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Performance of Fenugreek (*Trigonell foenum-graecum* L.) as influenced by micro irrigation under different planting patterns

Sangita Meena, AC Shivran, PK Boori, BC Dhayal and Lali Jat

Abstract
The field experiment conducted at Agronomy farm, S.K.N. College of agriculture, Jobner during *rabi* season 2013-14to select appropriate drip irrigation schedule for maximizing productivity and profitability of fenugreek. The experiment consisted nine treatments of irrigation levels and planting pattern *viz.* Surface irrigation at 1.0 IW/CPE ratio with normal row planting, drip irrigation at 0.4, 0.6, 0.8 and 1.0 IW/CPE ratio with normal as well as paired row planting. The experiment was laid out in Randomized Block Design with three replications. The results showed that drip irrigation at different IW/CPE ratios, except drip irrigation at 0.4 IW/CPE ratio with normal and paired row planting, significantly increased growth parameters, yield attributes and yields over surface irrigation at 1.0 IW/CPE ratio (control). The results further revealed that the drip irrigation at 0.6 IW/CPE ratio with paired row planting, being at par with 0.6 IW/CPE ratio in normal row planting, drip irrigation at 0.8 and 1.0 IW/CPE ratios in normal and paired row planting, recorded significantly higher plant height and dry matter accumulation per metre row length at 40, 80 DAS and at harvest, number of total and effective root nodules and pods per plant (28.72) over drip irrigation at 0.4 IW/CPE ratio with normal and paired row planting. Results further revealed that the drip irrigation at 0.6 IW/CPE ratio with paired row planting, being at par with 0.6 IW/CPE ratio in normal row planting, 0.4 IW/CPE ratio in paired row planting, 0.8 and 1.0 IW/CPE ratios with normal and paired row planting, recorded significantly higher seeds per pod, pod length and N content in straw over 0.4 IW/CPE ratio with normal row planting.
The further examination of data indicated that the irrigation at an IW/CPE ratio 0.8 with paired row planting, being at par with 0.8 IW/CPE ratio in normal row planting and 1.0 IW/CPE ratio with normal and paired row planting, recorded significantly increased number of branches per plant and total chlorophyll content over drip irrigation at 0.4 and 0.6 IW/CPE ratio with normal and paired row planting. Results further revealed that the drip irrigation at 0.6 IW/CPE ratio with paired row planting, being at par with 0.6 IW/CPE ratio in normal row planting, 0.4 IW/CPE ratio in paired row planting, 0.8 and 1.0 IW/CPE ratios with normal and paired row planting, recorded significantly higher seeds per pod and pod length over 0.4 IW/CPE ratio with normal row planting. Application of drip irrigation at 0.6 IW/CPE ratio with paired row planting proved to be best treatment in terms of growth and yield.

Kewywords: Dry matter, Drip irrigation, Fenugreek, IW/CPE ratio, Growth, Yield attributes.

1. Introduction
A spice is a dried seed, fruit, root, bark or vegetative substance used in flavouring, seasoning and imparting aroma in variety of food items and beverages. In India, wide varieties of spices are grown and many of them are native to the subcontinent and also known as "Home of Spices". Besides importance in food industry, the spices have medicinal properties and thus are used in various pharmaceutical preparations and also in cosmetic industry. The usages of spices by consumers are increasing world wide because they are completely natural, rather than artificial additives for seasoning and flavouring of foods. Thus, an increasing trend in export of spices has been observed in the last decade particularly to Asian, Latin American and Middle Eastern developing countries. The seed spices enhance or vary the flavour of foods. Seed spices stimulate the appetite and augment the flow of the salivary and gastric juice. The seed spices, besides being important from home consumption point of view, are increasing importance as medicinal herbs. In India, spices and seed spices occupies an area of 3.07 and 1.39 million hectare with production of 5.74 and 1.23 million tonnes, respectively (Anonymous, 2013) [1-3]. Similarly, in spices and seed spices Rajasthan occupies an area of 7.30 and 7.09 lakh hectare with production of 8.71 and 8.56 lakh tonnes, respectively (Anonymous, 2013) [1-3].
Fenugreek is considered as spice as well as legume crop. It is annual herbaceous and autogamous crop belonging to family fabaceae and sub family papillionaceae. Fenugreek (*Trigonella foenum-graecum* L.) popularly known by its vernacular name '*methi*' is an

important vegetable and condiment crop grown in Northern India during *rabi* season for leaves, shoots and seeds. Fenugreek has three culinary uses: as an herb (dried or fresh leaves), as a spice (seeds), and as a vegetable (fresh leaves, sprouts and microgreens). Its seeds are used as condiment and vegetable for human consumption and as a concentrate for cattle. The seeds are used in the preparation of pickles, vegetable dishes, daals and spice mixes, such as sambar powder. Fenugreek seeds are used both whole and in powdered form and are often roasted to reduce their bitterness and enhance their flavor. The seed is bitter in taste due to presence of alkaloids known as "trigonellin" which is considered as basic material for the synthesis of cellulose, hemicellulose, nutrient and amino acids. It prevents constipation, removes indigestion, stimulates spleen and liver and is appetizing and diuretic. It is used in certain aurvedic medicines and seed in caliclactylence, dysentery, diarrhoea and dyspepsia with loss of appetite (especially ment for gastric troubles).

Fenugreek is also used as a vegetable. Fresh fenugreek leaves are an ingredient in some Indian curries. The sprouted seeds and microgreens are used in salads. Its fresh tender leaves are also taken as vegetable which are rich in iron, calcium, vitamins and essential amino acid, like lysine, valine, leucine and phenylalaline. Fenugreek is one of the important spice having high nutritional quality i.e. 9.5 per cent protein, 42.3 per cent carbohydrate, 10.0 per cent fat, 18.5 per cent fibre and rich in Ca, P, Cu, Mg, Fe, Niacin, Riboflavin, Thiamine etc (Pruthi, 1998) [8]. Major fenugreek producing countries are Pakistan, India, Iran, Nepal, Bangladesh, Argentina, Egypt, France, Spain, Turkey and Morocco. The largest producer of fenugreek in the world is India, where the major fenugreek producing states are Rajasthan, Gujarat, Uttarkhand, Uttar Pradesh, Madhya Pradesh, Maharashtra, Haryana and Punjab. In India, fenugreek occupy an area of 93 thousand hectare with the production of 113 thousand tonnes having the productivity of 1215 kg/ha (Anonymous, 2013) [1-3]. Rajasthan produces the lion's share of India's production, accounting for over 80 per cent of the nation's total fenugreek output. It is a cash crop occupying prime place amongst the seed spices grown in Rajasthan. Its high market price attracts the farmers to include this crop in their cropping system. In Rajasthan, it occupies 65.51 thousand hectare area with the production of 71.52 thousand tonnes and average productivity of 1092 kg/ha. In Rajasthan, fenugreek is mainly cultivated in the districts of Bikaner, Sikar, Churu, Pratapgardh and Jhalawar (Anonymous, 2012-13) [1-3]. However, it's productivity has been reported to be stagnate in India and Rajasthan from many years.

Improper scheduling of irrigation often leads to reduction in crop yields. In areas having ample and cheap water resources with assured supplies throughout the crop season, it may be possible to schedule irrigation as and when required to meet the full water needs of crops and realize maximum yields. However, in recent years water resources have become scarce due to low rainfall, expansion in cultivated area and poor recharge of ground water, especially in the arid and semi-arid areas of Rajasthan. In such areas, instead of intensive irrigation over a limited area, the right approach would be to serve maximum area with reduced irrigation intensity in order to increase the overall production and irrigation water use efficiency which can be ensured by irrigating the crop at such phenological stages of growth which are very critical in their demand for water. Since water is a precious commodity and the studies on scheduling of irrigation, water use efficiency, consumptive use of water and moisture distribution pattern in the soil are of direct interest for maximizing crop yields.

Reduction in agricultural productivity and water use efficiency are mainly due to conventional method of irrigation (flooding) and poor adoption of scientific water management practices. Drip method of irrigation helps to reduce the over exploitation of ground water that party occurs because of inefficient use of water under surface method of irrigation. Environmental problems associated with the surface method of irrigation like water logging and salinity are also completely absent under drip method of irrigation. Drip method helps in achieving saving in irrigation water, increase water use efficiency, decrease tillage requirement, higher quality products, increased crop yields and higher fertilizer use efficiency. At field level, water use efficiency under conventional method of irrigation is very low (50 to 60 per cent) as against drip method (95 per cent). Drip irrigation system optimize the irrigation water and put it uniformly and directly to the root zone of the plants at frequent interval based on crop water requirement through a closed net work of pressure plastic pipes. Superiority of drip system in terms of water saving and increased yield along with other benefits over surface method of irrigation is proved by many research evidences. Drip irrigation system improves the WUE because of improving the yield and quality of produce (Singh *et al.*, 2005) [9]. Pressurized irrigation system has been found to be quite effective under limited water availability not only in achieving higher productivity but also economizing other inputs such as fertilizers, pesticides, labour etc. Drip irrigation system is a conventional and effective means of supplying water directly to soil and nearer to the roots of plant without much loss of water resulting in higher water productivity (Banyopadhyay *et al*., 2005) [4]. For efficient utilization of irrigation water under drip irrigation system, it is necessary to find out proper scheduling of irrigation evapotranspiration based scheduling of irrigation is a proper and scientific to provide required irrigation water through drip system for harnessing potential yield of fenugreek crop. There is need to work out optimum irrigation schedule based on various IW/CPE ratios for optimum utilization of limited water resources of this state. Moreover, studies should be undertaken to identify the most suitable IW/CPE ratio for successful cultivation of this crop under availability of limited water for irrigation. It is an essential to find out how much quantity of water to be applied at different IW/CPE ratios to crop for obtaining higher WUE and yield of crop without affecting soil health under drip system.

Materials and Methods

An experiment was conducted on plot No. B-1 at Agronomy Farm, S.K.N. College of Agriculture, Jobner, District Jaipur (Rajasthan). Geographically, Jobner is located 45 km west of Jaipur at 26^0 05' North latitute, 75 ^{0} 28' East longitude and at an altitude of 427 metres above mean sea level. The place falls in agroclimatic zone III A (Semi-arid Eastern Plain Zone) of Rajasthan. The soil was loamy sand in texture, alkaline inreaction (pH 8.15), poor in organic carbon (0.16%) with low available nitrogen (127.11 kg N/ha) and phosphorus (16.9 kg P 2 O 5 /ha) and medium in potassium content (175.1 kg K 2 O/ha). The field capacity and permanent wilting point of soil was 10.35% and 3.9% on dry weight basis (w/w) with bulk density of 1.46 Mg/m^3. The total rainfall received during crop season was 41.8 mm. Pan evaporation during crop season was 584.6 mm. The experiment consisted of nine treatments of irrigation levels and planting pattern (Drip irrigation at 0.4, 0.6, 0.8, 1.0 IW/CPE ratios with normal and

paired row planting and surface irrigation at 1.0 IW/CPE ratio with normal row planting as control). The experiment consisted of nine treatments of irrigation levels and planting pattern viz., Surface irrigation at 1.0 IW/CPE ratio with normal row planting (Control, T^1), drip irrigation at 1.0 IW/CPE ratio with normal row planting (T^2), drip irrigation at 1.0 IW/CPE ratio with paired row planting (T^3), drip irrigation at 0.8 IW/CPE ratio with normal row planting (T^4), drip irrigation at 0.8 IW/CPE ratio with paired row planting (T^5), drip irrigation at 0.6 IW/CPE ratio with normal row planting (T^6), drip irrigation at 0.6 IW/CPE ratio with paired row planting (T^7), drip irrigation at 0.4 IW/CPE ratio with normal row planting (T^8) and drip irrigation at 0.4 IW/CPE ratio with paired row planting (T^9). The experiment was laid out in Randomized Block Design with three replications. The plot size was 6.5x4.2 m. A uniform basal dose of 40 kg N + 45 kg P 2 O 5 /ha through urea and DAP was drilled prior to sowing. The crop variety RMt - 361 sown on November 14, 2013 using 25 kg/ha seed at a depth of 2-3 cm and harvested on April 12, 2014. In normal row planting, the crop was planted at 30 cm row spacing. In paired row planting, the two row of crop was paired at space of 20 cm leaving a space of 40 cm in between pair. After sowing a common irrigation of 30 mm was applied to ensure germination and subsequent irrigations with the measured quantity of water in each irrigation were given as per irrigation treatment at alternate days in drip irrigation treatments and when CPE reached 50 mm in surface irrigation. The irrigation water was supplied by drip irrigation in drip irrigation treatments and by surface irrigation according to IW/CPE ratios determined by cumulative pan evaporation situated on the farm. The required pressure and discharge in drip system was maintained with overflow valve with the supply source. The separate valve was provided for regulating water supply in each plot. Five plants were selected from net plot and tagged for measurement of plant height and number of branches per plant (at harvest). Height of each tagged plant was measured periodically at 35, 70, 105 DAS and at harvest from base of the plant to the tip of the main shoot by metre scale and average of five plants was computed as mean plant height. Dry matter production was recorded at 35, 70, 105 DAS and at harvest. For this, plants from one metre row length were uprooted randomly from sample rows of each plot. After removal of root portion, the samples were first air dried for some days and finally dried in an electric oven at 70^0C till constant weight. The weight was recorded and expressed as average dry matter (g) per metre row length. The chlorophyll content of fenugreek at 45 DAS was estimated by the method advocated by Arnon (1949) [3]. The leaf sample was ground in 80 per cent acetone, centrifuged for 10 minutes at 2000 rpm and made final volume to 10 ml. The resultant absorbance of clear supernatant was measured by spectronic 20 at 652 nm and presented in terms of mg/g fresh weight of leaves. Five plants were selected randomly at 45 DAS in sample rows of each plot and uprooted carefully in wet soil. The soil mass embodying the roots of the plants was washed off with water and total and effective root nodules were counted to record average number of total and effective root nodules per plant. The randomly selected plants used for recording the height and branches were used for counting the number of pods per plant at harvest and their average was worked out to record pods per plant. At the time of threshing, 10 pods were randomly selected from five tagged plants in each plot and their total seeds were counted to record the average number of seeds per pod.

Results and Discussion

Growth attributes

Drip irrigation levels up to 0.6 IW/CPE ratios significantly increased growth attributes viz., plant height and dry matter production at 35, 70, 105 DAS and at harvest over surface irrigation at 1.0 IW/CPE ratio (Table 1). Among drip irrigation, irrigation at an IW/CPE ratio 0.6 with paired row planting, being at par with 0.6 IW/CPE ratio in normal row planting, 0.8 and 1.0 IW/CPE ratios in normal and paired row planting, recorded significantly higher plant height at 40, 80 DAS and at harvest over 0.4 IW/CPE ratio with normal and paired row planting. Drip irrigation at an IW/CPE ratio 0.6 with paired row planting increased plant height at harvest to the tune of 31.0, 26.6 and 27.7 per cent over surface irrigation in normal row planting at IW/CPE ratio 1.0 and drip irrigation at 0.4 IW/CPE ratio with normal and paired row planting, respectively. The drip irrigation at an IW/CPE ratio 0.8 with normal row planting, being at par with 0.8 IW/CPE ratio in paired row planting and 1.0 IW/CPE ratio in normal and paired row planting, recorded significantly higher number of branches per plant over surface irrigation at 1.0 IW/CPE ratio with normal row planting and drip irrigation at 0.4 and 0.6 IW/CPE ratios with normal and paired row planting. Drip irrigation at an IW/CPE ratio 0.8 in normal row planting increased number of branches per plant by 31.1, 27.7, 29.7, 11.0 and 13.57 per cent over surface irrigation in normal row planting at IW/CPE ratio 1.0 and drip irrigation at 0.4 and 0.6 IW/CPE ratios with normal and paired row planting, respectively.

Drip irrigation at different IW/CPE ratios, except drip irrigation at 0.4 IW/CPE ratio with normal and paired row planting, also significantly increased total chlorophyll content over surface irrigation at 1.0 IW/CPE ratio. Among drip irrigation, irrigation at an IW/CPE ratio 0.8 with paired row planting, being at par with 0.8 IW/CPE ratio in normal row planting and 1.0 IW/CPE ratio in normal and paired row planting, recorded significantly higher total chlorophyll content over 0.4 and 0.6 IW/CPE ratios with normal and paired row planting.

Observed data showed that the drip irrigation at different IW/CPE ratios, except irrigation at 0.4 IW/CPE ratio in normal and paired row planting, significantly increased dry matter accumulation per metre row length at all growth stages over surface irrigation at 1.0 IW/CPE ratio. Among drip irrigation, irrigation at an IW/CPE ratio 0.6 with paired row planting, being at par with 0.6 IW/CPE ratio in normal row planting, 0.8 and 1.0 IW/CPE ratios in normal and paired row planting, recorded significantly higher dry matter accumulation per metre row length at 40, 80 DAS and at harvest over 0.4 IW/CPE ratio with normal and paired row planting. Drip irrigation at an IW/CPE ratio 0.6 with paired row planting increased dry matter accumulation per metre row length at harvest to the tune of 32.5, 31.7 and 27.3 per cent over surface irrigation in normal row planting at IW/CPE ratio 1.0 and drip irrigation at 0.4 IW/CPE ratio with normal and paired row planting, respectively.

Further, the data showed that the drip irrigation at an IW/CPE ratio 0.6 with paired row planting, being at par with 0.6 IW/CPE ratio in normal row planting, 0.8 and 1.0 IW/CPE ratios in normal and paired row planting, recorded significantly higher number of total and effective nodules per plant over surface irrigation at 1.0 IW/CPE ratio with normal row planting and 0.4 IW/CPE ratio with normal and paired row planting. In case of drip irrigation system the water is applied directly to the root zone of the plants. It delivers

precise and desired amount of water in at very low rates of application to the individual or groups of plants. The emitter applies the water as continuous drops, through a low-pressure delivery system. It helps in maintenance of precise amount of the moisture in the root zone of the plants that help in maintaining the stress free conditions for optimum growth and development of the plants. The marked improvement in growth attributes with increasing IW/CPE ratios under drip irrigation could be ascribed to over all improvement in crop growth by virtue of increased growth parameters of the crop. The increased water availability might have led to greater availability of photosynthates towards formation of reproductive structure and their growth resulting in their better initiation and development. Bhunia *et al*. (2005) [5] also observed that irrigating fennel at an IW/CPE ratio of 0.8 recorded significantly higher plant height, seed and stover yields over lower IW/CPE ratios. Patel *et al*. (2010) [6-7] at Anand (Gujarat), reported that scheduling of irrigation under drip system at 0.8 ADFPE recorded significantly higher seed yield of castor (2841 kg/ha) as compared to conventional method of irrigation. It is well known fact that under reduced moisture (stress) condition in surface irrigation at 1.0 IW/CPE ratio during last few days before next irrigation, coupled with aeration problem during first few days immediately after irrigation, all the growth factors are affected adversely to a great extent. Moreover, due to heavy application of irrigation water, the nutrients must have got leached down the root zone.

Table 1: Effect of micro-irrigation management on plant height number of branches and total chlorophyll content

Treatment	Plant height (cm)			Number of branches/plant	Total chlorophyll content (mg/g)
	40 DAS	80 DAS	At harvest		
Surface irrigation IW/CPE 1.0 (Normal row)	12.06	45.60	77.15	4.53	1.60
Drip IW/CPE 1.0 (Normal row)	16.20	59.88	110.12	6.02	1.99
Drip IW/CPE 1.0 (Paired row)	15.99	59.71	111.18	6.00	1.98
Drip IW/CPE 0.8 (Normal row)	16.05	59.30	107.07	5.94	1.94
Drip IW/CPE 0.8 (Paired row)	15.37	60.55	109.12	5.72	1.98
Drip IW/CPE 0.6 (Normal row)	15.71	56.47	97.04	5.35	1.80
Drip IW/CPE 0.6 (Paired row)	16.10	58.45	101.03	5.23	1.85
Drip IW/CPE 0.4 (Normal row)	13.04	46.85	79.79	4.65	1.59
Drip IW/CPE 0.4 (Paired row)	12.94	46.33.	79.11	4.58	1.61
SEm±	0.47	1.85	4.06	0.19	0.04
CD (P=0.05)	1.40	5.53	12.17	0.57	0.13

Table 2: Effect of micro-irrigation management on dry matter accumulation per metre row length, number of total and effective root nodules

Treatment	Plant height (cm)			Number of total root nodules/plant	Number of effective root nodules/plant
	40 DAS	80 DAS	At harvest		
Surface irrigation IW/CPE 1.0 (Normal row)	9.50	46.22	100.62	18.78	12.62
Drip IW/CPE 1.0 (Normal row)	11.05	63.05	132.33	21.94	15.89
Drip IW/CPE 1.0 (Paired row)	11.05	62.15	130.18	21.95	15.90
Drip IW/CPE 0.8 (Normal row)	11.03	62.21	135.20	21.92	15.95
Drip IW/CPE 0.8 (Paired row)	11.04	62.58	136.25	21.97	15.93
Drip IW/CPE 0.6 (Normal row)	10.68	59.26	128.35	21.76	15.80
Drip IW/CPE 0.6 (Paired row)	11.01	61.68	133.36	21.89	15.91
Drip IW/CPE 0.4 (Normal row)	9.45	46.56	101.27	18.95	13.45
Drip IW/CPE 0.4 (Paired row)	9.90	47.79	104.72	19.00	13.60
SEm±	0.34	1.98	4.91	0.74	0.52
CD (P=0.05)	1.02	5.93	14.71	2.23	1.57

Table 3: Effect of micro-irrigation management on yield attributes of fenugreek

Treatment	Pods/ plant	Seeds/ pod	Pod length (cm)	Test weight (g)
Surface irrigation IW/CPE 1.0 (Normal row)	23.64	14.20	10.60	12.40
Drip IW/CPE 1.0 (Normal row)	29.19	16.28	11.96	13.38
Drip IW/CPE 1.0 (Paired row)	29.05	16.20	11.91	13.39
Drip IW/CPE 0.8 (Normal row)	29.25	16.25	11.88	13.35
Drip IW/CPE 0.8 (Paired row)	29.50	16.41	11.97	13.39
Drip IW/CPE 0.6 (Normal row)	28.00	15.90	11.60	13.21
Drip IW/CPE 0.6 (Paired row)	28.72	16.24	11.95	13.32
Drip IW/CPE 0.4 (Normal row)	23.84	14.50	10.71	12.43
Drip IW/CPE 0.4 (Paired row)	24.20	15.05	11.02	12.56
SEm±	1.19	0.51	0.36	0.33
CD (P=0.05)	3.57	1.53	1.07	0.97

Yield attributes

The data indicated that drip irrigation at different IW/CPE ratios, except irrigation at 0.4 IW/CPE ratio in both row planting, significantly increased pods per plant, pod length and seeds per pod over surface irrigation at 1.0 IW/CPE ratio (Table 3). Among drip irrigation, irrigation at an IW/CPE ratio 0.6 with paired row planting, being at par with 0.6 IW/CPE ratio in normal row planting, 0.8 and 1.0 IW/CPE ratios in normal and paired row planting, recorded significantly higher pods per plant, pod length and seeds per pod over lower irrigation level at 0.4 IW/CPE ratio with normal and paired row planting.

The increase in pods per plant with drip irrigation at an IW/CPE ratio 0.6 in paired row planting was 21.4, 20.4 and

18.7 per cent over surface irrigation in normal row planting at IW/CPE ratio 1.0 and drip irrigation at 0.4 IW/CPE ratio with normal and paired row planting, respectively. The marked improvement in yield attributes with increasing IW/CPE ratios under drip irrigation could be ascribed to over all improvement in crop growth by virtue of increased growth parameters of the crop. The increased dry matter production of successive stages with increased water availability might have led to greater availability of photosynthates towards formation of reproductive structure and their growth resulting in their better initiation and development. Mehta *et al*. (2010) [10] also reported increased length of pod, number of pods per plant, number of seeds per pod and test weight of seeds with increasing levels of irrigation in fenugreek.

Conclusion

Based on results of one year experimentation it may be concluded that drip irrigation at IW/CPE ratio 0.6 with paired row planting proved to be the most superior treatment as it provided higher seed yield (17.00 q/ha), net returns (` 38632/ha), B:C ratio (2.32) and maximum water use efficiency (5.92 kg/ha-mm) from fenugreek.

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