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PRECISION IRRIGATION AND FERTIGATION FOR HIGHER PRODUCTIVITY AND WATER USE EFFICIENCY IN FENUGREEK (*TRIGONELLA FOENUM-GRAECUM* L.) IN SEMI ARID CONDITIONS OF RAJASTHAN

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ABSTRACT
Drip irrigation at 100% PE recorded higher plant height (64.8 cm), biomass accumulation (4.87 t/ha), number of pods per plant (38.5), seed yield per hectare (18.0 q) in fenugreek and it is on par with drip irrigation at 80% PE which recorded plant height 63.1 cm, 4.88 tonnes ha^{-1} dry biomass, 37.3 pods per plant and seed yield of 17.3 q per hectare. In case of fertigation at 100% RDF (recommended dose of fertilizers) and 75% RDF are recorded at par results. Fertigation at 75% RDF recorded plant height of 61.2 cm and 17.02 quintal seed yield per hectare. Water use efficiency was higher in case of drip irrigation at 40 % PE and it is 8.6 kg ha^{-1} mm of water and lowest was 8.6 kg ha^{-1} mm of water in case of drip irrigation at 100% PE. This can be concluded that 80 % PE and 75 % recommended dose of fertilizers are optimum for fenugreek production. Water use efficiency was higher in case of 40% CPE but it is advisable that 60% CPE is ideal for fenugreek cultivation.

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is one of the important seed spices grown in India. It is legume crop belongs to family Fabaceae in which both seed and herb is used as spice (Peteropoulos, 2002). The seeds of fenugreek are used as a condiment and seasoning agent. Leaves are used for garnishing, flavouring dishes and also it is having lot of medicinal properties particularly for diabetes. Crop is mainly grown in semi arid regions of India including Rajasthan, Gujarat, Madhya Pradesh, Karnataka, Telangana, Tamil Nadu etc in winter season.

In fenugreek crop cultivation water is the important natural resources which are pre requisite for higher productivity in semi arid conditions. Seed yield of fenugreek is mainly depends on biomass yield and number of pods per plant which is obtained by better plant growth. Pods are produced in the each node branch and growth continues as the irrigation and fertilizers are supplied regularly. But in semi arid regions where water scarcity and sandy or sandy loam soil type makes more number of irrigation necessary in crop production. Hence there is need to optimize the use of irrigation water and fertilizers by adopting appropriate precision farming technique which can help to use these resources in efficient manner. 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 (Kalpana and Anita Fanish, 2014). Fertigation is yet another precision farming technique which can save fertilizer up to 25 percent (Vaishnava *et al*., 1995). Thus fertigation helps in efficient use of fertilizers along with irrigation water. To overcome these difficulties adopting drip irrigation and fertigation is highly necessary among the farmers so that can save labour, water and even fertilizers also.

Under this scenario there is a need for standardizing drip irrigation level based on evaporation 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 with the objective to find the response of fenugreek to drip irrigation levels and fertigation levels in terms of growth, seed yield and water use efficiency under semi arid conditions.

MATERIALS AND METHODS

The field experiment was conducted during winter season of 2015 and 2016 at Research farm of ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan. The soil of experimental plot was sandy loam in nature having pH 7.6, EC 0.3 dSm^{-1} and available N 168 kg ha^{-1}, P_2O_5 16.5 kg ha^{-1} and K_2O 325 kg ha^{-1}. Fenugreek variety Afg-1 (Ajmer fenugreek-

1) was used in the trial**.** The field experiment was laid out in a split plot design and replicated three times as suggested by Panse and Sukhatme (1967). In this trial four drip irrigation levels (I_1- 40 % CPE, I_2- 60 % CPE, I_3- 80 % CPE and I_4-100% CPE) and three fertigation levels (F_1- 50 % RDF, F_2- 75 % RDF and F_3 - 100 % RDF). Recommended dose of fertilizer for fenugreek is 40:30:20 kg N, P_2O_5, K_2O per hectare. Drip irrigation lateral pipes with inline drippers spaced at 30 cm with discharge rate of 2.3 litre per hour were used in the trial. Irrigation pressure was maintained at 2.5 g/cc to have adequate discharge from the drippers. 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. Crop was raised on broad raised beds make with tractor drawn bed maker cum seed drill. Raised beds of 1.4m x 0.15m x 40m 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 15cm by thinning after thirty days of sowing. Pan evaporation data was recorded from USA type open pan evaporymeter daily at 8.30 hrs and 14.30hrs. Quantity of irrigation water was calculated based on cumulative pan evaporation as described by Michael A. M. (1983). For this purpose cumulative pan evaporation for respective treatments were determined and irrigation water is determined. Fertigation was given by water soluble fertilizers such as urea phosphate (16:44:0 N, P_2O_5, K_2O respectively), sulphate of potash and urea by ventury. During year 2014-15 total 405.7mm (from 47 standard week to 11 standard week) and during year 2015-16 total 410mm (from 44 standard week to 9 standard week) water was applied from sowing till crop maturity. Total of 34 irrigations were given during the cropping period. All necessary observation like growth and yield parameters were recorded time to time 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 (Michael A. M. 1983). The data collected on growth and yield parameters were subjected to analysis of variance (ANOVA and LSD @ 0.05) of Split plot design.

RESULTS AND DISCUSSION

Results pertaining to plant growth and seed yield of fenugreek are presented in Table 1 and 2. The results revealed that significant influence of drip irrigation on fenugreek in terms of both growth and seed yield. Fertigation effect on fenugreek is also found significant but effect was very meagre in some of the yield attributing characters. The effect of irrigation and fertigation are discussed in details here under (table 1 and 2).

Effect of drip irrigation on growth and seed yield

Drip irrigation levels in fenugreek influenced the crop growth significantly (table 1) during both the years 2014-15 and 2015-16. Mean of two years revels that higher plant height (64.8 cm) was recorded in drip irrigation at 100 % CPE (I_4) which is at par with I_3 -drip irrigation at 80 % CPE (63.1 cm). Higher plant height in higher irrigation level is due to continuous water supply once in four days and maintenance of soil in the field capacity. The similar results were also shown in coriander Sharangi and Roychowdhury (2014) in coriander In the same way biomass accumulation of fenugreek were also influenced significantly by drip irrigation levels. Higher mean biomass (4.88 t/ha) was obtained from drip irrigation at 80 % CPE followed by drip irrigation at 100 % CPE (4.87 t/ha) and drip irrigation at 60 % CPE (4.43) all are on par. Mean primary branches per plant were highest in drip irrigation at 100 % CPE (5.75) but there were no significant differences among the treatments in pooled data and during 2015-16. However in the year 2014-15 significant results were obtained and it was highest in drip irrigation at 100 % CPE (6.11) followed by drip irrigation at 80 % CPE (5.68). Higher dry matter production is due to various parameters such as plant height, number of branches, number of pods and seed. All these attributed to higher biomass yield in the treatment drip irrigation at 80 % CPE. Number of pods per plant was found to be significant and highest in drip irrigation at 100 % CPE (38.5) which is at par with drip irrigation at 80 % CPE (37.3). Lowest was recorded from drip irrigation at 40 % CPE (33.6) followed by drip irrigation at 60 % CPE (35.3). In the both years same trend were observed. Results clearly indicate that requirement of

Table 1: Effect of drip irrigation regimes and fertigation levels on growth attributing characters in fenugreek

Treatments	Plant height (cm)			Biomass accumulation (t/ha)			Primary branches/plant			Number of pods/plant		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Drip Irrigation (I)												
I1 – 40% CPE	61.7	53.6	57.7	3.63	3.72	3.67	5.16	4.77	4.96	33.5	33.6	33.6
I2 – 60% CPE	63.3	56.7	60.0	4.73	4.12	4.43	5.27	5.13	5.20	35.1	35.6	35.3
I3 – 80% CPE	67.3	59.0	63.1	5.03	4.73	4.88	5.68	5.31	5.49	37.1	37.4	37.3
I4– 100% CPE	68.9	60.6	64.8	5.09	4.66	4.87	6.11	5.37	5.75	37.5	39.4	38.5
F test	*	*	*	*	*	*	*	NS	NS	*	*	*
SE.m±	0.45	1.23	0.39	0.11	0.18	0.14	0.14	0.16	0.12	0.59	0.97	0.39
CD (p=0.05)	1.59	4.37	1.83	0.39	0.64	0.69	0.48	-	-	2.07	3.42	1.81
Fertigation (F)												
F1 – 50% RDF	64.1	56.0	60.0	3.99	4.06	4.02	5.35	5.05	5.20	34.7	34.9	34.8
F2 – 75% RDF	65.2	57.2	61.2	4.67	4.33	4.50	5.55	5.20	5.37	35.7	36.8	36.2
F3 – 100% RDF	66.6	59.2	62.9	5.20	4.53	4.87	5.76	5.20	5.48	37.0	37.9	37.4
F test	NS	*	*	*	*	*	*	NS	*	NS	*	*
SE.m±	0.73	0.80	0.31	0.13	0.11	0.12	0.10	0.11	0.04	0.69	0.52	0.26
CD (p=0.05)	-	2.42	1.03	0.41	0.34	0.42	0.31	-	0.15	-	1.57	0.89
F at same levels of I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I at same levels of F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of drip irrigation regimes and fertigation levels on seed yield and water use efficiency in fenugreek

Treatments	Pod length (cm)			Test weight (g)			Seed yield (qt/ha)			WUE (kg/ha mm)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Drip Irrigation												
I1 – 40% CPE	9.14	9.03	9.08	16.5	13.8	15.2	1537.5	1418.3	1477.9	8.4	8.7	8.6
I2 – 60% CPE	9.32	9.21	9.26	16.8	14.2	15.5	1670.4	1476.1	1573.3	6.1	6.0	6.0
I3 – 80% CPE	9.45	9.40	9.42	17.1	13.7	15.4	1767.3	1693.8	1730.6	4.8	5.2	5.0
I4– 100% CPE	9.56	9.23	9.41	17.2	14.5	15.8	1819.4	1781.1	1800.3	4.0	4.3	4.1
F test	*	NS	NS	*	NS	NS	*	*	*	*	*	*
SE.m ±	0.08	0.11	0.054	0.09	0.20	0.19	29.2	70.8	33.6	0.10	0.26	0.10
CD (p = 0.05)	0.27	-	-	0.32	-	-	103.2	249.8	157.0	0.38	0.94	0.48
Fertigation												
F1 – 50% RDF	9.25	9.07	9.16	16.7	14.5	15.6	1635.1	1539.9	1587.5	5.6	5.9	5.7
F2 – 75% RDF	9.39	9.32	9.35	16.9	13.9	15.4	1706.4	1585.8	1646.1	5.9	6.0	5.9
F3 – 100% RDF	9.47	9.28	9.37	17.0	13.8	15.4	1754.4	1651.3	1702.9	6.0	6.3	6.2
F test	NS	NS	*	NS	NS	NS	NS	NS	*	NS	NS	*
SE.m ±	0.07	0.26	0.052	0.11	0.37	0.20	55.9	62.9	10.2	0.22	0.22	0.04
CD (p = 0.05)	-	-	0.17	-	-	-	-	-	34.08	-	-	0.13
F at same levels of I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I at same levels of F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

irrigation to fenugreek to achieve higher seed yield as number of pods per plant are directly related to seed yield. Pod length and test weight was found non-significant even though it has some positive effect during 2014-15. In case seed yield significant differences were observed and it was highest in the treatment drip irrigation at 100 % CPE (1800.3 kg/ha) followed by drip irrigation at 80 % CPE (1730.6 kg/ha). Results of the both the years also indicates similar trend of yield. All the results on growth and seed yield indicate that there is need of irrigation to fenugreek and it is up to 100% CPE. The higher seed yield is due to higher growth, biomass and number of pods, in drip irrigation at 100% CPE. This is due to better utilization of water and nutrients which in turn leads to better photosynthetic efficiency. But viewing to the water scarcity scenario saving water is more important along with achieving higher seed yield. From this it can be concluded that drip irrigation at the rate of 80% CPE is optimum to obtain seed yield which is equivalent to drip irrigation at the rate of 100% CPE. From this 20 percent of the water can be saved by drip irrigation if we considering evaporation as basis for irrigation. The findings are in accordance with Yanglem and Tumbare (2014) in cauliflower and Patel *et al*. (2014) in cluster beans.

Effect of drip irrigation on water use efficiency

Fenugreek crop is very efficient user of water. It will grow luxuriantly if water and nutrients are applied in right time and quantity. Mean of two years data (table 2) shows that drip irrigation at 40 % CPE is having higher WUE (8.6 kg ha^{-1} mm) and lowest use efficiency is by drip irrigation at 100% CPE (4.1 kg ha^{-1} mm). The increased WUE under drip irrigation at 40% CPE may be due to less consumptive use of water, runoff and seepage losses. Higher water use efficiency at drier regimes (40 per cent CPE) may be attributed to reduced total water use in comparison to moist and wet regimes and comparatively higher seed yield. Quezada *et al*. (2011) reported that, the lower water use efficiency at 1.2 IW/CPE and 100 per cent CPE might be due to a greater expense of water use and comparatively lower yield in carrot. Salunkhe *et al* (2015) also reported that irrigation water at 0.6 CPE recorded highest WUE and it reduces as irrigation level increased in wheat. This is also similar in case of fenugreek. Initial crop growth and less ground coverage lead more evaporation losses during initial crop growth stage.

Effect of fertigation on growth and seed yield

There was significant effect of fertigation on fenugreek plant height. Mean plant was highest (62.9 cm) in fertigation @ 100% RDF. Among the both year fertigation @ 100% RDF recorded higher plant height. Similarly mean biomass accumulation was higher in case of fertigation @ 100% RDF (4.87 t/ha) which is at par with fertigation @ 75 % RDF (4.50 t/ha), mean number of primary branches per plant was influenced significantly and it was highest in fertigation @ 100% RDF (5.48) followed by 5.37 branches in the treatment in fertigation @ 75% RDF. Mean number of pods per plant was found to be higher in fertigation @ 100% RDF (37.4) followed by fertigation @ 75% RDF (36.2). Mean pod length was significant and high in fertigation @ 100% RDF. But during the both years it was not observed any difference in pod length. Similarly test weight of fenugreek was not influenced significantly during both the years. Mean seed yield of fenugreek was influenced by fertigation. It was higher in the treatment fertigation @ 100% RDF (1702.9 kg/ha) followed by fertigation @ 75% RDF (1646.1 kg/ha). Fertigation @ 50% RDF was recorded lowest growth and yield parameters in fenugreek among all the drip irrigation treatments. This indicates fenugreek is luxurious consumer of nutrients as it is one of the leafy vegetable which tends to produce more biomass as it gets water and nutrients at regular intervals. These results are similar to reported by Patel *et al*. (2014) in cluster beans. In another study Brahma *et al*. (2010) also reported that 75% and 100% fertigation levels with N and K resulted in higher yield and yield attributing characters as compared to 60% RDF and soil application in capsicum.

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