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Drip fertigation improves biophysical and economic water productivity of turmeric (*Curcuma longa*)

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ABSTRACT

A field experiment was conducted to find out 1) optimum drip irrigation and fertigation rate to realize potential yield of turmeric; 2) to quantify water saving and yield improvement under drip fertigation over control during 2014–15. The experiment was laid out in randomized complete block design, keeping combinations of three drip irrigation {60, 80 and 100 reference evapotranspiration (ETo)} and three fertigation rate {60, 80 and 100% recommended dose of fertilizers (RDF), i.e. 62.5, 25, and 25 kg/ha N, P_2O_5 and K_2O, respectively} under drip with an extra control (surface flood irrigation and soil application of RDF). Drip irrigation at 100% ETo recorded maximum processed turmeric yield which was statistically at par with that drip irrigation at 80% ETo but significantly better than 60% ETo. Fertigation at 80 and 100% RDF resulted in 12.7 and 17.6% higher processed turmeric yield than fertigation at 60% RDF. Drip fertigation at 80% ETo with 80% RDF recorded 18.9% higher processed turmeric yield than control. Irrigation water input was 162.9 mm lesser under 80% ETo than 100% ETo and processed turmeric yield was 8.6 q/ha higher under 80% ETo than 60% ETo. Actual crop evapotranspiration (ETa) was 96.6 and 187.5 mm higher under drip irrigation at 80 and 100% ETo than 60%, respectively. Drip fertigation at 80% ETo with 80% RDF recorded 18.9% higher processed turmeric yield, 7.7% higher biophysical water productivity, 71.7% higher apparent water productivity, 21.6% higher water use efficiency and 77740 ₹/ha higher net returns along with saving of 311.1 mm irrigation water than control.

Key words: Biophysical water productivity Crop evapotranspiration, Economic water productivity, Irrigation water input, Turmeric

Seemingly water is available in abundance but actually becoming a scarce resource and limiting agricultural production in developed and developing countries. Agricultural sector, being a leading user of fresh water (80%), should have to pick wide strides to tackle this problem of water scarcity. As water use efficiency (WUE) in agricultural sector is only 30–40%, there is considerable scope to produce more with less or equal quantity of water. The solution of growing water scarcity and persistent degradation of water resources is of the two fold. Firstly, improvement in supply side through watershed management and development of water resources in the form of major, medium and minor irrigation projects. Secondly, demand management through efficient management of available water resources, both in short-term and long-term perspectives. Among demand management strategies micro irrigation (Drip and sprinkler irrigation system), have the potential to save considerable irrigation water. Dar *et al*. (2017) reported saving of 50% irrigation water in wheat when drip irrigation was applied at 15% depletion from field capacity over check basin. Because in drip irrigation water is delivered beneath the roots of the plants, hence, effective wetting area reduced up to 20%. Secondly, surface run-off, deep percolation and soil evaporation reduced considerable along with reduced weed growth in drip as compared to flood irrigation (Kaur and Brar 2016).

In Punjab increased area under rice from 0.39 ha in 1970–71 to 3.05 M ha in 2016–17 (Anonymous 2017) led to degradation of water resources and at present water table is lowing 0.4–0.9 m per annum (Brar *et al.* 2012). Thus, there is need to diversify some area from rice to another crops and turmeric offers good scope to be an alternate to rice. Turmeric is a long duration crop and remains in field for 9–10 months. Early period of turmeric growing season faces hot and dry weather, which makes its water requirement quite high. Secondly, drip fertigation facilitates precise and frequent supply of nutrients and water beneath the roots of plant. Hence, effective uptake of nutrients which resulted in higher input use efficiency (Sadarunnisa *et al.* 2010).

MATERIALS AND METHODS

A field experiment was conducted at Research Farm

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of Punjab Agricultural University, Ludhiana (Punjab), India, during 2014–15. The experimental site is located at an altitude of 247 m amsl; at 30° 56'N latitude; 75^0 48' E longitude; as a part of the Indo-Gangetic alluvial plains. The climate of region is characterized as semi-arid (dry) with 755 mm average annual rainfall of which >80% is received in monsoon (July–September). Weather data recorded at meteorological observatory located at 350 m away from experimental site is presented in Fig 1. Almost similar weather conditions were experienced during both the cropping years.

The experiment was laid out in randomized complete block design, keeping combinations of three drip irrigation {60, 80 and 100 reference evapotranspiration (ETo)} and three fertigation rate {60, 80 and 100% recommended dose of fertilizers (RDF), i.e. 62.5, 25, and 25 kg/ha N, P_2O_5 and K_2O, respectively (Anonymous 2018)} schedules under drip with an extra control (surface flood irrigation and soil application of RDF). Turmeric cultivar Punjab Haldi No. 1 was planted on 28th April, 2014 and 2015 at 30 cm × 20 cm using 20 q/ha mother and primary rhizomes of 5–10 cm on flat seed bed. Gross plot size of 3 m × 6 m with buffer zone of 1.5 m around each plot was maintained to kept check on variation arising due to water application. The crop was irrigated just after planting keeping 50 mm depth in drip plots and 75 mm in extra control plot. In control whole P_2O_5 and K_2O was applied just before planting and nitrogen was applied at 75 and 100 days after planting

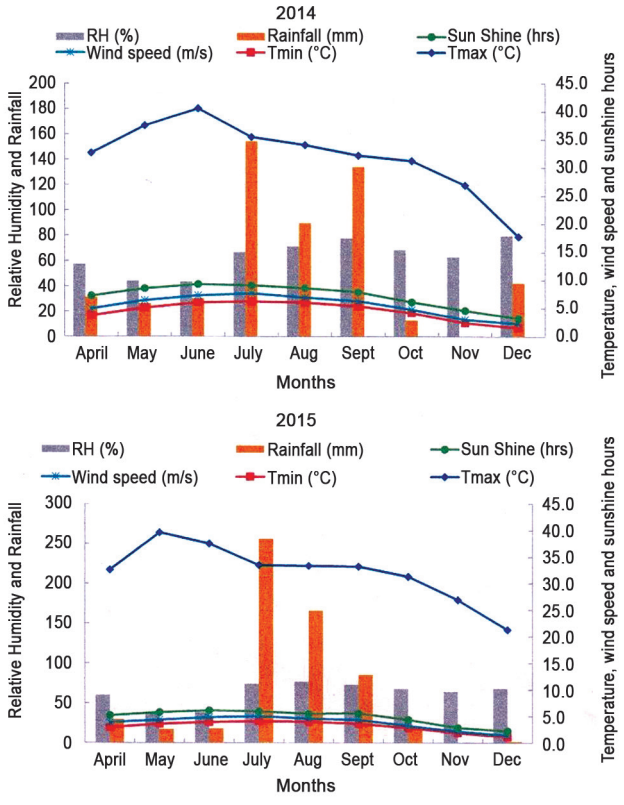

Fig 1 Mean monthly meteorological data recorded during the crop season 2014 and 2015.

(DAP) in two equal splits. Drip irrigation was applied at three days interval keeping depth of irrigation equal to sum of corresponding three days reference evapotranspiration (ETo) as per treatments. Daily ETo was calculated from location specific weather data with the help of ETo calculator available on website of FAO (www.fao.org). Each plot was drip irrigated with a lateral pipe having inbuilt dripper at spacing of 30 cm with discharge of 2.2 lph, placed between two rows of turmeric. To compute amount of irrigation water applied, a water meter was installed on PVC pipe used for irrigation to drip, as well as in control plots. Total irrigation water applied during whole crop growing season was calculated by cumulating the irrigation water applied in each irrigation. Fertigation was started at 45 DAP and completed in 15 equal splits applied at 9 days interval as per treatment. Various productivity indices are obtained as:

$ET_a = (I+P) - (R+D\pm\Delta SW)$ Dar *et al.* (2017)

$$BPWP = \frac{PTY}{ETa} \text{ ....Sahoo } et\ al. \text{ (2018)}$$

$$AWP = \frac{PTY}{IWA} \text{ .... Kaur and Brar (2016)}$$

$$WUE = \frac{ETa}{\text{Total water input } (I+P+\Delta SW)} \times 100 \text{ .... Heydari (2011)}$$

$$EWP = \frac{NR}{ETa} \text{ ....Sahoo } et\ al. \text{ (2018)}$$

where ETa, Actual crop evapotranspiration (mm); I, irrigation water applied (mm); P, precipitation (mm); R, surface runoff (mm); D, deep drainage (mm); ΔSW, change in soil profile moisture storage (mm); BPWP, bio-physical water productivity (kg/m^3); PTY, processed turmeric yield (q/ha); AWP, apparent water productivity (kg/m^3); IWA, irrigation water applied (m^3/ha); WUE, water use efficiency (%); EWP, economic water productivity (₹/m^3); R, net returns (₹/ha).

Soil water content was determined with time domain refrectometry from 0-10, 10-20, 20-30, 30-40, 40-60, 60-100 cm profile at 9 days interval. Runoff was absent as sufficient dikes were maintained. Deep drainage was considered zero when soil profile moisture storage was remained less than field capacity. But when soil moisture storage exceeded the field capacity storage after irrigation or rainfall, then deep drainage was worked out as difference between the field capacity storage and soil moisture storage plus irrigation/ rainfall.

Processing of turmeric: One kilogram fresh rhizomes from each plot was washed with clean water and then boiled in vertical autoclave at 121°C temperature, 15 lbs/$inch^2$ pressure for half an hour. After boiling, the rhizomes were dried in sun for 2–3 days and then dried in oven at 60°C and dry weight was recorded. Oven dried rhizomes after dry weight were polished manually and grounded with the help of grinder and processed/powder yield of turmeric in q/ha was calculated.

Statistical analysis: Statistical analysis of different parameters of turmeric was done using Proc GLM (SAS software 9.3, SAS institute Ltd, USA) for both the years separately and since trends in results were similar during both years, data were pooled keeping years as main factor to increase the precision for drip irrigation and fertigation rate.

RESULTS AND DISCUSSION

Site characteristics: The soil of the experimental site was sandy loam (Typic Ustochrept) in texture; tested low in organic carbon (0.32%) and available nitrogen (175.3 kg/ha), medium in available phosphorous (18.4 kg/ha) and high in available potassium (337.5 kg/ha). Soil reaction (*p*H 7.79) and electrical conductivity (0.35 dS/m) was found to be in normal range. Field capacity and permanent wilting point of the 0–100 cm profile was 25% and 8%, respectively, with average bulk density of 1.61 g/cc.

Processed turmeric yield: Crop drip irrigated at 100% ETo produced maximum processed turmeric yield (66.1 q/ha) which was statistically at par with that drip irrigated

Table 1 Effect of drip irrigation and fertigation rates on processed turmeric yield, biophysical water productivity (BPWP), apparent water productivity (AWP), water use efficiency (WUE), net returns and economic water productivity of turmeric (Pooled mean of 2 years)

Fertigation rate (FR)	Drip irrigation rate (IR)				Control#
	ETo 60%	ETo 80%	ETo 100%	Mean	
			Processed turmeric yield (q/ha)		
60 % RDF	50.9	60.2	59.0	56.7	
80 % RDF	57.2	66.2	68.2	63.9	
100 % RDF	60.7	68.2	71.2		
Mean	56.3	64.9	66.1	66.7	55.7
LSD (P=0.05)		IR= 4.4; FR= 4.4; IR × FR = NS; IR × FR vs Control = 5.7			
Bio-physical water productivity (kg/m^3)					
60 % RDF	0.589	0.635	0.570	0.598	
80 % RDF	0.653	0.682	0.639	0.658	
100 % RDF	0.685	0.687	0.557	0.643	
Mean	0.642	0.668	0.589		0.633
LSD (P=0.05)		IR=NS; FR=0.045; IR × FR = NS; IR × FR vs Control=NS			
			Apparent water productivity (kg/m^3)		
60 % RDF	0.946	0.859	0.683	0.829	
80 % RDF	1.064	0.945	0.789	0.933	
100 % RDF	1.128	0.972	0.824	0.975	
Mean	1.046	0.925	0.765		0.552
LSD (P=0.05)		IR= 0.063; FR= 0.063; IR × FR = NS; IR × FR vs Control = 0.081			
			Water use efficiency (%)		
60 % RDF	85.9	83.1	81.3	83.4	
80 % RDF	86.7	84.3	82.7	84.6	
100 % RDF	87.2	85.4	83.3	85.3	
Mean	86.6	84.3	82.4		62.7
			Net returns (₹/ha)		
60 % RDF	2,84,180/-	3,57,825/-	3,46,905/-	3,29,615/-	
80 % RDF	3,34,555/-	4,05,210/-	4,19,380/-	3,86,360/-	
100 % RDF	3,61,335/-	4,21,850/-	4,41,805/-	4,08,330/-	
Mean	3,26,690/-	3,94,940/-	4,02,675/-	3,74,790/-	3,27,470/-
			Economic water productivity (₹/m^3)		
60 % RDF	52.78	51.02	40.17	47.97	
80 % RDF	62.14	57.52	48.55	56.09	
100 % RDF	67.08	60.12	51.09	59.41	
Mean	60.64	56.22	46.60	54.47	60.65

#Surface flood irrigation and soil application of RDF

Table 2 Irrigation water input (IWI), change in soil profile moisture (ΔS), drainage (D) and crop evapotranspiration (ETa) of turmeric under different drip irrigation and fertigation rate during 2014–15

Drip irrigation rate	Fertigation rate	2014					2015				
		IWI (mm)	Rainfall (mm)	ΔS (mm)	D (mm)	ETa (mm)	IWI (mm)	Rainfall (mm)	ΔS (mm)	D (mm)	ETa (mm)
ETo 60%	RDF 60%	547.1	446.9	29.4	135.9	828.7	530.0	556.4	41.6	148.4	896.4
	RDF 80%	547.1	446.9	26.5	130.6	836.9	530.0	556.4	34.9	139.3	912.2
	RDF 100%	547.1	446.9	22.7	127.8	843.5	530.0	556.4	27.8	132.5	926.1
	Mean	547.1	446.9	26.2	131.4	836.4	530.0	556.4	34.8	140.1	911.6
ETo 80%	RDF 60%	712.8	446.9	56.4	179.4	923.9	690.0	556.4	69.4	204.5	972.5
	RDF 80%	712.8	446.9	44.8	168.8	946.1	690.0	556.4	55.5	193.6	997.3
	RDF 100%	712.8	446.9	38.1	154.3	967.3	690.0	556.4	43.2	186.7	1016.5
	Mean	712.8	446.9	46.4	167.5	945.8	690.0	556.4	56.0	194.9	995.4
ETo 100%	RDF 60%	878.5	446.9	85.8	230.4	1009.2	850.0	556.4	98.4	247.1	1060.9
	RDF 80%	878.5	446.9	68.5	213.7	1043.2	850.0	556.4	83.7	232.4	1090.3
	RDF 100%	878.5	446.9	59.3	209.3	1056.8	850.0	556.4	71.8	226.3	1108.3
	Mean	878.5	446.9	71.2	217.8	1036.4	850.0	556.4	84.6	235.3	1086.5
Control#	RDF 100%	1050.0	446.9	102.8	515.6	878.5	975.0	556.4	119.7	530.6	881.1

#Surface flood irrigation and soil application of RDF

at 80% ETo (64.9 q/ha) but significantly better than drip irrigated at 60% ETo (56.3 q/ha) (Table 1). Drip irrigated crop at 80% and 100% ETo recorded 15.3 and 17.4% higher processed turmeric yield than 60% ETo, respectively (Table 1). Better performance of crop drip irrigated at 80 and 100% ETo resulted from optimum supply of water which help in effective uptake and translocation of nutrients towards developing rhizome. Secondly, crop drip irrigated at 60% ETo faces water stress which is evident from 96.6 mm and 187.5 mm lesser actual crop evapotranspiration under 60% ETo than 80 and 100% ETo, respectively (Table 2). Kaur and Brar (2016) reported that turmeric crop drip irrigated at 1.2 and 1.0 IW: CPE recorded statistically at par yield which was significantly better than that drip irrigated at 0.6 and 0.8 IW: CPE. Furthermore, optimum water level resulted in better turgidity of cell, leading to cell enlargement and better cell wall development (Madhumathi *et al*. 2004). Fertigation rate had significant effect on growth and yield attributes of turmeric and crop fertigated with 100% recommended dose of fertilizers (RDF) recorded maximum processed turmeric yield (66.7 q/ha) which was statistically at par with 80% RDF but significantly better that 60% RDF (Table 1). Fertigation rate at 80 and 100% RDF resulted in 12.7 and 17.6% higher processed turmeric yield than at 60% RDF. Better growth and yield attributes under fertigation rate of 80 and 100% RDF attributed to enhanced uptake of nutrients under optimum level of nutrition, which ensures better photosynthesis efficiency thereby causing greater synthesis, translocation and accumulation of assimilates (Ghanta *et al.* 1995).

Processed turmeric yield influenced significantly between combinations of drip irrigation and fertigation rate versus control (flood irrigation and soil application of 100 RDF). Drip irrigation at 80 or 100% ETo with fertigation at 80 and 100% RDF recorded significantly higher processed turmeric yield than control (Table 1). Drip fertigation combination of 80% ETo with 80% RDF recorded 18.9% higher processed turmeric yield than control (Table 1). Because under drip fertigation frequent and light dose of nutrients and water is supplied beneath the root zone of the plant with the concept of irrigate and fertigate the plant not to the field. Furthermore, light irrigation under drip fertigation kept check over leaching of nutrients particularly nitrogen which is more prone to leaching, this is evident from the 346.8 and 337.0 mm less drainage under drip irrigation at 80% ETo than control during 2014 and 2015, respectively (Table 2).

Water productivity functions: Biophysical water productivity (BPWP) was the highest from crop drip irrigated at 80% ETo than 60 and 100% ETo (Table 1). Because irrigation water input was 162.9 mm lesser under 80% ETo than 100% ETo and processed turmeric yield was 8.6 q/ha higher under 80% ETo than 60% ETo. However, apparent water productivity (AWP) was the highest from crop drip irrigated at 60% ETo and decreased successively and significantly from 60 to 100% ETo. Similar trend was observed for water use efficiency (WUE) because of increase in irrigation water input from 60 to 100% ETo. Irrigation water input was 162.8 and 325.7 mm lesser under deficit drip irrigation at 60% ETo than 80 and 100% ETo, respectively. However, actual crop evapotranspiration (ETa) was 96.6 and 187.5 mm higher under drip at irrigation at 80 and 100% ETo than 60%, respectively (Table 2). This is the main reason for higher processed turmeric yield under optimum irrigation than deficit.

Similarly, BPWP, AWP and WUE were significantly better under fertigation rate at 80 and 100% RDF than 60% RDF owing to significantly higher growth and yield

parameters because rate of irrigation water input remained the same for fertigation rate from 60–100% RDF (Table 1). However, ETa remained 37.8 and 22.4 mm higher under 80 and 100% fertigation rate than 60% RDF, respectively, which further supports the better performance of crop under 80 and 100% RDF fertigation rate than 60% RDF (Table 2).

BPWP, AWP and WUE were also 7.7, 71.2 and 21.6% higher under drip irrigation at 80% ETo with fertigation rate at 80 RDF than control (Table 1). This is resulted from 311.1 mm lesser irrigation water input under drip irrigation at 80% ETo with fertigation at 80% RDF than control and 91.9 mm higher ETa under former than latter in mean data of the years (Table 2). Furthermore, drainage was 346.8 and 337.0 mm higher under control than drip irrigation and at 80% ETo with 80% RDF during 2014 and 2015, respectively, because of heavy irrigation in control treatment (Table 2).

Economic analysis: Turmeric crop drip irrigated at 80 and 100% ETo recorded 68250 and 75985 ₹/ha higher net returns than drip irrigated at 60% ETo, respectively (Table 1). However, economic water productivity (EWP) was the highest when drip irrigation at 80% ETo and decreased with increase in drip irrigation rate to 100% ETo or decreased to 60% ETo. Crop drip irrigated at 80% ETo registered 4.1 and 6.6% higher EWP than drip irrigation at 60 and 100% ETo, respectively (Table 1). Net returns increased successively with increase in fertigation rate from 60–100% RDF and fertigation rate at 80 and 100% RDF recorded 56745 and 78715 ₹/ha higher net returns than at 60% RDF (Table 1). EWP also followed the same trend and registered 9.3 and 12.4% higher EWP under drip fertigation at 80 and 100% RDF than 60% RDF, respectively.

All combinations of drip irrigation and fertigation recorded higher net returns than control except drip irrigation at 60% ETo and fertigation at 60% RDF (Table 1). The highest net returns of 441805 ₹/ha was recorded from drip irrigation at 100% ETo with 100% RDF and the least (284188 ₹/ha) under deficit irrigation and fertigation at 60% ETo with 60% RDF. Crop drip irrigated at 80% ETo along with fertigation at 80% RDF registered 77740 ₹/ha higher net returns than control, which resulted in 7.7% higher EWP under former than latter. Hence, drip irrigation at 80% ETo with fertigation of 80% RDF resulted in 18.9% higher processed turmeric yield, 7.7% higher BPWP, 71.7% higher AWP, 21.6% higher WUE and 77740 ₹/ha higher net returns along with saving of 311.1 mm irrigation water than control.

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