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Effect of irrigation schedule and organic manures on growth and water use efficiency of fenugreek (*Trigonella foenum-graecum* L.) under middle Gujarat conditions

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Abstract

A field experiment was conducted during *rabi* seasons of 2010-11 and 2011-12 at College Agronomy Farm, to study the effect of irrigation levels at vegetative and reproductive phases with and without organic manures on growth, yield and consumptive use of fenugreek (*Trigonella foenum-graecum*L.). Significantly maximum values of growth attributes were obtained with irrigation applied at 0.8 IW: CPE + 1.0 IW: CPE (I_3) during vegetative and reproductive stages, respectively. Similarly, all the yield attributes of fenugreek *viz.*, number of pods plant^{-1} (55.98), number of grains pod^{-1} (16.48), grain yield plant^{-1} (7.40 g) and test weight (12.33 g) were recorded significantly higher under with application of irrigation at 0.6 IW: CPE +1.0 IW: CPE (I_2) over I_1 and I_4 and remained at par with I_3. In addition, significantly higher grain yield of fenugreek was recorded (1827 kg ha^{-1}) with the application of irrigation at 0.6 IW: CPE + 1.0 IW: CPE (I_2) over all other treatments except the treatment I_3 (0.8 IW: CPE + 1.0 IW: CPE) which was also equally effective. Treatment I_3 (0.8 IW: CPE + 1.0 IW: CPE) recorded the maximum moisture content (9.64%) before irrigation while treatment I_2 (0.6 IW: CPE +1.0 IW: CPE) recorded the highest WUE (6.61 kg ha^{-1} mm) and being at par with I_1 (6.51 kg ha^{-1} mm). Significantly higher grain yield (1831 kg ha^{-1}), straw yield (2712 kg ha^{-1}) and the moisture content before irrigation (9.08 %) and WUE (6.58 kg ha^{-1} mm) was recorded with application of FYM 5 t ha^{-1} + CC 1 t ha^{-1} over no FYM application but FYM alone (M_1) also remained as good as M_2.

Key words : Castor cake, FYM, fenugreek, irrigation, water use efficiency

Introduction

India is the largest producer and consumer of seed spices in the world. Rajasthan and Gujarat has been emerged as "seed spice bowl" and together contribute more than 80 per cent of total seed spices produced in the country and our country is in position to contribute 51 per cent of the total global demand. India occupies a prime position among fenugreek growing countries of the world. The total area under fenugreek is 0.91 lakh hectares with annual production of 1.11 lakh tonnes (Annonymous 2016). The productivity of this crop is controlled by many factors, of which mineral nutrition and irrigation are the most important factors. Therefore, to sustain the productivity of land and sustainability in the productivity of crop, integration of organic manures with chemical fertilizers and timing of irrigation interval with the stages of crop growth might bring about a reduction in the number of irrigations and results in an economic crop yield. Hence, the present experiment was conducted to study the effect of irrigation at vegetative and reproductive phases with and without organic manures on growth, yield and nutrient content and uptake of fenugreek.

Materials and methods

A field experiment was conducted during *rabi* seasons of 2010-11 and 2011-12 at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat.The soil of the experimental plot was loamy sand in texture. It was low in organic carbon and available

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nitrogen, while medium in available phosphorus and high in available potash with pH 7.9 and EC 0.11 dS m^{-1}. There were twelve treatment combinations comprising of four irrigation schedules and three levels of organic manures which were tested in a split plot design with four replications. Irrigation schedule treatments were allotted in the main plots and organic manures in sub plots. The treatments consisted of four irrigation schedules (at vegetative and reproductive phase) *viz.*, I_1: (0.6 + 0.8 IW: CPE ratio); I_2: (0.6 + 1.0 IW: CPE ratio); I_3: (0.8 + 1.0 IW: CPE ratio) and I_4 (At critical growth stages) and three levels of organic manures *viz.*,M_0 (No FYM), M_1 (FYM 10 t ha^{-1}) and M_2 (FYM 5t ha^{-1} + Castor Cake 1 t ha^{-1}). A basal dose of recommended phosphorus (40 kg P_2O_5 ha^{-1}) was applied in the form of DAP to all the plots, whereas organic manures were applied as per treatments through FYM and castor cake. Fenugreek variety GF-2 was used for sowing during *rabi* seasons of both the years. The seeds were sown manually 2-3 cm deep in previously opened furrows as per the treatments with a recommended seed rate of 25 kg ha^{-1}. The quantity of irrigation water applied in each experimental plot was measured with a 7.5 cm throat size Parshall Flume installed in the main water channel near the field head. One common irrigation of 80 mm depth was given to all the plots for assured germination and crop establishment. Thereafter, irrigations were scheduled according to treatments viz., I_1, I_2 and I_3 based on variable IW: CPE ratio at vegetative and reproductive phases when cumulative pan evaporation (CPE) reading showed the required values with fixed depth of 50 mm water at each irrigation and in treatment I_4, based on critical crop growth stages. The cumulative pan evaporation (CPE) values were calculated from daily pan evaporation measured with the help of USWB Class-'A' open pan evaporimeter installed at the meteorological observatory, College Agronomy Farm, which was in the proximity of the experimental plot. Five critical growth stages were selected viz., early vegetative growth, branching, flowering, pod formation and pod development to apply irrigations in treatment I_4.

Results and discussion

Effect of irrigation

Irrigation levels significantly influenced growth parameters, yield attributes and yield of fenugreek. Application of irrigation at 0.6 IW: CPE + 1.0 IW : CPE (I_2) at vegetative and reproductive phases, respectively recorded significantly higher grain yield of fenugreek (1827 kg ha^{-1}) over all other treatments except the treatment I_3 (0.8 IW : CPE + 1.0 IW : CPE) which was also found at par (1796 kg ha^{-1}). While, in case of straw yield, irrigation practiced at 0.8 IW: CPE + 1.0 IW: CPE (I_3) produced significantly highest straw yield of fenugreek with the value of 2700 kg ha^{-1}. Higher yield with higher levels of irrigation might be due to its key role in root development by reducing mechanical resistance of soil, higher transpiration, greater nutrient uptake and more photosynthesis due to metabolic activities in the plant. (Bhunia *et al.*, 2006). The other reason of yield increase might be that scheduling irrigation at 1.0 IW: CPE ratio at reproductive phase created longer reproductive period with larger photosynthetic surface and reproductive storage capacity to attain higher allocation of net photosynthates to grain yield of fenugreek.

The growth parameters were appreciably increased due to different irrigation schedules (Table 1). Significantly maximum values of all the growth attributes *viz.*, plant height (at 90 DAS), dry matter accumulation $plant^{-1}$ (at 90 DAS), number of branches per plant, number and dry weight of nodules per plant at 40 DAS were obtained with irrigation applied at 0.8 IW : CPE + 1.0 IW : CPE (I_3) during vegetative and reproductive stages, respectively. The optimum moisture supplies under more frequent irrigation promoted the division and expansion of cell components and thereby stem elongation, which virtually increased the plant growth in terms of plant height, adequate moisture in optimum condition during active growth period might helped in increasing leaf area and more plant spread due to accelerated photosynthetic activity and more carbohydrate synthesis and translocation of nutrients in the plant body which ultimately helped in increased branching and dry matter accumulation.These results also corroborate with the findings of Mehta *et al.*, (2010).

Similarly, all the yield attributes of fenugreek *viz.*, significantly higher number of pods $plant^{-1}$ (55.98), number of grains pod^{-1} (16.48), grain yield $plant^{-1}$ (7.40 g) and test weight (12.33 g) were recorded under the treatment receiving irrigation at 0.6 IW: CPE +1.0 IW: CPE (I_2) over I_1 and I_4 and remained at par with I_3 (Table 1).This might be due to the fact that during vegetative period, crop received irrigation with greater interval of 25 to 27 days i.e., at 0.6 IW: CPE but when the crop reached at reproductive stage, more frequent irrigations were applied at an interval of 11 to 14 days (i.e., at 1.0 IW: CPE) based on evaporative demand of atmosphere. This has resulted in water stress in the vegetative stage that stimulated the growth of reproductive parts which might have caused higher reproductive efficiency of plants on account of improved synchrony in flowering and higher conversion rates of flowers to pods and pods to seed. Similar results

Table 1. Effect of irrigation scheduling and organic manures on growth and yield attributes of fenugreek (pooled data of two years).

Treatments	height (cm)	Dry matter (g)	Branches Plant^{-1}	No. of nodules plant^{-1}	Dry weight of nodules (mg)	Pods plant^{-1}	Seed pod^{-1}	Test weight (g)
A Main Plot :Irrigation scheduling) (Vegetative phase + Reproductive phase)								
I_1: 0.6 IW : CPE + 0.8 IW : CPE	49.12	8.42	5.38	22.83	125.1	44.91	13.51	10.50
I_2: 0.6 IW : CPE + 1.0 IW : CPE	54.20	10.75	6.11	25.42	138.3	55.98	16.48	11.91
I_3: 0.8 IW : CPE + 1.0 IW : CPE	61.10	12.39	6.37	28.54	140.4	54.42	16.28	12.33
I_4: At Critical growth stages	57.78	11.90	5.74	25.83	129.0	48.28	15.78	11.17
S.Em +	1.07	0.35	0.12	0.48	1.61	1.31	0.37	0.23
CD(P= 0.05)	3.19	1.15	0.35	1.42	4.78	3.88	1.09	0.69
B Sub Plot :Organic manures								
M_0: No FYM	52.87	9.97	5.53	24.06	128.8	48.36	14.52	10.83
M_1: FYM 10 t ha^{-1}	56.29	11.13	5.92	26.47	134.5	51.76	16.02	12.18
M_2: FYM 5 t ha^{-1} + Castor Cake 1 t ha^{-1}	57.48	11.50	6.24	26.44	136.3	52.57	16.00	11.43
S.Em +	0.63	0.41	0.10	0.41	1.28	0.76	0.23	0.21
CD(P= 0.05)	1.76	NS	0.29	1.15	3.59	2.14	0.64	0.58

were also reported by Nautiyal *et al.*, (1999) in ground nut.

Further results showed that treatment I_3 (0.8 IW: CPE + 1.0 IW: CPE) recorded the maximum moisture content (9.64%) before irrigation (Table 2). The maximum moisture content shown by the treatment I_3 might be due to more frequent irrigation applied under this treatment during the entire growth period of crop. These results are also supported by the findings of Bhunia *et al.*, (2006). Treatment I_2 (0.6 IW: CPE + 1.0 IW: CPE) recorded the highest WUE (6.61 kg ha^{-1} mm) and being at par with I_1 (6.51 kg ha^{-1} mm) proved significantly superior over I_3 and I_4 by 10.35 and 5.42 per cent respectively. While lowest WUE (5.99 kg ha^{-1} mm) was registered under treatment I_3 (0.8 IW: CPE + 1.0 IW: CPE). Unlike consumptive use of water, the WUE decreases with each successive increase in IW: CPE ratio. When more quantity of water was applied (I_3), the reduction in WUE could be due to more moisture used for evaporation rather than for production, thereby reducing the WUE (Table 2). The higher WUE with lower irrigation (I_1 and I_2) was resulted from either less water loss due to evapo-transpiration under limited water supply or more diversion of photosynthates in the production of economic yield. Findings of Balasio *et al.*, (2004) are in conformity with these results who reported that imposition of some stress by longer irrigation interval or skipping irrigation during the early vegetative or during maturation could attain similar economic yield as well as saving irrigation water and improving WUE.

Treatment I_2 (Irrigations at 0.6 + 1.0 IW: CPE ratio) fetched maximum gross and net return of ` 92632 and ` 68173 ha^{-1}, respectively, followed by treatment I_3 (Irrigations at 0.6 + 0.8 IW: CPE ratio) which realized gross and net income of ` 91150 and ` 66025 ha^{-1}, respectively.

Effect of organic manures

Significantly higher periodical plant height (49.58 cm at 60 DAS and 57.48 cm at 90 DAS), dry matter accumulation (except at 30 DAS), number and dry weight of nodules (26.47 and 134.5 mg) and branches plant^{-1} (6.24) were recorded under treatment M_2 (FYM 5 t ha^{-1} + CC 1 t ha^{-1}) which remained at par with FYM 10 t ha^{-1} (M_1) with respect to all growth parameters (Table 1). Likewise all the yield attributes (Table 1) *viz.*, number of pods plant^{-1} (52.57), number of grains pod^{-1} (16.02), grain yield plant^{-1} (6.96 g) and test weight (12.18 g) was observed significantly higher with the application of manures FYM 5t ha^{-1} + CC 1 t ha^{-1} (M_2) or M_1 (FYM 10 t ha^{-1}) over M_0 (No FYM). This may be attributed to better physico-chemical properties of soil and nutrient availability after the decomposition of organic matter and supply of readily available nutrients through castor cake. The results are in conformity with those of Shivkumar *et al.*, (2002).

With respect to yield, the significantly higher grain (1831 kg ha^{-1}) and straw yield (2712 kg ha^{-1}) was recorded under treatment M_2 (FYM 5 t ha^{-1} + CC 1 t ha^{-1}) over M_0 by 19.67 and 14.19 per cent, respectively (Table 2). However, it remained at par with M_1 (FYM 10 t ha^{-1}) in case of grain yield. Significantly lowest grain and straw yield was recorded under M_0. It might be attributed to the favourable effect of organic manures which play a key role in root development, energy translocation and metabolic processes of plant through which increased translocation of photosynthates towards the sink development might have occurred. Further, application of castor cake with low C: N ratio in combination with FYM (wide C: N ratio) might have increased the mineralization process which resulted into increased availability of nutrients to the crop. The beneficial effect of combine use of (FYM and CC) organic manure on seed and straw yields could be attributed to the fact that proper decomposition and mineralization of organic manures supply available P with other essential plant nutrients directly to the plant and also solubility effects on fixed form of P in legumes (Poonia and Jat, 2008). These findings are in close agreement with those reported by Khiriya and Singh (2003). Significantly the highest moisture content was measured in treatment M_2 (9.08%) and the significantly lowest moisture content (8.42 %) was observed in M_0. It is obvious to mention that organic manures enhance water holding capacity of soil and also act as barrier to reduce surface evaporation and deep percolation and thereby increase the water availability in soil. Hence, manure treated plots might have shown more moisture content over control plots. These results are also in line with those of Mandal *et al.*, (2003).

Organic manures also exerted their significant influence on WUE. The treatment M_2 (6.58 kg ha^{-1} mm) being at par with M_1 (6.52 kg ha^{-1} mm) enhanced the WUE over M_0 (5.94 kg ha^{-1} mm) with the corresponding increase of 10.77 per cent. The reason may be ascribed to the fact that proportionate increase in grain yield was greater than the evapo-transpiration due to combined application of FYM and castor cake. Thus WUE enhanced significantly over no manure treatment where increase in yield was lesser than the loss of water through ET. Results are in close proximity with those of Kader *et al.*, (2010) .

Treatment M_2 (FYM 5 t ha^{-1} + CC 1 t ha^{-1}) accrued maximum gross and net realization (` 92906 and ` 65589 ha^{-1}, respectively) followed by treatment M_1

Table 2. Effect of irrigation scheduling and organic manures on yield, WUE and economics of fenugreek (pooled data of two years)

Treatments	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Moisture content before irrigation (%)	WUE (kg ha^{-1}mm)	Net realization (ha^{-1})	Gross realization (ha^{-1})
A. Main Plot (Irrigation scheduling) (Vegetative phase + Reproductive phase)						
I_1: 0.6 IW: CPE + 0.8 IW: CPE	1544	2367	7.63	6.51	54592	78384
I_2: 0.6 IW: CPE + 1.0 IW: CPE	1827	2563	9.30	6.61	68173	92632
I_3: 0.8 IW: CPE + 1.0 IW: CPE	1796	2700	9.64	5.99	66025	91150
I_4: At Critical growth stages	1688	2576	8.50	6.27	61229	85688
S.Em ±	24.24	36.85	0.06	0.09		
CD(P=0.05)	72	109	0.19	0.28		
B. Sub Plot (Organic manures (M))						
M_0: No FYM	1530	2375	8.42	5.94	56629	77688
M_1: FYM 10 t ha^{-1}	1780	2567	8.80	6.52	65335	90284
M_2: FYM 5 t ha^{-1} + Castor Cake 1 t ha^{-1}	1831	2712	9.08	6.58	65589	92906
S.Em ±	19.09	30.25	0.05	0.07		
CD(P=0.05)	54	85	0.13	0.19		

(FYM 10 t ha^{-1}) with the gross and net realization of ` 90284 and ` 65335 ha^{-1}, respectively.

It is inferred that potential yield and profit from fenugreek cultivation can be obtained by irrigating the crop at 0.6 IW: CPE ratio (21-27 days interval) during vegetative phase and 1.0 IW: CPE ratio (10-12 days interval) during reproductive phase with application of FYM 5 t ha^{-1} + castor cake 1 t ha^{-1}.

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