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Yield, economics and water use of fenugreek (*Trigonella foenum-graecum*) as influenced by irrigation and weed management practices

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ABSTRACT

Field experiment was conducted during *rabi* seasons of 2006-07 and 2007-08 at Sardarkrushinagar to study the effect of irrigation scheduling and weed control on fenugreek. Irrigation at 1.0 IW/CPE ratio producing higher yield attributes, *viz.* length of pod or pods/plant, seeds/pod, 1,000-seed weight resulted in significantly higher seed yield (1.47 t/ha), net returns (Rs 25,487/ha) and consumptive use of water over 0.6 and 0.8 ratios. However, water use efficiency and water expense efficiency were higher with 0.8 IW/CPE ratio. Weed population as well as dry weight increased with increasing levels of IW/ CPE ratio from 0.6 to 1.0. Application of pendimethalin @ 0.75 kg/ ha with inter-culture at 40 days after sowing (DAS) and hand-weeding at 20 and 40 DAS were found as effective as weed free treatment in respect of yield, net returns and water use efficiency parameters. Thus, application of irrigation at 1.0 IW/CPE ratio along with weed control by pre-emergence application of pendimethalin @ 0.75 kg/ha + inter-culture at 40 DAS is better for getting higher yield and net return from fenugreek.

***Key words**:* Economics, Fenugreek, Water management, Water use

Fenugreek (*Trigonella foenum-graecum* L.) is an important seed spice crop of arid and semi-arid region of India. It is mainly grown in Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Haryana, Punjab, Bihar and Andhra Pradesh. The seeds of fenugreek are used as a condiment and seasoning agent for garnishing and flavouring dishes. Water is an indispensable factor for every metabolic activity of plant and limited quantity of water available for irrigation calls for scheduling of irrigation to improve water productivity of fenugreek. Recently irrigation is being scheduled on the basis of climatological approach which is now considered as most scientific, since it integrate all weather parameters giving them natural weightage in a given climate-plant continuum (Parihar *et al.*,1976). The highest seed yield of fenugreek was obtained with irrigation at IW/CPE ratio of 1.0 at Nadia, West Bengal (Dutta and Chatarjee, 2006). Weed is an important factor responsible for causing tremendous loss in fenugreek owing to initial slow growth which leads to severe crop-weed competition and reduces growth and yield by as high as 91.4% (Mali and Suwalka, 1987). Weeds in a crop field compete with crop and reduce the yield, increase evapo-transpiration, water needs and decrease water use efficiency. The information on weed and water interaction and its effect on crop growth and yield are meagre. Hence, there is urgent need to generate precise information on irrigation requirement and weed management in fenugreek.

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MATERIALS AND METHODS

Field experiment was conducted at Sardarkrushinagar, Dantiwada Agricultural University, Sardar Krushinagar geographically situated at 24^0 19' North latitude and 72^0 19' East longitude of North Gujarat agro-climatic region, during *rabi* seasons of 2006-07 and 2007-08 on different field each year. No rainfall was received during experimental period. The soil of the experimental field was loamy sand having field capacity moisture of 7.09 and 7.14% and permanent wilting point 2.40 and 2.42% and soil moisture before sowing was 5.5 and 5.7%, pH 7.75 and 7.73 and electrical conductivity (EC) 0.12 and 0.11 dS/m, respectively during 2006-07 and 2007-08. The soil in both the sites was low in organic carbon (0.17 and 0.22%) available nitrogen (152.8 and 165.3 kg/ha), medium in available P (18.0 and 21.0 kg/ha) and high in available K (216.9 and 220.6 kg/ha). The experiment was laid out in split- plot design with four replications, keeping three levels of irrigation [0.6, 0.8 and 1.0 irrigation water (IW) cumulative pan evaporation (CPE) ratio] in main plot and six weed control treatments [weedy check, weed free, hand weeding (HW) at 20 and 40 days after

sowing (DAS), HW at 20 DAS + inter-culture (IC) at 40 DAS, pre-emergence (PE) application of pendimethalin @ 0.75 kg/ ha and pendimethalin + IC at 40 DAS] in sub-plots. Fenugreek (GM-2) was sown in lines 30 cm apart on 13 and 21 November in 2006 and 2007, respectively using a seed rate of 20 kg /ha. A full dose of 20 kg N and 17.6 kg P was drilled manually through DAP and urea at the sowing. A total of 623.3 and 618.9 mm water was evaporated during crop season (from sowing to harvesting) in 2006-07 and 2007-08, respectively. Irrigation water was measured by parshall flume and total of 7, 8 and 10 irrigations of 5 cm each at IW/CPE ratio of 0.6, 0.8 and 1.0, respectively were provided during both the seasons (Table 4). Pendimethalin @ 0.75 kg/ha was applied two days after sowing following the post-sowing irrigation with a spray volume of 600 litres/ha. In weed free plots, the weeds were removed manually after every seven days to ensure complete weed free condition. Periodic soil samples at 15 cm interval up to 75 cm depth with the help of a screw auger were taken and dried at 105°C till constant weight is attained. Soil moisture percentage and consumptive use of water (CUW) were worked out by using the formula suggested by Dastane (1972). Monocot, dicot and sedge weed population at two representative sites from each plot were taken at maturity using 0.25 m^2 quadrate and then converted into number of weeds/m^2. The data were subjected to square root transformation $\ddot{O}(x+0.5)$ to normalize their distribution. The economics of the treatment was calculated based on prevailing prices of input and output. Benefit: cost ratio was calculated by dividing net return with cost of cultivation. The trend of response of irrigation scheduling as well as weed control methods was same during both the years, therefore, the pooled results are presented for drawing valid conclusion.

RESULTS AND DISCUSSION

Weed flora

The weed flora emerged during the experimentation were: grasses like *Cynodon dactylon, Digitaria sanguinalis* L., and *Polycurpea corymbosa* L.; sedges like *Cyprus rotundus* L. and *C iria* L. and broad leaved weeds like *Chenopoodium album* L.; *Melilotus alba* L.; *Convolvulus arvensis* L.; *Anagalis arvensis, Phyllanthus niruri* L. etc. These weeds emerged along with germination of crop and thereafter continued throughout the growth stages. The weed population and weed dry weight at maturity increased significantly with increasing levels of irrigation i.e. from IW/CPE ratio of 0.6 to 1.0. Though weed control efficiency (WCE) was not affected due to IW/CPE ratio but lowest weed index (WI) was obtained with irrigation at 0.6 ratio. These results confirm the findings of Singh *et al*. (2001).

The number of dicot and sedges were the lowest with pendimethalin + IC at 40 DAS followed by two HW at 20 and 40 DAS and one HW at 20 DAS + IC at 40 DAS. The number of monocot weeds and dry weight of all weeds was the lowest with two HW at 20 and 40 DAS. The lowest weed population at maturity in pendimethalin + IC might be due to effective weed control from the very beginning due to herbicide application and inter-culture operation at 40 DAS which resulted in effective weed control (Table 2). Tiwari *et al*. (2006) reported reduced weed population and weed biomass with application of pendimethalin @ 1.0 kg /ha+ HW at 25 DAS

Yield attributes and yield

The yield attributes, seed and biological yields were highest due to irrigation at IW/CPE ratio of 1.0 followed by 0.8 ratio (Table 1). Application of irrigations at 1.0 IW/CPE ratio resulted in 10 and 38% higher seed yield over 0.8 and 0.6 IW/CPE ratio, respectively. The lowest seed and biological yields were recorded with irrigation at 0.6 IW/CPE ratio. The increase in seed and biological yield with 1.0 IW/CPE ratio could be explained by the fact that frequent irrigations under this treatment facilitated maintenance of optimum moisture level in soil as well as in plant during entire growth period which resulted in better translocation of photosynthates from source to sink of fenugreek. These findings are in agreement with those of Dutta and Chatarjee (2006).

Application of pendimethalin + IC at 40 DAS and HW at 20 and 40 DAS were found as effective as weed free treatment in respect of yield attributes, seed and biological yield which were significantly higher over rest of the treatments. This might be due to significant reduction of weed population and biomass which might have resulted in efficient use of moisture, space, and light thereby resulting in significant increase in yield attributes and yield of fenugreek over weedy check. Similar views were expressed by Tiwari *et al*. (2006) and Patel *et al*. (2007).

Irrigation at 1.0 IW /CPE ratio with weed free treatment resulted in higher seed and biological yield that being at par with irrigation at 1.0 IW/CPE ratio + pendimethalin + IC at 40 DAS was significantly higher over rest of the treatments (Table 3). Effective weed control with pendimethalin + IC at 40 DAS and two HW at 20 and 40 DAS along with adequate availability of moisture at 1.0 IW/CPE ratio produced higher growth and yield attributes which in turn resulted higher seed and biological yields.

Water use

The consumptive use of water (CUW) was higher with irrigation at 1.0 IW/CPE ratio but water use efficiency

(WUE) and water expanse efficiency (WEE) were higher at 0.8 ratio (Table 1). This might be on account of ease with which moisture was available for crop growth due to more number of irrigations at 1.0 IW/CPE ratio which enhanced the CUW of water by luxuriant plant growth. The higher CUW at 1.0 IW/CPE ratio reduced WUE. But at 0.8 IW/CPE ratio, WUE was the highest due greater increase in seed yield as compared to increase in quantity of water used. These findings are similar to those of Patel *et al*.(2007) in fennel.

Weedy check has higher CUW might be due to presence of higher weed canopy, which resulted in more evapo–transpiration loss of water. This was reflected in the weed free treatment where nearly absence of weeds resulted in the lower water use. Significantly the highest WUE and WEE were recorded in weed free treatment that was at par with application of pendimethalin + IC at 40 DAS and two HW at 20 and 40 DAS. The lowest WUE

Table 1. Yield attributes, seed yield and biological yield of fenugreek as influenced by irrigation levels and weed management practices (pooled data of 2006-07 and 2007-08)

Treatment	Pods/ plant	Seeds/ pod	1,000 seed weight (g)	Seed yield (t /ha)	Biological yield (t/ha)	CUW (mm)	WUE (kg/ha-mm	WEE (kg/ha -mm)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	BCR
Irrigation level (IW/CPE ratio)											
0.6	20.4	10.4	10.3	1.07	3.20	306.5	3.55	3.06	19,938	15,789	0.79
0.8	25.9	13.1	11.9	1.35	4.03	344.0	3.94	3.37	21,088	23,683	1.11
1.0	28.0	14.8	12.9	1.47	4.31	409.9	3.63	2.95	23,388	25,487	1.08
SEm±	0.4	0.2	0.2	0.02	0.06	5.0	0.06	0.04			
CD (P=0.05)	1.1	0.6	0.5	0.06	0.19	15.4	0.18	0.14			
Weed management practice											
Weedy check	17.9	9.2	8.6	0.94	2.86	377.2	2.52	2.27	19,897	11,321	0.57
Weed free	28.2	14.5	13.2	1.48	4.38	337.7	4.39	3.56	26,237	26,237	1.14
HW at 20 and 40 DAS	27.4	14.1	12.8	143	4.27	344.9	4.16	3.45	22,026	25,368	1.13
HW at 20 DAS and IC at 40 DAS	24.6	12.6	11.4	1.29	3.84	357.7	3.60	3.09	21,496	21,293	0.98
Pendimethalin @ 0.75 kg/ha	22.9	11.8	10.9	1.20	3.58	366.8	3.28	2.90	20,921	18,952	0.90
Pendimethalin @0.75 kg/ha+IC at 40 DAS	27.6	14.2	13.0	1.45	4.29	336.4	4.30	3.48	21,321	26,748	1.25
SEm±	0.4	0.2	0.2	0.02	0.06	6.4	0.06	0.05			
CD (P=0.05)	1.0	0.5	0.5	0.05	0.17	18.1	0.16	0.13			

Table 2. Weed flora dry weight of weed, weed control efficiency and weed index at maturity as influenced by irrigation levels and weed management practices in fenugreek (pooled data of 2006–07 and 2007–08)

Treatment	Weed flora (Number of weeds/m^2)			Dry weight of weed (g /m^2)	WCE (%)	Weed index (%)
	Monocot	Dicot	Sedges			
Irrigation level (IW/CPE ratio)						
0.6	4.27 (20.8)	4.41 (23.4)	2.73 (8.3)	7.56 (67.45)	46.87	9.92
0.8	4.48 (22.9)	4.60 (25.7)	2.86 (9.3)	7.76 (71.30)	46.91	13.20
1.0	4.61 (24.3)	4.70 (26.8)	2.91 (9.7)	8.07 (76.95)	46.14	13.17
SEm±	0.05	0.05	0.03	0.06		
CD (P=0.05)	0.15	0.14	0.09	0.17		
Weed management practice						
Weedy check	6.56 (42.0)	7.82 (60.7)	4.73(21.9)	11.64(135.12)	0.00	35.93
Weed free	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71(0.00)	100.00	0.00
HW at 20 and 40 DAS	4.51 (19.9)	4.09 (16.3)	2.52 (5.9)	7.98(63.26)	53.01	2.98
HW at 20 DAS and IC at 40 DAS	4.60 (20.7)	4.54 (20.1)	2.78 (7.3)	8.17(65.84)	51.12	12.99
Pendimethalin @ 0.75 kg/ha	5.28 (27.5)	6.32 (39.6)	3.84(14.3)	9.36(87.26)	35.01	18.58
Pendimethalin @ 0.75 kg/ha + IC at 40 DAS	5.05 (25.2)	3.94 (15.1)	2.43 (5.4)	8.95(79.90)	40.71	2.11
SEm±	0.05	0.05	0.03	0.07		
CD (P=0.05)	0.14	0.13	0.09	0.21		

Data subjected to square root transformation ($\sqrt{x+0.5}$) and figures in parenthesis are original values

Table 3. Seed yield, biological yield, number of pods/plant, number of seeds/pod as and net return as influenced by interaction effect between irrigation levels and weed management practices (pooled data of 2006-07 and 2007-08)

Weed management practice	IW/CPE ratio														
	Seed yield (t/ ha)			Biological yield (t/ ha)			Pods /plant			Seeds /pod			Net returns (Rs./ha)		
	0.6	0.8	1.0	0.6	0.8	1.0	0.6	0.8	1.0	0.6	0.8	1.0	0.6	0.8	1.0
Weedy check	0.86	0.93	1.02	2.74	2.30	3.02	16.40	17.85	19.34	8.36	9.01	10.19	10,520	11,445	12,000
Weed free	1.19	1.60	1.70	3.59	4.61	4.95	22.64	29.80	32.30	11.54	15.05	17.02	18,239	29,012	31,461
HW at 20 and 40 DAS	1.16	1.50	1.65	3.53	4.47	4.81	22.15	28.71	31.29	11.29	14.50	16.49	17,992	27,781	30,330
HW 20 DAS and IC at 40 DAS	1.04	1.32	1.50	3.18	3.94	4.40	19.83	25.30	28.60	10.10	12.77	15.07	14,764	22,676	26,438
Pendimethalin @ 0.75 kg/ha a (PE)	1.00	1.28	1.32	3.04	3.84	3.85	18.97	24.68	25.06	9.67	12.46	13.21	13,839	22,171	20,846
Pendimethalin @ 0.75 kg/ha-1 + IC at 40 DAS (PE)	1.19	1.50	1.70	3.55	4.48	4.83	22.40	28.87	31.62	11.41	14.57	16.67	19,381	29,014	31,850
SEm±	0.04	0.03	0.03	0.12	0.10	0.10	0.68	0.63	0.63	0.35	0.32	0.32			
CD (P=0.05)	0.11*	0.09**	0.09***	0.33*	0.29**	0.29***	1.96*	1.77**	1.77***	1.00*	0.91**	0.91***			

*CD for irrigation levels means at same level of weed management practices
**CD for weed management practices means at same level of irrigation mean
** CD for interaction effect between irrigation and weed management practices

Table 4. Irrigations applied in fenugreek during 2006-07 and 2007-08

Irrigation No.	0.6 IW/CPE ratio				0.8 IW/CPE ratio				1.0 IW/CPE ratio			
	Date of irrigation		Irrigation interval		Date of irrigation		Irrigation interval		Date of irrigation		Irrigation interval	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
1st	13.11.06	21.11.07	-	-	13.11.06	21.11.07	-	-	13.11.06	21.11.07	-	-
2nd	18.11.06	26.11.07	5	5	18.11.06	26.11.07	5	5	18.11.06	26.11.07	5	5
3rd	07.12.06	18.12.07	19	22	02.12.06	14.12.07	14	18	29.11.06	11.12.07	11	15
4th	28.12.06	11.01.08	21	24	17.12.06	31.12.08	15	17	11.12.06	24.12.07	12	13
5th	20.01.07	02.02.08	23	22	05.01.07	16.01.08	19	16	25.12.06	07.01.08	14	14
6th	09.02.07	20.02.08	20	18	21.01.07	03.02.08	16	18	08.01.07	20.01.08	14	13
7th	27.02.07	20.02.08	18	14	05.02.07	17.02.08	15	14	21.01.07	03.02.08	13	14
8th					20.02.07	29.02.08	14	12	02.02.07	14.02.08	12	10
9th									14.02.07	24.02.08	12	9
10th									24.02.07	03.03.08	10	8

Date of sowing: 13 and 21 November of 2006 and 2007, respectively; Date of harvesting: 17 and 26 March of 2007 and 2008, respectively

and WEE were obtained in weedy check followed by Pendimethalin (Table 1). This was due to lower CUW and higher seed yield in weed free and reverse in weedy check treatments.

Economics

Significantly higher net returns were recorded with 1.0 IW/CPE ratio but B:C ratio (BCR) was higher with 0.8 IW/CPE ratio. The higher net returns was due to higher seed yield. These results are in conformity with the findings of Dutta and Chatarjee (2006). Pre-emergence application of pendimethalin @ 0.75 kg/ha + IC at 40 DAS exhibited the highest net return and BCR followed by weed free and two hand weeding at 20 and 40 DAS which were at par with each other and significantly higher over rest of the weed management treatments. These results corroborate with the findings of Patel and Mehta (1989).

The highest net returns and BCR was recorded by irrigation at 1.0 IW/CPE ratio with pendimethalin + IC at 40 DAS. These results corroborate with those of Dungarwal *et al.* (2002).

Thus it can be inferred that irrigation at 1.0 IW/CPE ratio with pre emergence application of pendimethalin @ 0.75 kg /ha + inter-culture at 40 DAS is most effective for realising higher yield and returns from fenugreek cultivation in North Gujarat agro-climatic region.

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