



Growth, yield, water use efficiency of coriander (*Coriandrum sativum*) affected by irrigation levels and fertigation

C B HARISHA¹, HONNAPP A ASANGI² and RAVINDRA SINGH³

ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan 305 206, India

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ABSTRACT

Understanding the effect of irrigation and fertigation on yield is essential for planning irrigation and nutrient management strategies in water scarce regions. Therefore two years field experiment (2014-15 and 2015-16) was conducted to find out the interaction effect of irrigation regimes and fertigation on growth, seed yield, quality, water and nutrient use efficiency of coriander (*Coriandrum sativum* Benth.). In this study four irrigation levels (0.4 ET, 0.6 ET, 0.8 ET and 1.0 ET) and three fertigation levels (F₁-50% nutrients F₂-75% nutrients and F₃-100% nutrients) were maintained using drip irrigation. Irrigation and fertigation significantly influenced the growth and seed yield along with water and nutrient use efficiency. The study revealed that irrigation at 0.8 evapotranspiration (ET) was optimum for obtaining better crop growth and seed yield in coriander. Significantly increase the essential oil content of seeds varying from 0.19% to 0.24% in drip irrigation at 0.4 ET and 1.0 ET, respectively. But fertigation has no significant influence on essential oil content. Water use efficiency was found higher in irrigation at 0.4 ET and it is 7.98 kg/ha mm of water and lowest was 5.07 kg/ha mm of water in case of irrigation at 1.0 ET. It is also observed that increasing irrigation level tends to improve nutrient use efficiency. It is concluded that drip irrigation at 0.8 ET along with 75% recommended dose of nutrients are optimum for coriander production, which ensures higher seed yield, water use efficiency and essential oil content.

Key words: Coriander, Drip irrigation, Evapotranspiration, Fertigation, Water use efficiency

Coriander (*Coriandrum sativum* Benth.) is one of the major seed spice crop of winter, cultivated in India for both seed as well as herb. Fruit or seed is used in culinary purposes and as condiment, whereas, herb is used in seasoning and flavouring of food items (Burdock and Carabin 2009). A characteristic aromatic character is present in the stem, leaves and fruits of coriander, which is due to an essential oil containing mainly linalool (Ravi *et al.* 2007, Sahib *et al.* 2013). In Indian arid and semi-arid regions irrigation water is main constraint for agriculture and water use efficiency is very low as soils are sandy loam in nature. In regions where water scarcity is the major limiting factor for cultivation, farmers adopt crops that are able to perform well in limited moisture conditions (Bannayan *et al.* 2008). Therefore, the priority is to adopt most appropriate, efficient and cost effective irrigation strategies which saves irrigation water and also gives optimum crop yield (Favati *et al.* 2009, Honnappa *et al.* 2017). Erratic rainfall and mid season drought reduces the soil moisture in the root zone is not sufficient to meet the crop water and nutrient requirement

(Harisha *et al.* 2017). Irrigation water can be saved either by reducing the frequency of irrigation or by a reduction of water itself based on crop requirement (Darwish *et al.* 2006, Fereres and Soriano 2007). Apart from all changing climatic scenario poses significant challenges to crop production by high temperature, droughts, frost etc. but it also provides opportunity to mitigate these effects and improve crop yield in arid and semiarid regions (Quezada *et al.* 2011). Fertigation is considered as key strategy to unlock the yield potential and also improve nutrient use efficiency. In healthy coriander plants, a noticeable N uptake (22 to 40 mg/plant) with large variations according to genotype and management practices has been reported (Donega *et al.* 2013). Managing nutrients in correct quantity at right time will improve the nutrient use efficiency and productivity (Honnappa *et al.* 2017). Therefore management of resources such as water and nutrients to obtain higher productivity and use efficacies is much required in coriander crop. In the present situation it is essential to find out the effect of reduced irrigation by varying the irrigation levels throughout the crop cycle. Therefore, the study conducted with objective of effect of varying irrigation regimes combined with varied doses of fertigation in coriander crop on seed yield and water use efficiency. The results will be helpful in formulating irrigation and nutrient management of coriander crop to improve growth seed yield and essential oil content.

¹Scientist (harisha.cb@gmail.com), ICAR-NIASM, Baramati.

²Scientist (hdasangi@gmail.com), IISR (RS), Appangala. ³Principal Scientist (mahla_rs@yahoo.com), ICAR-NRCSS, Ajmer.

MATERIALS AND METHODS

The field experiment was conducted during winter season of 2014-15 and 2015-16 at Research farm of Ajmer, Rajasthan, India, at latitude: 26°21'57.83"N, longitude: 74°35'36.80" E and 440 m above MSL. Experimental location is situated western part of India which receives average annual rainfall of 450mm which distributed over four months from June to September. The soil of experimental field is sandy loam in nature and having pH 8.1, EC 0.33 dS/m, organic carbon 0.3%, available nitrogen 148 kg/ha, available P₂O₅ 16.1 kg/ha and available K₂O 325.5 kg/ha. In this trial four irrigation regimes (0.4 ET, 0.6 ET, 0.8 ET and 1.0 ET) and three fertigation levels F₁-50% nutrients (30:15:10 kg N, P₂O₅ and K₂O per ha), F₂-75% nutrients (45:22:15 kg N, P₂O₅ and K₂O per ha) and F₃-100 % nutrients (60:30:20 kg N, P₂O₅ and K₂O per ha respectively) were studied in split plot design with three replications. Crop was irrigated by drip irrigation system. Lateral pipes with inline drippers spaced at 0.3m with discharge rate of 2.3 l/hr were used in the trial and they are placed 50cm apart. Irrigation pressure was maintained at 2.5 per gcc to have adequate discharge from the drippers. Irrigation was given once in four days and eight fertigations were given during entire cropping period starting from thirty days after germination of crop at eight days interval. Crop was raised on broad beds made with help of tractor drawn bed maker cum seed drill. Raised beds of 1.4m × 0.15m × 40m are prepared and seeds were sown in lines with a drill at the spacing of 0.25m between the rows. Plant to plant distance was maintained to 0.15m by thinning after 30 days of sowing. Irrigation water was applied from sowing till crop maturity. The coriander crop was irrigated at four days intervals by different irrigation levels. Total of 34 irrigations through drip irrigation system were given during the cropping period of both the years. Irrigation water was calculated using following equations:

The daily ETo was computed by Eq. (1) according to Doorenbos and Pruitt (1992)

$$ETo = K_{pan} \times E_{pan} \quad (1)$$

where, E_{pan}= evaporation from the Class A pan (mm/day); K_{pan} = the pan evaporation coefficient.

The crop water requirements (ET_c) were estimated using the crop coefficient according to equation (2).

$$ET_c = ETo \times K_c \quad (2)$$

where, ET_c = crop water requirements (mm/day); K_c= crop coefficient.

The crop coefficient values of the coriander cultivation in the seedling, flowering and seed setting phonological stages were 1.0, 0.8 and 0.90 respectively,

Recommended dose of nutrients (RDN) for fenugreek is 60:30:20 kg N, P₂O₅, K₂O per ha for Rajasthan state has taken as reference to give fertigation treatments. Nutrients were supplied in 8 split doses starting from 30 days after sowing at eight days interval. Fertigation as per the treatments was given by water soluble fertilizers such

as urea phosphate (16:44:0 N, P₂O₅ and K₂O respectively) sulphate of potash and urea through ventury.

Randomly selected five plants per treatment and replication were tagged in the field for observation recording for plant height, number of primary branches, umbels per plant and seed yield at the time of harvest. Seed yield per plant was recorded and converted to seed yield per ha.

Water use efficiency values as kg seeds/ha-mm of irrigation water applied were calculated for each treatment after harvest using equation (3) according to Jensen 1983).

$$\text{Total WUE (kg/ha mm)} = \frac{\text{Seed yield (kg/ha)}}{\text{Total water applied (mm/ha)}} \quad (3)$$

Nutrient use efficiency (nitrogen, phosphorus and potassium) values in kg seeds/ha nutrients were calculated for each treatment using equation (4) as suggested by Gerloff and Gabelman (1983)

$$\text{NUE (kg/kg)} = \frac{\text{Units of yield (kg/ha)}}{\text{Nutrient content in plant (kg)}} \quad (4)$$

The essential oil percentage in dried fruits of coriander (30 g) obtained from each replicate of every treatment during both the seasons and were determined by a hydro distillation method and oil content was expressed in per cent on weight by weight basis as described by AOAC (1990) using the following equation (5)

$$\text{Essential oil (\%)} = \frac{\text{Oil weight in the graduated tube (g)}}{\text{Weight of sample (g)}} \times 100 \quad (5)$$

Plant samples including seeds were collected before harvest (at maturity stage) for plant nutrient status analysis.

Statistical analysis were performed by ANOVA following split plot design with irrigation regimes in main plot and fertigation levels in subplots with three replications using SPSS 16.0 software to determine the Least Significant Difference (LSD, P≤0.05) and Duncan's Multiple Range Test (DMRT) to compare the treatment means. Pearson's correlation was carried out to find out the relation between the morphological, water and nutrient use efficiency. Some other calculations were carried out using MS excel 2010.

RESULTS AND DISCUSSION

Growth and seed yield: Results revealed the significant effect of irrigation and fertigation on growth and seed yield of coriander (Table 1). Higher plant height (116.9 cm and 118.6 cm) was recorded in irrigation treatment at 1.0 ET (I₄) during both years and which is at par with I₃ - irrigation at 0.8 ET (115.8 cm and 116.6 cm) but lowest plant height (110.1 and 111.6 cm) was recorded in I₁- irrigation at 0.4 ET. In similar way primary branches, umbels per plant are also found higher in irrigation at 1.0 ET. Seed yield of coriander was found significant and it was highest in 1.0 ET (1824.1 kg/ha and 1580.7 kg/ha during 2014-15 and 2015-16 respectively) followed by irrigation at 0.8 ET (1796.3 kg/ha and 1467.6 kg/ha during 2014-15 and 2015-16 respectively). Lowest yield was recorded from the plots

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

Treatment	Plant height (cm)		Primary branches/plant		Number of umbels/plant		Seed yield (kg/ha)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
<i>Drip irrigation (I)</i>								
I1 – 0.4 ET	110.1 ^b	111.6 ^c	5.9 ^c	6.3 ^b	19.4 ^c	23.6 ^b	1525.1 ^b	1134.3 ^c
I2 – 0.6 ET	113.1 ^a	115 ^{ab}	6.2 ^{bc}	7.2 ^a	20.1 ^{bc}	23.9 ^b	1618.6 ^b	1237.2 ^{bc}
I3 – 0.8 ET	115.8 ^a	116.6 ^a	6.3 ^{ab}	7.3 ^a	21.1 ^b	26.0 ^a	1796.3 ^a	1467.6 ^{ab}
I4– 1.0 ET	116.9 ^a	118.6 ^a	6.5 ^a	7.6 ^a	22.3 ^a	26.4 ^a	1854.1 ^a	1580.7 ^a
LSD (P≤0.05)	4.62	3.71	0.31	0.77	1.55	1.96	191.3	281.9
<i>Fertigation (F)</i>								
F1- 50% nutrients	112.5 ^b	113.7 ^b	6.0 ^b	7.0 ^a	20.1 ^b	24.2 ^b	1608.5 ^b	1201.5 ^{ba}
F2-75% nutrients	114.2 ^{ab}	114.5 ^b	6.2 ^{ab}	7.1 ^a	20.8 ^{ab}	24.2 ^b	1674.5 ^b	1360.7 ^{ab}
F3- 100% nutrients	115.9 ^a	118.6 ^a	6.4 ^a	7.1 ^a	21.3 ^a	26.5 ^a	1812.5 ^a	1505.8 ^a
LSD (P≤0.05)	2.59	3.89	0.26	-	1.55	1.96	136.3	230.1
I × F	NS	NS	NS	NS	NS	NS	NS	NS
F × I	NS	NS	NS	NS	NS	NS	NS	NS

Mean values followed by alphabets in superscript differs significantly by Duncan test (P≤0.05)

received irrigation at 0.4 ET (1525.1 kg/ha and 1134.3 kg/ha during 2014-15 and 2015-16 respectively) followed by plots with irrigation at 0.6 ET (1618.6 kg/ha and 1237.2 kg/ha during 2014-15 and 2015-16 respectively) which are at par with each other. Higher growth and yield attributing characters in drip irrigation at 1.0 ET and 0.8 ET may be due fact that better availability of moisture in field condition helps in nutrient uptake and assimilation. In this study it was also found that nutrient use efficiency (N, P, K) tends to increase as irrigation levels increased. This makes the crop to perform better than other drip irrigation levels. Also higher the growth in terms of number of branches which produce more number umbels per plant which is the main yield attributing character in coriander. Similar observations were also made by Abd El-Wahed and Ali (2013) in corn, Yangle and Tumbare (2014) in cauliflower and Patel *et al.* (2014) in cluster bean. They found that, better growth parameters were recorded when crop was irrigated at 100% and tends to decrease when irrigation levels decreased. The results indicate that reducing irrigation up to 60% is not affecting crop growth and other parameters. It is also reported that in moisture stress situations, viz. 0.4 or 0.6 ET irrigation regimes, lower yield and growth may be due to inadequate water supply, partially closure of stomata inhibit the entry of CO₂ which reflected in stomatal conductance, less transpiration rate which lead to reduced photosynthetic rate (Hnilickova and Duffek 2004). Hence, drip irrigation at 0.8 ET is optimum to obtain seed yield which is equivalent to drip irrigation at the rate of 1.0 ET. From this 20% of the water can be saved by drip irrigation.

Fertigation in coriander crop (Table 1) influenced the growth and seed yield during both the years (2014-15 and 2015-16). Fertigation @ 100% nutrients (60:30:20 kg N, P₂O₅ and K₂O per ha) recorded higher plant height (115.9 and 118.6 cm during 2014-15 and 2015-16 respectively). In case of number of umbels per plant was significant and

highest in fertigation @ 100% nutrients (21.3 and 26.5 during 2014-15 and 2015-16 respectively) and lowest umbels were found in fertigation plots with 50% nutrients. Coriander seed yield was influenced by fertigation significantly. It was higher in the treatment fertigation @ 100% nutrients (1812.5 kg/ha and 1505.8 kg/ha during 2014-15 and 2015-16 respectively) followed by fertigation @ 75% nutrients (1674.5 and 1360.7 kg/ha during 2014-15 and 2015-16 respectively). Fertigation @ 50% nutrients recorded lowest growth and yield parameters in coriander. Since coriander variety used in the experiment is semi erect type and dual purpose variety it produces fresh biomass and needs higher nutrients. Hence, application of 45:22:15 kg N, P₂O₅ and K₂O per ha respectively (75% nutrients) as a fertigation to coriander crop is found optimum as it results similar yield of fertigation at 60:30:20 kg N, P₂O₅ and K₂O per ha respectively (100% nutrients). These results are similar to reported by Patel *et al.* (2014) in cluster bean and by Godara *et al.* (2013) in fennel. Therefore, supply of 45:22:15 kg N, P₂O₅ and K₂O per ha is found optimum if irrigation level is maintained at 0.8 ET. Due to this plant roots are able to absorb the nutrients efficiently throughout crop cycle when soil moisture is at field capacity. Since drip irrigation enabled with fertigation supplies nutrients and water in the root zone of crop help in optimum moisture and nutrient uptake.

Essential oil content: Results indicate that irrigation regimes have significant influence on essential oil content of seeds during both the years (Fig 1). It was found that highest oil content was highest in irrigation at 1.0 ET (0.23 and 0.25 %) which is at par with irrigation at 0.8 ET (0.24 and 0.23%). Lowest oil content was recorded in 0.6 ET and 0.4 ET respectively. But fertigation had no influence on essential content in coriander fruits. Higher essential oil content in seeds obtained from drip irrigation at 1.0 ET is may be due to adequate moisture in plant system which

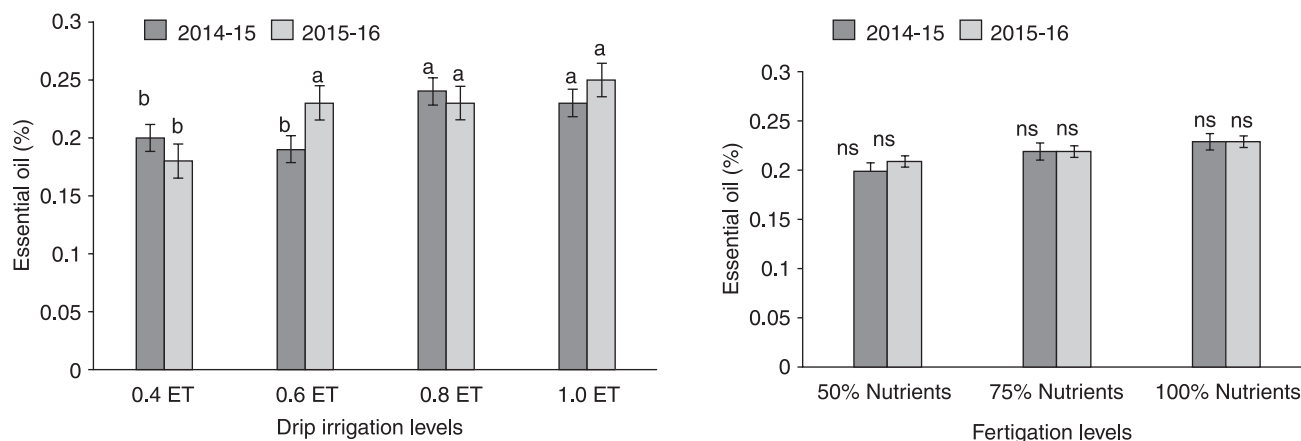


Fig 1 Variation in essential oil content of coriander seeds under varied irrigation and fertigation levels. Alphabets indicated above bars differs significantly by Duncan test ($P \leq 0.05$) and ns- non significant.

influenced the synthesis and accumulation more volatile compounds in seeds. These results are in accordance with Hassan and Ali (2014), Mehanna *et al.* (2015) and Unlukara *et al.* (2016). They reported that essential oil percentage as well as essential oil yield in coriander increased significantly with increasing irrigation regimes. These results may be due to the higher water stress at lower irrigation rates, which alters the rate of metabolic process for secondary products which lead to synthesis of volatile oil.

Water use efficiency: Water use efficiency (Table 2) of coriander was influenced significantly by irrigation treatments at varying levels. It was found that higher water use efficiency was in the treatment irrigation at the rate of 0.4 ET (7.94 and 8.02 kg/ha mm during 2014-15 and 2015-16, respectively) and lowest use efficiency was observed in irrigation at the rate of 1.0 ET (5.17 and 4.96 kg/ha mm during 2014-15 and 2015-16, respectively) followed

by irrigation at the rate of 0.8 ET. WUE decreased with increase in the level of irrigation. Relation between WUE and seed yield explain that irrigation level between 0.6-0.8 ET is optimum where yield and water use is optimum (Fig 2). Therefore, looking to average seed yield, irrigation at 0.8 ET is optimum for coriander crop. Higher water use efficiency in lower irrigation levels is due to effective use of applied water in plant functions and ultimately crop yield. In higher irrigation levels water tends to loss more either by percolation, leaching, and evaporation or remains in soil. But plants can only use required amount of water. Yanglem and Tumbare (2014) reported that in higher irrigation levels stomatal resistance will be less which leads to more transpiration losses as compared to lower irrigation levels in cauliflower. Abd El-Wahed *et al.* (2017) confirmed that higher WUE can be achieved in lower irrigation levels than higher levels in common bean. These are confined with

Table 2 Effect of drip irrigation regimes on water and nutrient use efficiency in coriander

Treatment	WUE (kg/ha-mm)		NUE (kg/kg nitrogen)		PUE (kg/kg phosphorus)		KUE (kg/kg potassium)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Drip irrigation (I)								
I1 – 0.4 ET	7.94 ^a	8.02 ^a	35.8 ^b	26.6 ^b	71.8 ^b	53.3 ^b	107.6 ^b	80.0 ^b
I2 – 0.6 ET	6.51 ^b	6.17 ^b	38.4 ^b	29.1 ^b	76.8 ^b	58.1 ^b	115.2 ^b	87.2 ^b
I3 – 0.8 ET	5.93 ^c	5.65 ^{bc}	42.7 ^a	34.3 ^a	85.5 ^a	68.6 ^a	128.3 ^a	103.0 ^a
I4 – 1.0 ET	5.17 ^c	4.96 ^c	44.2 ^a	37.0 ^a	88.5 ^a	74.0 ^a	132.8 ^a	111.0 ^a
LSD ($P \leq 0.05$)	0.80	1.11	4.28	5.54	8.59	11.07	12.87	16.63
Fertigation (F)								
F1- 50% nutrients	6.02 ^b	4.55 ^b	53.6 ^a	40.0 ^a	107.2 ^a	80.1 ^a	160.8 ^a	120.1 ^a
F2-75% nutrients	6.31 ^b	5.15 ^{ab}	37.2 ^b	30.2 ^b	74.4 ^b	60.4 ^b	111.6 ^b	90.6 ^b
F3- 100% nutrients	6.86 ^a	5.66 ^a	30.2 ^c	25.0 ^c	60.4 ^c	50.1 ^c	90.6 ^c	75.1 ^c
LSD ($P \leq 0.05$)	0.53	0.92	2.87	4.8	5.72	9.61	8.58	14.42
I × F	NS	NS	NS	NS	NS	NS	NS	NS
F × I	NS	NS	NS	NS	NS	NS	NS	NS

Note: Mean values followed by alphabets in superscript differs significantly by Duncan test ($P \leq 0.05$)

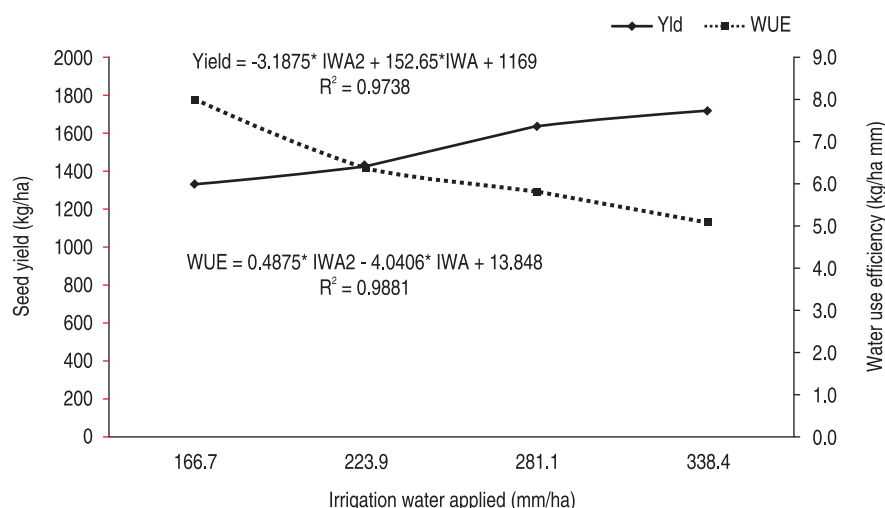


Fig 2. Relation between total water applied, seed yield and water use efficiency in coriander.

Honnappa *et al.* (2017) in fenugreek. Other researchers also found increased WUE values under limited irrigated conditions in red pepper (Sezen *et al.* 2014) and in brinjal (Kirkak *et al.* 2002). In another study by Igbadun *et al.* (2012) reported that, relationship between bulb yield and water applied in onion, implying that bulb yield up to some irrigation level and decreases with additional water supply.

Nutrient use efficiency: Nitrogen, phosphorus and potassium use efficiency (kg grain/kg nutrient applied) during 2014-15 and 2015-16 was calculated and results are presented in Table 2. In case of irrigation levels higher mean nitrogen use efficiency was observed in irrigation @ 1.0 ET (44.2 and 37.0 kg/kg during 2014-15 and 2015-16 respectively) and it was at par with I_3 - irrigation at 0.8 ET. Range of mean N use efficiency was observed between 31.2 to 40.6 kg/kg. In case of fertigation levels higher N use efficiency was noticed in F_1 -fertigation at 30:15:10 N P_2O_5 and K_2O (53.6 and 40.0 kg/kg during 2014-15 and 2015-16 respectively) and its efficiency was decreased at increased fertigation rate. Mean P and K use efficiency was increased with increase of irrigation levels and it was highest in I_4 - irrigation @ 1.0 ET (81.3 kg/kg P and 121.9 kg/kg K, respectively). Nutrient use efficiency was tends to increase as drip irrigation levels was increased. This is due to fact

that better moisture content in the soil of root zone enables the plant to absorb more nutrients and assimilate them in to biomass. In lower moisture condition plants under go moisture stress condition where absorbing nutrients from soil will limited as many nutrients enters the plant system by mass flow or ion exchange mediated by water regulations. These results are in confirmation with Harisha *et al.* (2017) in fenugreek. In case of fertigation reverse trend was observed i.e. as increase in fertilizer levels use efficiency was reduced. This may be due to fact that only part of applied nutrients along with native soil nutrients are being used by crop. Vasu and Reddy (2013) was noticed in cabbage that nitrogen use efficiency was higher at 75% RDN and it also saves 25% of fertilizers. Zhenan Hou *et al.* (2017) also reported that fertigation of nitrogen at starting of irrigation cycle improved nutrient use efficiency. Similar trend was observed in case of phosphorus and potassium use efficiency. Similarly higher dose of fertilizers leads to more loss than lower dose. This is the fact that contributed the poor use efficiency of all the nutrients at higher fertigation levels. Nutrient use efficiency in fertigation increases as a result of controlled and regular application of fertilizer.

Relation between plant growth parameter, seed yield and nutrient use efficiency: The interrelationship between the parameters in the data set was analysed by Pearson's correlation which reveals relationships among variables. It is found that water use efficiency is negatively correlated (Table 3) with plant growth seed yield and nutrient use efficiency. This may be due to higher water use efficiency in lower levels of drip irrigation where less growth and seed yield was recorded. N, P and K use efficiency is positively correlated with all growth and yield parameters.

Irrigating coriander at 0.8 ET is at four days interval along with 45:22:15 kg N, P_2O_5 and K_2O per ha as fertigation is optimum in obtaining better growth, yield and essential

Table 3 Pearson correlation coefficient for different growth and nutrient parameters

	Plant ht.	No. branches	No. Umbels	Seed yield	IWUE	NUE	PUE	KUE
Plant ht.	1	0.480**	0.688**	0.597**	-0.539**	0.471**	0.344*	0.584**
No. branches		1	0.509**	0.618**	-0.586**	0.310	0.566**	0.426**
No. umbels			1	0.646**	-0.444**	0.422*	0.320	0.569**
Seed yield				1	-0.373*	0.408*	0.445**	0.533**
IWUE					1	-0.073	-0.292	-0.193
NUE						1	0.595**	0.628**
PUE							1	0.543**
KUE								1

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

oil content. It indicates that 20% reduced irrigation as compared to 100% evapotranspiration is ideal for better productivity without much reduction in yield. Higher nutrient use efficiency in coriander can be achieved by drip irrigation crop at 0.8 ET and lower doses of fertilizers. Nitrogen and potassium use has significant effect on seed yield and its parameters in coriander. Hence, fertilizing crop by N and K is most necessary. Regression model worked out for yield prediction may be used to estimate the yield of coriander under varying water levels. So that in any water scarcity conditions irrigation management and yield prediction will be possible.

REFERENCES

- Abd El-Wahed M and Ali E A. 2013. Effect of irrigation systems, amounts of irrigation water and mulching on corn yield, water use efficiency and net profit. *Agricultural Water Management* **120**: 64–71.
- Abd El-Wahed M H, Baker G A, Alia M M and Adel F. 2017. Effect of drip deficit irrigation and soil mulching on growth of common bean plant, water use efficiency and soil salinity. *Scientia Horticulturae* **225**: 235–42.
- Bannayan M, Nadjafi F., Azizi M, Tabrizi L and Rastgoo M. 2008. Yield and seed quality of *Plantago ovata* and *Nigella sativa* under different irrigation treatments. *Industrial Crops and Products* **27**: 11–6.
- Burdock G A and Carabin I G. 2009. Safety assessment of coriander (*Coriandrum sativum* L.) essential oil as a food ingredient. *Food and Chemical Toxicology* **4**: 22–34.
- Colak Y B, Yazar A, Sertan Sesveren and Ilker Colak. 2017. Evaluation of yield and leaf water potential (LWP) for eggplant under varying irrigation regimes using surface and subsurface drip systems. *Scientia Horticulturae* **219**: 10–21.
- Darwish T M, Atallah T W, Hajhasan S and Haidar A. 2006. Nitrogen and water use efficiency of fertigated processing potato. *Agricultural Water Management* **85**: 95–104.
- Donega M A, Mello S C, Moraes R M and Cantrell C L. 2013. Nutrient uptake, biomass yield and quantitative analysis of aliphatic aldehydes in cilantro plants. *Industrial Crops and Products* **44**: 127–31.
- Doorenbos J and Pruitt W O. 1992. Crop water requirements. FAO Irrigation and Drainage Paper No. 24, FAO, Rome, Italy.
- Favati F, Lovelli S, Galgano F, Miccolis V, Di Tommaso T and Candido V. 2009. Processing tomato quality as affected by irrigation scheduling. *Scientia Horticulturae* **122**(4): 562–71.
- Fereres E and Soriano M A. 2007. Deficit irrigation for reducing agricultural water use. *Journal of Experimental Botany* **58**: 147–59.
- Gerloff G C and Gabelman W H. 1983. Genetic basis of inorganic plant nutrition. *Encyclopaedia of Plant Physiology* pp 453–80. Auchli A L and Bielecki R L (Eds). New series, 15B. Springer Verlag, New York.
- Godara S R, Verma I M G, Bairwa S and Yadav P K. 2013. Effect of different levels of drip irrigation along with various fertigation levels on growth, yield and water use efficiency in fennel (*Foeniculum vulgare* Mill.). *Asian Journal of Horticulture* **8**(2): 758–62.
- Harisha C B, Asangi H and Singh R. 2017. Impact of drip irrigation and fertigation on residual soil nutrient status, nutrient uptake and nutrient use efficiency of fenugreek under semi arid conditions. *International Journal of Pure Applied Biosciences* **5**(2): 661–7.
- Hassan F A S and Ali E F. 2014. Impact of different water regimes based on class-A pan on growth, yield and oil content of *Coriandrum sativum* L. plant. *Journal of the Saudi Society of Agricultural Sciences* **13**: 155–61.
- Hnilickova H and Duffek J. 2004. Water deficit and its effect on physiological manifestations in selected varieties of cauliflower (*Brassica oleracea* var. botrytis L.). *Scientia Agriculturae Bohemica* **35**(2): 57–63.
- Honnappa A, Harisha C B and Ravindra Singh. 2017. Precision irrigation and fertigation for higher productivity and water use efficiency in fenugreek (*Trigonella foenum-graecum* L.) in semi-arid conditions of Rajasthan. *Bioscan Supplements on Agronomy* **12**(1): 591–4.
- Igbadun H E, Ramalan A A and Oiganji E. 2012. Effects of regulated deficit irrigation and mulch on yield water use and crop water productivity of onion in Samaru, Nigeria. *Agricultural Water Management* **109**: 162–9.
- Jensen M E. 1983. Design and operation of farm irrigation systems. ASAE monograph, Revised printing No. 3.
- Kirnak H, Tas I, Kaya C and Higgs D. 2002. Effects of deficit irrigation on growth, yield and fruit quality of eggplant under semi-arid conditions. *Australian Journal of Agriculture Research* **53**: 1367–73.
- Mehanna M H, Ahl H A, Hussein, Mursy M H, Ngezimana W and Mudau F N. 2015. Yield and essential oil response in coriander to water stress and phosphorus fertilizer application. *Journal of Essential Oil Bearing Plants* **18**(1): 82–92.
- Patel S J, Patel B M, Raval C H, Patel KI, Patel P B, Patel P M and Vekaria L C. 2014. Response of vegetable cluster bean [*Cyamopsis tetragonoloba* L.) to fertigation of P and K. *Legume Research* **37**(4): 420–3.
- Quezada C, Fischer S, Campos J and Ardiles D. 2011. Water requirements and water use efficiency of carrot under drip irrigation in a haploxer and soil. *Journal of Soil Science and Plant Nutrition* **11**(1): 16–28.
- Ravi R, Prakash M and Keshava Baht K. 2007. Aroma characterization of coriander (*Coriandrum sativum* L.) oil samples. *European Food Research and Technology* **224**(3): 367–74.
- Sahib N G, Anwar F, Gilani A H, Hamid A A, Saari N and Alkharfy K M. 2013. Coriander (*Coriandrum sativum* L.): A potential source of high-value components for functional foods and nutraceuticals—a review. *Phytotherapy Research* **27**: 1439–56.
- Sezen S M, Yazar A, Dasgan Y, Yucel S, Akyildiz A Tekin and Akhoundnejad Y. 2014. Evaluation of crop water stress index (CWSI) for red pepper with drip and furrow irrigation under varying irrigation regimes. *Agricultural Water Management* **143**: 59–70.
- Unlukara A, Beyzi E, Ipek A and Gurbuz B. 2016. Effects of different water applications on yield and oil contents of autumn sown coriander (*Coriandrum sativum* L.). *Turkish Journal of Field Crops* **21**(2): 200–9.
- Vasu D and Reddy M S. 2013. Effect of fertigation on yield, quality, nutrient uptake, fertilizer and water use efficiency in cabbage (*Brassica oleracea*). *Agropedology* **23**(2): 106–12.
- Yangle S D and Tumbare A D. 2014. Influence of irrigation regimes and fertigation levels on yield and physiological parameters in cauliflower. *Bioscan* **9**(2): 589–94.
- Zhenan Hou, Pinfang Li, Baoguo Li, Jiang Gong and Yanna Wang. 2007. Effects of fertigation scheme on N uptake and N use efficiency in cotton. *Plant and Soil* **290**: 115–26.