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Study on Irrigation Levels Based on IW/CPE Ratio and Irrigation Methods on Growth and Yield of Fenugreek (*Trigonella foenium graecum* L.)

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ABSTRACT

The current study was carried out to investigate the effect of different irrigation methods with water level based on IW/CPE ratio on growth and seed yield of fenugreek during the *rabi* season of 2 consecutive years (2016-17) at ICAR-National Research Centre on Seed Spices (NRCSS), Tabiji, Ajmer, Rajasthan. This investigation consisted of four irrigation regimes (IW/CPE ratio *viz* 0.4, 0.6, 0.8 and 1.0) and three irrigation methods *i.e*. (Micro sprinkler, Drip irrigation and Surface irrigation). The experiment was laid out in factorial randomized block design with four replications. Among the irrigation methods tested, drip and micro sprinkler system gave maximum irrigation efficiency and minimum yield loss than surface irrigation. Results showed that irrigation regimes 0.6 IW/CPE ratio with drip irrigation gave superior seed yields (2049.80 kg ha^{-1}) of fenugreek compared to other treatments. Total water applied was 321.96 mm by different irrigation methods. Water productivity and water use efficiency was found highest in 0.4 IW/CPE ratio followed by 0.6 IW/CPE ratio from the finding of the investigation. It was inferred that farmers were over irrigating their farms without equivalent returns. The water saved through use of optimized irrigation method and level can be used more profitably to irrigate supplemental lands, thus achieving a more efficient and rational use of land and water resources.

Key words: Fenugreek, Irrigation methods, IW/CPE ratio, Seed yield, Water use efficiency.

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) prevalently known as its vernacular name “Methi” is an important condiment crop grown in northern India during *rabi* season. Its seeds are used as condiment and vegetable for human consumption and concentrate for cattle. Its fresh tender leaves are also used as vegetable which are rich in iron, calcium, protein, vitamins and essential amino acids. Besides this, it has medicinal utility as it prevents constipation, removes indigestion, stimulates digestive process and metabolism in general. Its seeds are used for the treatment of diabetes, dysentery, diarrhea, rickets etc. its roots are endowed with mini factory to synthesize nitrogen food for plant. Thus, its cultivation enriches the soil in nitrogen.

Water is the key input in crop production (FAO, 1971). The crops should get adequate water at various stages of the growth of plants to give satisfactory yield. The poor on-farm water management emanates from both excesses and insufficient allocation of resources that enables optimum and timely water supply and also plant water uptake. Putting in a different way inappropriate irrigation scheduling, non-uniform on-farm water distribution, wrong duration of irrigation, *etc.* are some of the factors contributing to poor on-farm water management. Farmers’ lack sound knowledge of on-farm water management, particularly on how much to irrigate and when to irrigate (as they tend to over-irrigate as long as water is available) results in water shortages and conflicts in other parts of the schemes. Irrigation also plays a very significant role for reducing the growing pressure on the land by bringing unused land under cultivation. It is also possible to increase production by producing double in a year and hence, growing more food for internal market, improve food security and nutritional status of the population (FAO, 1971).

Besides this to avoid yield reduction and adverse effects on the soil properties irrigation scheduling *i.e*., application in times of crop need with just enough amount of water need to be followed (Rockström and Barron, 2000). The interval between two irrigations should be as wide as possible to save irrigation water without affecting adversely the growth and yield (Dilip, 2000). However, the irrigation method and level system lacks scientific management. Farmers either irrigate over the crop water requirement, which causes water logging, rise of water table, salinity, etc or under irrigate their farms, which results in scarcity of water for plant physiological activities. Appropriate times and sufficient

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amounts are unknown. This in turn resulted in yield decline and adverse changes on soil chemical properties (Haileslassie *et al*., 2016; Demeku *et al*., 2011; Van Halsema *et al.,* 2011).

Therefore, this study was conducted to determine the appropriate frequency and amount of irrigation water for improving the productivity of fenugreek crop.

MATERIALS AND METHODS

Description of the study sites

The current study was conducted at ICAR-National Research Centre on Seed Spices, Tabiji, Ajmer, Rajasthan during the *Rabi* season 2015-16 and 2016-17. The experiment was laid out in FRBD Design with three irrigation methods M_1 (Micro sprinkler), M_2 (Drip irrigation) and M_3 (Surface irrigation) with four irrigation regimes (IW/CPE ratio *viz* 0.4, 0.6, 0.8 and 1.0) with four replications. Summary of descriptions of the study sites has been shown in Table 1 below.

Evapotranspiration and crop water requirement

There was well-established weather station at the study sites. Meteorological observatory climatic database was used in single data for single unit and provides long-term daily and monthly mean values of seven climatic parameters, namely daily maximum and minimum temperatures; maximum and minimum relative humidity, wind speed, monthly (effective) rainfall and reference evapo-transpiration calculated with the open pan evaporimeter method. Latitude, longitude and altitude were directly measured at the sites using Geographic Positioning System and used to access meteorological parameters from meteorological observatory unit.

Minimum and maximum temperatures, relative humidity, wind speed, and rainfall of experimental site were used to calculate reference evapo-transpiration (ETo). The ETo of study site were calculated on daily and summarized monthly bases by employing open pen evoporimeter incorporates procedures for and allows the calculation of ETo, crop water requirements and irrigation scheduling for various crops under various climate, crop and soil conditions (Martin, 1996).

Water use efficiency or water expense efficiency and water productivity

Water use efficiency, water expense efficiency and water productivity was calculated as per standard method as per formula given below.

$$WUE = \frac{Y}{CU}$$

Where,

WUE = Water use efficiency (kg ha^{-1}-mm).

Y = Seed yield (kg ha^{-1}).

CU = Consumptive use of water (mm).

$$WEE = \frac{Y}{ET}$$

Where,

WEE = Water expense efficiency (kg ha^{-1}-mm).

Y = Seed yield (kg ha^{-1}).

ET = seasonal crop evapo-transpiration (mm).

$$\text{Water productivity} = \frac{Y}{WR} \times 1000$$

Where,

WP = Water productivity (kg grain m^3 water).

Y = Seed yield (kg ha^{-1}).

WR = Water required (L/ha).

Data collection

The observation was recorded on number of primary branch $plant^{-1}$, number of pods $plant^{-1}$, plant heights, seed yield and water use efficiency. The crop harvest at the end of physiological maturity, a net plot area of 12 m^2 (the central five rows of each plot) was harvested manually and weighed to determine total seed yield. All the supplied irrigation water was recorded and summed up to find out the total amount of irrigation water applied per cropping season and each treatment. The weighed samples of seed from each plot of the four treatments were converted into kilogram per hectare.

Statistical analysis

Analysis of variance was carried out for each of the measured or computed parameters following the method described by Gomez and Gomez (1984). The significance of differences among treatment means was compared using least significant difference (FRBD test).

RESULTS AND DISCUSSION

Trend of climatic parameters during growing period

The climatic data of the study site is presented in Table 2. The mean maximum temperatures during the crop growing period at ICAR-NRCSS was 28.2°C however corresponding values for mean minimum temperatures was 10.6°C.

Table 1: Summary of descriptions of climatic data on crop growing period on the study sites.

Parameters	2015-16	2016-17
Minimum temperature (°C)	10.7	10.6
Maximum temperature (°C)	27.6	28.8
Minimum relative humidity (%)	54.4	48.4
Maximum relative humidity (%)	90.5	91.0
Rainfall (mm)	0.0	1.0
Altitude (m a.s.l.)	460.17	
Latitude	260 22′ 12" to 260 22′ 31" N	
Longitude	740 35′ 39" E to 740 36′ 01"	

December to January was a period with the highest records of mean minimum temperatures. February to March was a period with the highest records of mean maximum temperatures at ICAR- NRCSS, Ajmer.

The mean annual rainfall at ICAR-NRCSS during crop growing period was 0.5 mm. As expected, the amount and distribution of rainfall got decreased as one went from *kharif* season to winter season. The rainfall trend followed a predictable trend; the lowest rainfall was recorded in October to May; it gradually increased and reached peak in July.

The mean annual humidity during crop growing period maximum and minimum was 90.75% and 51.40%, respectively. Humidity was highest in January significant difference however there was no observed in humidity between crop growing periods.

Variation in evapotranspiration (ETo) during cropping period

The computed ETo for study site has been summarized and the computed results for ETo varied from 3.00 mm day^{-1} in December-January to 6.10 mm day^{-1} in March. The lowest ETo values were recorded during December to January, which is the wet season. The lowest values attributed to the highest rainfall and humidity and the corresponding reduced values for temperature and radiation. While the highest ETo was recorded in dry season with peak values in March. It attributed to the highest values of temperature and radiation and reduced values for rainfall and humidity. These results are in accordance with Wubengda *et al*. (2014) and Adeniran *et al.* (2010), which showed that ETo was lowest during the

Table 2: Mean average data of climatic conditions of study site during 2015-16 and 2016-17.

Months	Maximum temperature (°C)	Minimum temperature (°C)	Maximum Relative humidity (%)	Minimum Relative humidity (%)	Evapo-transpiration mm/day	Total rainfall (mm)
October	33.80	20.40	87.20	56.25	4.65	17.10
November	30.30	11.75	89.75	49.50	3.70	0.00
December	26.15	7.05	92.05	53.90	2.95	0.00
January	23.90	7.05	91.95	56.60	3.00	2.45
February	27.90	9.00	91.20	48.05	4.30	0.00
March	32.70	13.30	89.15	42.15	6.10	0.00

Table 3: Effect of irrigation methods and water levels on days to germination initiation, complete germination, days flowering initiation, days to 50% flowering and plant height (cm) attributing characters in different growth stage in fenugreek (Pooled 2015-16 and 2016-17).

Treatments	Days of initiation of germination	Days of complete germination	Days to initiation of flowering	Days to 50 % flowering	Plant height at 30 DAS (cm)	Plant height on 60 DAS (cm)	Plant height at 90 DAS (cm)	Plant height at harvest (cm)
Irrigation Methods (M)								
M_1	2.56	4.22	44.88	54.94	7.97	18.26	58.61	62.59
M_2	2.59	4.06	43.69	53.60	8.43	20.32	59.75	64.01
M_3	2.63	4.22	46.51	56.60	6.97	16.45	56.89	59.93
SEm±	0.06	0.09	0.63	0.49	0.10	0.19	0.82	0.88
CD (0.05)	NS	NS	1.93	1.52	0.32	1.86	2.54	2.71
CV%	13.05	11.66	7.86	5.07	7.47	5.98	7.97	7.99
Water level (IW/CPE ratios)								
0.4	2.63	4.04	45.43	55.53	7.54	17.67	58.19	61.73
0.6	2.63	4.25	45.00	55.17	7.77	18.44	58.52	62.21
0.8	2.67	4.21	44.88	54.72	7.90	18.50	58.40	62.44
1.0	2.46	4.17	44.79	54.72	7.95	18.50	58.56	62.32
SEm	0.14	0.14	0.73	0.38	0.18	0.31	0.95	1.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV %	12.30	14.24	6.92	2.93	9.89	7.08	6.87	6.86
M×W	NS	NS	NS	NS	NS	NS	NS	NS
Y×M	NS	NS	NS	NS	NS	NS	NS	NS
Y×W	NS	NS	NS	NS	NS	NS	NS	NS
Y×M×W	NS	NS	NS	NS	NS	NS	NS	NS

M_1 (Drip irrigation), M_2 (Micro sprinkler) and M_3 (Surface irrigation), M×W- Irrigation methods and water level, Y×M- Year and Irrigation methods, Y×W- Year and water level, Y×M×W- Year, Irrigation methods and water level.

Table 4: Effect of irrigation methods and water levels on nodules/plant at 45 DAS and 75 DAS, branches/plant and yield attributing characters in fenugreek (Pooled 2015-16 and 2016-17).

Treatments	Nodules /plant at 45 DAS	Nodules /plant at 75 DAS	Number of primary branches /plant	Number of secondary branches /plant	Number of pods /plant	Number of seeds /pod	Seed yield / plot (g)	Seed yield / ha (kg)
Irrigation Methods (M)								
M_1	18.06	14.05	7.37	20.09	40.84	20.20	2291.38	1915.47
M_2	19.32	14.74	8.68	22.28	43.47	21.69	2488.41	2049.80
M_3	17.09	12.89	6.46	17.79	38.59	17.84	2189.06	1814.30
SEm±	0.22	0.20	0.11	0.26	0.57	0.37	29.12	23.98
CD(0.05)	0.66	2.03	0.35	0.79	1.77	1.13	89.72	292.97
CV%	6.71	8.06	8.52	7.27	7.91	10.42	7.09	7.04
Water level (IW/CPE ratios)								
0.4	17.87	13.70	7.27	19.61	40.69	19.48	2290.46	1895.43
0.6	18.45	13.89	7.49	20.29	41.20	19.95	2360.00	1950.36
0.8	18.19	13.95	7.65	20.13	40.97	20.06	2331.58	1945.69
1.0	18.12	13.95	7.61	20.19	41.00	20.14	2309.75	1945.69
SEm	0.24	0.22	0.14	0.29	0.65	0.36	38.34	37.73
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV %	5.69	6.85	7.85	6.23	6.71	7.66	7.00	8.31
M×W	NS	NS	NS	NS	NS	NS	NS	NS
Y×M	NS	NS	NS	NS	NS	NS	NS	NS
Y×W	NS	NS	NS	NS	NS	NS	NS	NS
Y×M×W	NS	NS	NS	NS	NS	NS	NS	NS

M_1 (Drip irrigation), M_2 (Micro sprinkler) and M_3 (Surface irrigation), M×W- Irrigation methods and water level, Y×M- Year and Irrigation methods, Y×W- Year and water level, Y×M×W- Year, Irrigation methods and water level.

peak of the winter season and highest during the peak of the dry season for the respective study areas.

Effect of irrigation methods on growth and yield attributing characters

The results of present investigation clearly indicate that days to germination initiation, final germination, plant height at different stages, number of branches per plant and nodules per plant (45 and 75 DAS) were significantly increased with different methods of irrigation. However, days to germination were not significantly influenced (Table 3 and 4). The earliest flowering (53.60 DAS), highest plant height at different stages 30, 60, 90 and at harvest (8.43, 20.32, 59.75, 64.01 cm), number of primary and secondary branches plant^{-1} (8.68 and 22.28) and nodules per plant at 45 and 75 DAS (19.32 and 14.74) were recorded with the application of irrigation through drip method. This might be due the fact that availability of adequate soil moisture to the plants through out the crop growth period, facilitated absorption of adequate quantity of water leading to higher uptake of nutrients resulting in higher turger pressure of the merismetic cells, thereby causing better cell division and enlargement which enhanced plant height. In drip irrigation, water tension remains low and almost constant for entire growth period of the crop as compared to surface irrigation (Hapase, 1993). It may be due to the fact that under micro sprinkler and drip irrigation, water was applied in right quantities at right time and at right place, which provided sufficient soil moisture surrounding root zone area constantly, which favour better growth, vigorous of plant resulting in more number of branches per plant (Lal *et al.,* 2013). Varying methods of irrigation significantly influenced number of pods plant^{-1}, number of seeds pod^{-1}, seed yield plot^{-1} and seed yield ha^{-1} of fenugreek. Irrigation with drip method had given the highest number of pods plant^{-1} (43.47), seed pod^{-1} (21.69), seed yield g plot^{-1} (2488.41 g) and seed yield kg ha^{-1} (2049.80) which were significantly higher as compared to other treatment. Application of irrigation with drip system exhibited 12.64, 13.67 and 12.98 per cent higher number of pods, seed yield (g plot^{-1}) and seed yield (kg ha^{-1}), respectively followed by micro sprinkler over surface irrigation. The superiority of drip and micro sprinkler for these yield attributing parameters could be explained on the basis of moisture status and nutrients availability in the soil. In drip and micro sprinkler treatments, the soil remains moist and soft because of frequent irrigation on the basis of evapo-transpiration demand of the crop. In drip and micro sprinkler irrigation, right quantity of water is applied in the vicinity of root zone which helps in maintaining optimum water potential in plant system favouring photosynthesis, which consequently resulted in better growth and higher yield attributes of the crop. These results are in conformity with the findings reported by Sharma *et al.* (2016), Vadar *et al.* (2016), Mehta *et al.* (2010) and Lal *et al.* (2013), Meena *et al.* (2017) in fenugreek.

Table 5: Effect of irrigation methods and water levels based on IW/CPE ratio on water use efficiency, water expense efficiency and water productivity in fenugreek (Pooled 2015-16 and 2016-17).

Treatment	Irrigation applied (mm)	Water productivity (kg seed m^3 water)	WUE (kg-ha^{-1} -mm^{-1})	WEE (kg-ha^{-1} -mm^{-1})
Irrigation Methods (M)				
M_1	321.96	0.67	7.12	3.55
M_2	321.96	0.73	7.79	3.86
M_3	321.96	0.64	6.77	3.39
SEm±	-	0.01	0.10	0.07
CD(P =0.05)	-	0.03	0.31	0.21
Water Levels (IW/CPE ratios)				
W_1 (0.4)	183.98	1.04	11.41	3.55
W_2 (0.6)	275.96	0.72	7.60	3.66
W_3 (0.8)	367.95	0.53	5.54	3.61
W_4 (0.1)	459.94	0.42	4.35	3.58
SEm±		0.02	0.20	0.11
CD (P=0.05)		0.05	0.58	NS
C.V %		11.69	11.98	12.49
M × W Interaction		Sig.	NS	NS
Y× M		NS	NS	NS
Y × W		NS	NS	NS
Y×M×W		NS	NS	NS

M_1 (Drip irrigation), M_2 (Micro sprinkler) and M_3 (Surface irrigation), M×W- Irrigation methods and water level, Y× M- Year and Irrigation methods, Y×W- Year and water level, Y×M×W- Year, Irrigation methods and water level.

Effect of water levels based on IW/CPE ratio on growth and yield attributing characters

Observations on plant heights for different stage were non-significantly influenced by various irrigation level based on IW/CPE ratios (Table 3 and 4). Seed germination initiation was earliest (2.63 DAS) and the germination process completed earliest (4.04 DAS) was found in 0.4 IW/CPE ratio however the earliest flowering initiation (44.88 DAS) and 50 per cent of flowering (54.72 DAS) was obtained in the 0.8 IW/CPE ratio. The highest growth and yield attributes like plant height at harvest (62.44 cm), root nodules $plant^{-1}$ at 45 DAS (18.45), number of secondary branches $plant^{-1}$ (20.29), number pod $plant^{-1}$ (41.20), seed yield g $plot^{-1}$ (2360.0) and seed yield kg ha^{-1} (1950.36) were maximum found in water level 0.6 IW/CPE ratio through drip-irrigation followed by 0.8 IW/CPE ratio respectively. 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 hectare 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 0.6 IW/CPE ratio resulted in effective absorption of water and nutrients by fenugreek plants. Same trends are found Datta and Chatterjee (2006).

Effect on water use efficiency

Water use efficiency decrease with increase in irrigation level. Maximum water requirements of fenugreek were recorded under different irrigations at IW/CPE ratio 1.0, which was significantly higher than other treatments, where as the minimum water requirements increased with increase in IW/CPE ratio. Water use efficiency and water expanse efficiency was recorded the highest with irrigation by drip irrigation method (M_2) at 0.4 IW/CPE ratio followed by micro sprinkler method (M_1) at 0.4 IW/CPE ratio and the lowest Water expense efficiency and water use efficiency were recorded under surface irrigation method (M_3) and 1.0 IW/CPE ratios (Table 5). 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. This might be on account of ease with which moisture was available for crop growth due to more number of irrigations resulted in application of more quantity of water which enhanced the CU of water by luxuriant growing plant body which in turn increased the evapotranspiration losses. Frequent irrigation maintained wet surface for longer period which consequently lead to higher loss of moisture due to evaporation. Water productivity was statistically significant however the highest water productivity was found in drip irrigation method (0.73) and 0.4 IW/CPE (1.04) followed by 0.6 IW/CPE ratio reduce WUE due to less proportionate increase in yield but at 0.6 IW/CPE ratio WUE was highest on account of higher seed yield obtained proportion to quantity of water used as compared to other treatments. This might be due to the fact that under more irrigation water, evaporation was at potential rate due to availability of more water than the crop irrigated with less irrigation water, this findings is in close conformity with Bhunia *et al*. (2006) in fenugreek, Bharti *et al*. (2007) in

maize, Kumar *et al*. (2008) in coriander, Patel *et al*. (2007) in fennel and Kamkar *et al.* (2011) in canola.

CONCLUSION

The results of the present study has indicated that scheduling irrigation for fenugreek at 0.6 IW/CPE ratio with drip irrigation throughout is desirable to obtain higher fenugreek yield under assured available irrigation water. However, under water scarce situation, irrigation at 0.4 IW/CPE ratio could be given with a marginal reduction in yield, whereas maintenance of higher plant water status helps to achieve higher fodder yield.

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