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Growth, Seed Yield, Protein Content and Water Use Efficiency of Fenugreek (*Trigonellafoenum – graceum* L.) as Influenced by Drip Irrigation Regimes and Fertigation Levels

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A B S T R A C T

Irrigation and nutrients are most prerequisite factors for crop growth and development. Any imbalance in supply of water or nutrients may leads to poor crop performance and lower production. Therefore there is need to optimize irrigation and fertigation practices to sustain the fenugreek growth, yield and also better seed quality. In the present study drip irrigation at three levels (I_1 - 25 % CPE, I_2- 50 % CPE and I_3 - 75 % CPE) and fertigation at four levels (F_1 - 25 % RDF, F_2 - 50 % RDF, F_3 – 75% RDF and F_4 - 100 % RDF) were studied in split plot design with three replications. Results reveled that drip irrigation at 75 per cent cumulative pan evaporation recorded highest growth and yield but it was on par with drip irrigation at 50 per cent cumulative pan evaporation (CPE) (I_2). Drip irrigation at 50 per cent CPE (I_2) recorded plant height of 75.6 cm, biomass accumulation (7,507.45 kg/ha), number of pods per plant (55.68), number of seeds per pod (7.88), pod length (4.9 cm), test weight of seeds (16.16 g) and seed yield (1,793.8 kg/ha). Whereas, in case of fertigation application of fertilizers at 100 per cent recommended dose of fertilizers (RDF) (F_4) was recorded highest plant height and it is at par with fertigation 75 per cent RDF. However there were no significant differences were found in case of biomass production, number of pods per plant and seed yield. But fertigation at 100 per cent recommended dose of fertilizers resulted in higher seed protein (30.67 %) content. Water use efficiency was optimum in drip irrigation at 50 per cent CPE (I_2) which is at par with drip irrigation at 25 per cent CPE (I_1). It is concluded that drip irrigation at 50 per cent CPE and 50 per cent RDF as fertigation in fenugreek crop is optimum for higher seed yield and water use efficiency.

Introduction

Fenugreek (*Trigonellafoenum-graecum* L.) important major seed spice crop belongs to the family of Leguminosae (Fabaceae). It is a dual purpose crop used as spice (seed) and vegetable (fresh leaves). The dried seeds, leaves and tender shoots are all consumed and are valued as food, flavouring agent and medicine. Fenugreek seed are rich in protein, minerals and vitamins and seeds could be used against diabetes (Rao and Sharma, 1987).

Fenugreek is important spice crop of semi-arid conditions cultivated in rabi season for seed and mostly throughout the year for herb. India is the largest producer of fenugreek in the world. In India fenugreek is being cultivated in the states of Rajasthan, Madhya Pradesh, Maharashtra, Haryana, Punjab, Gujarat and Uttar Pradesh. Rajasthan is considered as "fenugreek bowl of country". Rajasthan has maximum area and production of about more than 80% of total production of the country.

There are several factors to improve the productivity of crops. Among them water and nutrient management is important operation which influences the crop growth and productivity to great extent. In case of fenugreek crop, moisture is the most critical factor and any fluctuations in irrigations shows moisture deficit symptoms in early stage itself (Honnappa *et al.,* 2017). Seed yield of fenugreek is mainly depends on timely irrigation and adequate nutrients supply. In arid and semi-arid regions scarcity of water and soil type necessitates frequent irrigation for success crop production. Uncertain rainfall and midseason moisture stress reduces the soil moisture in the root zone which reduces the crop yield drastically (Harisha *et al.,* 2017b). Therefore, drip method of irrigation is most suited for semi-arid and arid areas where water is scarce and where low water consuming and high value crops can be grown (Bastug *et al.,* 2006). Drip irrigation system has the potential for improving two of the most common contributing factors to N leaching *i.e.* over fertilization and over irrigation. It is also reported that crop growth will be optimum when crop is supplied with nutrients and irrigation in right time and in right quantity (Sonu *et al.,* 2016). It also found that untimely application of nutrients by inappropriate method of application leads to severe loss of nutrients by leaching and fixation (Harisha *et al.,* 2017a). To fulfill these objectives adopting drip irrigation and fertigation is most necessary so that water, fertilizers and energy can be saved. The reasonable use of scarce water resources in states like Rajasthan is a top priority for agriculture to use drip irrigation. In recent years, there has been tremendous interest in applying nutrients through the irrigation system (fertigation) as a source of providing nutrients to plants. Supply of nutrients according to the crop development phase throughout the season in order to meet the actual nutritional requirement of the crop. Fertigation improves the nutrient use efficiency by staggered supply throughout the cropping period.

Under this scenario there is a need for optimize drip irrigation level based on evapotranspiration and fertigation levels suitable for economic crop production. To get maximum production of fenugreek, it is most important and essential to enhance the growth and biomass of crop and increases seed yield and this could be achieved successively by providing the optimum irrigation and fertilizers to root zone. Hence, the study has been conducted to find the response of fenugreek to drip irrigation levels and fertigation levels in terms of growth, seed yield, quality and water use efficiency under semi-arid conditions of Rajasthan.

Materials and Methods

The field experiment was conducted during winter season of 2016-17 at Research farm of ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan. The soil of experimental plot was sandy loam in nature and details of physical and chemical properties of soil are provided in table 1.

The experiment was laid out in a split plot design and replicated three times. In this trial three drip irrigation levels in mainplots (I_1 - 25 % CPE, I_2- 50 % CPE andI_3 - 75 % CPE) and

four fertigation levels in subplots (F_1 - 25 % RDF, F_2 - 50 % RDF, F_3 – 75% RDF and F_4 - 100 % RDF). Recommended dose of fertilizer for fenugreek is 25:30:20 kg N, P_2O_5, K_2O per hectare is applied in split doses of eight through irrigation water. Crop was irrigated by drip irrigation system of Netafim make. In line laterals of 16 liter discharge spaced at 30cm are used in the trial and they are placed at 50cm apart. Irrigation was given once in four days and eight fertigation was given during entire cropping period starting from fifteen days after germination of crop at eight days interval. Total 26 drip irrigations were given during entire crop period as per evapotranspiration readings and the daily ETo was computed according to Doorenbos and Pruitt (1992)

ETo = Kpan × Epan

Where:

Epan= evaporation from the Class A pan (mm day^{-1}).
Kpan = the pan evaporation coefficient.

Chlorophyll (Chl a and Chl b) and total chlorophyll content was determined spectrophotometrically using 100 mg FW of leaf material ground in a pre-chilled mortar in the presence of 8 ml of acetone 80% (v/v). After complete extraction, the mixture was filtered and the volume adjusted to 10 ml with cold acetone. The absorbance of the extract was read at 663.2, 646.8, and 470 nm and pigment concentrations were calculated according to Lichtenthaler (1987).

Crop was raised on broad raised beds make with tractor drawn bed maker cum seed drill. Raised beds of 1.4m x 44m are prepared and seeds were sown in lines with a drill spacing of 25 cm between the rows. Plant to plant distance was maintained to 10 cm by thinning after thirty days of sowing. Fertigation was given by water soluble fertilizers such as urea phosphate (16:44:0 N, P_2O_5, K_2O respectively), urea and sulphate of potash (SOP) by ventury. All necessary observation like growth, yield and protein parameters were recorded and water use efficiency (WUE) was calculated by dividing the seed yield (kg/ha) with the amount of water consumed by the crop (i.e. irrigation water applied, mm) during crop growth period. Statistical analysis was performed by ANNOVA following split plot design with three replications using SPSS 16.0 software to determine the Least Significant Difference (LSD, $P \leq 0.05$).

Results and Discussion

Results obtained from the study reveals significant variations in fenugreek plant growth, seed yield and seed protein content which is influenced by drip irrigation regimes and fertigation levels (Table 2 and 3).

Drip irrigation regims in fenugreek influenced the crop growth significantly (Table 2) and it was highest in (107.1 cm) in drip irrigation treatment at 75 per cent CPE (I_3) which was on par with drip irrigation level 50 per cent CPE (I_2) which recorded plant height of 75.6 cm. In case of fertigation treatments, significantly highest plant height of 88.8 cm was recorded by drip fertigation of 100 per cent (F_4) recommended dose of fertilizer. In similar way the least plant height (79.6 cm) was recorded in 25 per cent (F_1) recommended dose of fertilizer followed by fertigation at (F_3) 75 per cent RDF (80 cm) and 50 per cent (F_2) (81.1 cm) RDF. The improvement in plant height in I_3 and F_4 may be due to beneficiary effect of higher drip irrigation regime and higher fertigation level. The growth promoting effect of drip irrigation and fertigation which aims to deliver water and nutrients directly to root zone which enable the plants in the respective treatment to absorb more moisture and nutrients at all critical

stages of crop. Higher drip irrigation and fertigation helped the plants for better uptake of nutrients and consequently the good growth of plant. These results are in confirmation with Honnappa *et al.*, (2017) in fenugreek.

In case of biomass production was highest (7,890.9 kg/ha) in the treatment I_3 (75 % drip irrigation) which is on par with I_2 (7,507.4 kg/ha) and the same irrigation level recorded higher primary branches (5.25), pods per plant (60.3), seeds per pod(7.88) which is at par with I_3 (50 % drip irrigation). This can be attributed to the fact that, which might be due to better crop growth, more number of branches, higher number of pods and seed yield per plant in irrigation treatments which intern contributed to biomass production, which intern helps in higher pods and seed production. Due to the maintenance of adequate soil moisture in the root zone by drip irrigation at 75 per cent CPE resulted in effective absorption of water and nutrients by fenugreek plants.

Table.1 Some soil physical and chemical characteristics at the experimental plot

Soil depth	Texture	Bulk density (gcm^{-3})	pH	EC (dSm^{-1})	Org. C. (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
0-15 cm	Sandy loam	1.34	8.0	0.29	0.30	112	23.5	271
15-30 cm	Sandy loam	1.45	7.8	0.27	0.21	98	18.2	264

Table.2 Effect of drip irrigation regimes and fertigation levels on growth attributing characters in fenugreek

Treatments	Plant height (cm)	branches/plant	Biomass (kg/ha)	Pods/ plant	Pod length (cm)	Seeds/ Pod	Test weight (g)	Seed yield (kg/ha)
Drip Irrigation (I)								
I_1 – 25% CPE	64.5	5.13	6,006.5	52.7	3.8	6.8	13.56	1,342.3
I_2 – 50% CPE	75.6	5.20	7,507.4	55.6	4.9	7.8	16.16	1,793.8
I_3 – 75% CPE	107.1	5.25	7,890.9	60.2	6.2	10.4	17.35	2,112.6
F test	*	NS	*	*	*	*	*	*
SE.m±	0.98	0.071	77.67	1.13	0.11	0.10	0.160	52.35
CD (p=0.05)	3.96	-	313.16	4.57	0.47	0.40	0.644	211.09
Fertigation (F)								
F_1 – 25% RDF	79.6	5.13	6,775.8	53.1	4.3	7.6	14.62	1,638.3
F_2 – 50% RDF	81.1	5.06	7,083.9	54.4	4.7	8.1	15.39	1,699.8
F_3 – 75% RDF	80.0	5.13	7,245.1	57.8	5.2	8.6	16.25	1,825.1
F_4 – 100% RDF	88.8	5.45	7,434.8	59.4	5.6	9.1	16.53	1,835.0
F test	*	NS	NS	NS	*	*	*	NS
SE.m±	1.33	0.119	222.1	1.82	0.20	0.33	0.234	116.89
CD (p=0.05)	4.00	NS	NS	NS	0.62	0.99	0.702	NS
I X F	7.13	-	-	-	-	-	-	-
F XI	7.39	-	-	-	-	-	-	

Table.3 Effect of drip irrigation regimes and fertigation levels on yield attributing, protein and WUE in fenugreek

Treatments	WUE (kg ha^{-1}mm)	Chl. a	Chl. b	Total chlorophyll	Seed Protein (%)
Drip Irrigation (I)					
I_1 – 25% CPE	13.9	2.97	1.50	6.23	24.45
I_2 – 50% CPE	9.3	3.40	1.53	6.81	28.64
I_3 – 75% CPE	7.3	3.67	1.58	7.20	29.82
F test	*	*	*	*	NS
SE.m±	0.33	0.12	0.13	0.9	1.388
CD (p=0.05)	1.33	0.34	0.34	0.28	-
Fertigation (F)					
F_1 – 25% RDF	9.5	2.23	0.98	4.70	23.83
F_2 – 50% RDF	9.7	2.48	1.15	5.08	26.81
F_3 – 75% RDF	10.6	2.65	1.25	5.23	29.24
F_4 – 100% RDF	10.8	2.68	1.22	5.21	30.67
F test	NS	*	*	*	*
SE.m±	0.69	0.08	0.12	0.32	1.041
CD (p=0.05)	NS	0.27	0.34	0.92	3.118
I X F		0.47	0.60	0.55	-
F X I	-	0.47	0.60	0.54	-

All these attributed to higher biomass yield in the treatment drip irrigation at 75 % CPE. The results are in agreement with those of Jat *et al.*, (2015) in highest dry weight at harvest time in fennel. In case of fertigation higher biomass, pods per plant and seeds per pod was recorded in fertigation level at 100 per cent RDF (F_4) which is on par with fertigation at 75 % RDF and 50% RDF.

The highest seed yield (2,112.6 kg/ha) was obtained in drip irrigation treatment I_3 (drip irrigation @ 75% CPE) which is followed by I_2 (1,793.8 kg/ha) (drip irrigation @ 50% CPE) and lowest seed yield was recorded in I_1 - drip irrigation at 25 per cent CPE (1342.3 kg/ha). In case of fertigation treatments, seed yield was found to be non-significant. However, fertigation influenced the seed protein content and it was significant and highest (30.6%) in fertigation at 100% RDF which was at par with fertigation at 75% RDF. It is most obvious that fenugreek is being nitrogen fixing crop which demands very less nitrogen and there by its response to fertilizer application is poor. Even though, higher seed yield and protein content in fenugreek is due to good vegetative growth which had resulted in higher dry biomass production and higher number of pod per plant, higher number of seed/pod, higher seed yield per plant and test weight of seeds in the said treatments. These results are in accordance with Patil *et al.*, (2014) in cluster beans, Harisha *et al.*, (2017) in coriander.

Different drip irrigation levels exerted significant difference on chlorophyll content and WUE of fenugreek. Chlorophyll a, b and total chlorophyll was found highest in higher level of irrigation and in case of fertigation higher level of nutrients improved the chlorophyll content of fenugreek leaves. It is mainly due to the water content and optimum

nutrients make the crop to maintain its chlorophyll content in sufficient range so that higher chlorophyll content was obtained. Results showed that water use efficiency was decreased as irrigation level increased. Therefore highest water use efficiency (13.9 kg/ha mm) was found in I_1 (drip irrigation at 25 % CPE) which was on par with (9.3 kg/ha mm) in I_2 (drip irrigation 50% CPE). The lowest water use efficiency (7.3 kg/ha mm) was recorded in I_3 (drip irrigation 75% CPE). Higher water use efficiency with lower level of drip irrigation might be due to less water application and better utilization by crop under stress condition. The decrease in water use efficiency with increase in drip irrigation level from 25 to 75 per cent CPE indicates that seed yield per mm of water utilized decrease with increase in irrigation water supply and the relative increase in seed yield of fenugreek has not been in proportional to the increase in consumptive use, thereby resulting in decrease in water use efficiency under higher levels of drip irrigation levels. Therefore, the water use efficiency clearly indicates that when water is limiting factor in fenugreek production, irrigation scheduling should be adjusted in accordance to maximize water productivity. These results are in agreement with the finding of Honnappa *et al.*, (2017) in fenugreek and Verma *et al.*, (2015) in coriander.

It is concluded that the irrigation of fenugreek crop by drip method once in every four days is most optimum in fenugreek crop. Fenugreek is moisture loving crop and produces more biomass when irrigated in most frequently. It also delays the crop maturity by continuous growth and flowering. From the present study the results reveals significant influence of drip irrigation and fertigation on growth and seed yield. It is found that there is need of irrigation to fenugreek and it is up to 75 % CPE and in case of water scarcity irrigation level may be bring down up to 50% of CPE. Being a legume crop nutrient demand is much less in fenugreek, therefore application of 50% RDF as a fertigation is better to achieve seed yield and protein content.

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