favourably towards higher yield in treatment having 2 irrigations at 25 and 100 days and lower yield with no irrigation treatment. Reduced irrigation tends to enhance flower production (Mauk *et al.*, 1983). Flower and pod abscission (%) was significantly less under higher irrigations than low irrigations. Pods/plant, 1,000-seed wight and seed yield were reduced significantly by soil-moisture stress during vegetative growth, flowering or from pod development to maturity stages. Under gradually increasing mild-water stress, seed weight

Table 1. Effect of irrigations on yield-contributing characters and yield of Frenchbean (1989–90 and 1990–91)

Treatment	Branches/ plant		Pods/ plant		Seeds/ pod		1,000-seed weight (g)		Seed yield/ plant (g)		Seed yield (kg/ha)		Straw yield (kg/ha)	
	1989–90	1990–91	1989–90	1990–91	1989–90	1990–91	1989–90	1990–91	1989–90	1990–91	1989–90	1990–91	1989–90	1990–91
No irrigation (IR)	3.8	2.5	6.9	5.7	3.1	3.2	470	478	6.0	5.5	1,938	957	2,157	1,852
1 IR at 25 days*	3.9	2.7	7.9	6.7	3.1	2.8	463	468	6.1	6.7	1,990	1,392	2,448	3,021
1 IR at 50 days*	5.4	2.7	9.3	6.4	3.2	2.9	445	457	7.5	6.3	1,979	1,142	2,188	3,546
1 IR at 75 days*	9.1	2.9	12.0	6.1	3.9	3.7	458	460	11.9	7.9	2,007	1,343	2,098	2,701
1 IR at 100 days*	5.0	3.4	6.5	6.7	3.0	3.6	478	493	8.5	6.4	1,875	1,423	2,083	3,732
2 IR at 25 and 75 days*	5.1	2.4	8.9	5.5	3.1	4.3	435	490	7.5	7.1	1,803	1,509	2,583	3,130
2 IR at 25 and 100 days*	4.2	3.8	7.7	7.7	3.0	5.4	453	448	5.7	10.1	1,667	1,957	2,033	4,556
2 IR at 50 and 100 days*	4.2	2.3	7.9	6.3	3.1	2.8	440	463	6.4	5.9	1,819	1,253	1,265	2,327
3 IR at 25, 50 and 75 days*	5.0	2.1	9.3	4.2	3.0	2.8	448	481	8.1	4.0	1,750	1,219	2,229	2,701
3 IR at 25, 75 and 100 days*	7.8	3.1	7.2	6.9	3.2	3.6	443	428	6.2	6.5	1,803	1,843	2,240	2,651
3 IR at 50, 75 and 100 days*	5.5	2.2	8.6	5.0	2.9	3.0	435	440	7.2	5.7	1,642	1,549	2,129	4,293
4 IR at 25, 50, 75 and 100 days*	6.5	2.4	5.1	4.7	2.9	2.8	430	423	6.1	5.3	1,271	1,333	3,854	2,679
IR at 0.4 IW : CPE ratio	4.9	2.5	8.1	4.7	3.3	2.9	430	487	6.8	5.4	1,854	1,077	2,188	3,370
IR at 0.6 IW : CPE ratio	8.5	2.5	9.9	4.8	3.6	2.9	450	428	9.7	4.9	2,021	1,460	2,417	3,417
IR at 0.8 IW : CPE ratio	4.7	2.5	7.9	4.9	3.3	3.4	455	462	7.5	5.9	1,917	1,312	2,104	3,503
CD (P = 0.05)	1.3	0.6	1.7	1.9		0.6	28	41	2.6	2.7	328	338	645	1,284

* Days after sowing

followed by pods/plant were most affected and seeds/pod were the least affected yield attributes, as also reported by Couto (1979).

Yield

Both stage of crop (at which irrigation is applied) and frequency of irrigations affected the total yield. Irrigation treatments significantly affected grain yield/ha during both the years. Irrigation at 0.6 IW : CPE ratio during the first year and 2 irrigations at 25 and 100 days after sowing during the second year gave higher seed yield than other treatments, whereas treatment of 4 irrigations at 25, 50, 75 and 100 days during the first year and no irrigation during the second year gave the lowest yield (Table 1). Flowering and pod-development stages are considered to be the critical stages of Frenchbean for moisture supply (El-Nadi, 1969; Dubetz and Mahalle, 1969). Irrigation at 0.6 IW : CPE ratio (80 days) during the first year and second irrigation of the treatment having 2 irrigations at 25 and 100 days during second year, which coincides with pod-development stage, might have resulted in better pod development and finally higher yield. Large yield depression under moisture stress during flowering and early maturity were reported by and Saraf and Ahlawat (1975). Treatment with 4 irrigations at 25, 50, 75 and 100 days gave lowest yield during the first year. Excess moisture due to rainfall and frequent irrigation might have resulted in lowest yield (Miladnovic and Corokalo, 1976).

Higher straw yield/ha was recorded from treatment having 4 irrigations at 25, 50, 75 and 100 days during first year, and 2 irrigations at 25 and 100 days and 3 irrigations at 25, 75 and 100 days during second year (Table 1). Lower straw yield was recorded from 1 irrigation at 100 days after sowing during the first year and no irrigation treatment during the second year. Parihar and Tripathi (1989) found that stover yield increased with increasing frequency and amount of irrigation.

Consumptive use of water

Consumptive use of water increased with the increase in frequency of irrigation. Consumptive use of water and moisture extraction were higher when 3 irrigations given at 25, 50 and 75 days and at 25, 75 and 100 days during the first year and 3 irrigations at 50, 75 and 100 days during the second year. Lower consumptive use and extraction of water were recorded from 1 irrigation at 100 days and irrigation at 0.4 IW : CPE ratio during first year and second year respectively (Table 2). Similar findings were also reported by Ahlawat and Sharma (1989) and Silveira *et al.* (1984). Consumptive use of water might be higher due to weather parameters, especially evapotranspiration (Vithov, 1975).

Moisture-extraction pattern

Generally contribution of upper 0—30 cm layer in moisture extraction was higher than that of lower or deeper 30—60 cm layer (Table 4). Grewal *et al.* (1984) and Nayar and Singh (1985) reported similar findings. Treatments with lower number of irrigations resulted in more contribution of water extraction from lower or deeper layers, whereas with more irrigations upper layer contributed more, as the Frenchbean is a shallow-rooted crop (Dubetz and Mahalle, 1969).

Water-use efficiency

There is inverse relationship between the moisture stress and water-use efficiency (Sindhwani and Moolani, 1969). Water-use efficiency was higher with irrigation at 0.4

Table 2. Moisture extraction, contribution from different soil layers and consuumptive use and water-use efficiency under different levels irrigation in Frenchbean (1989–90 and 1990–91)

Treatment	Moisture extraction (cm) from different soil layers (cm)						Total consumptive use of water (cm)		Water-use efficiency (kg grain/ha-cm)	
	1989–90			1990–91						
	0–30	30–60	Total	0–30	30–60	Total	1989–90	1990–91	1989–90	1990–91
No irrigation (IR)	4.6 (54.9)	3.8 (45.1)	8.3	4.6 (62.6)	2.8 (37.4)	7.4	28.31	21.98	68.5	43.5
1 IR at 25 days*	5.3 (47.4)	5.8 (52.6)	11.1	5.8 (54.0)	4.9 (46.0)	10.7	31.50	25.80	63.2	54.0
1 IR at 50 days*	4.4 (49.5)	4.5 (50.5)	8.8	7.0 (47.3)	7.8 (52.7)	14.9	28.82	29.73	68.7	38.4
1 IR at 75 days*	3.9 (53.6)	3.4 (46.4)	7.3	4.0 (54.4)	3.4 (45.6)	7.3	28.09	22.37	71.5	60.0
1 IR at 100 days*	3.0 (39.8)	4.5 (60.2)	7.5	3.4 (49.2)	3.6 (50.8)	7.0	25.49	22.43	73.6	63.4
2 IR at 25 and 75 days*	8.3 (59.2)	5.8 (40.8)	14.1	6.1 (37.6)	10.1 (62.4)	16.1	35.32	31.67	51.1	47.7
2 IR at 25 and 100 days*	8.8 (51.4)	8.3 (48.6)	17.1	6.3 (47.5)	7.0 (52.5)	13.3	35.44	29.23	47.0	67.0
2 IR at 50 and 100 days*	6.1 (49.8)	6.2 (50.2)	12.3	7.9 (55.0)	6.5 (45.0)	14.3	30.33	30.08	60.0	41.7
3 IR at 25, 50 and 75 days*	9.6 (52.0)	8.8 (48.0)	18.4	10.0 (51.6)	9.4 (48.4)	19.3	38.96	35.16	44.9	34.7
3 IR at 25, 75 and 100 days*	12.5 (64.1)	7.0 (35.9)	19.5	7.3 (49.6)	7.4 (50.4)	14.7	37.71	30.13	47.8	61.2
3 IR at 50, 75 and 100 days*	8.1 (55.2)	6.6 (44.8)	14.7	9.6 (47.1)	10.7 (52.9)	20.3	33.56	36.49	48.9	42.5
4 IR at 25, 50, 75 and 100 days*	7.6 (62.8)	4.5 (37.2)	12.1	9.4 (48.8)	9.9 (51.2)	19.3	31.41	36.00	47.9	37.0
IR at 0.4 IW : CPE ratio	4.2 (52.6)	3.8 (47.4)	8.0	2.8 (44.9)	3.4 (55.1)	6.2	27.95	20.81	66.3	51.8
IR at 0.6 IW : CPE ratio	4.5 (66.8)	2.3 (33.2)	6.8	7.9 (55.2)	6.4 (44.8)	14.4	27.25	24.75	74.2	59.0
IR at 0.8 IW : CPE ratio	8.3 (49.8)	8.4 (50.2)	16.6	7.1 (41.6)	9.9 (58.4)	17.0	37.16	33.12	51.6	39.6

* Days after sowing

IW : CPE ratio receiving no irrigation (74.2 kg seed/ha-cm) and 1 irrigation at 100 days after sowing (71.5 kg grain/ha-cm) during the first year, 2 irrigations at 25 and 100 days after sowing (67.0 kg grain/ha-cm) during the second year (Table 3). Higher water-use efficiency in these treatments might be due to production of relatively higher grain yields with minimum water use. Dobaria *et al.* (1985) and Maity and Jana (1987) also reported similar results.

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