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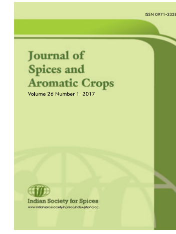

Effect of scheduling of drip irrigation on growth, yield and water use efficiency of turmeric (*Curcuma longa* L.) var. CO 2

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Abstract

Field experiments were conducted during 2012–13 and 2013–14 at Horticulture College and Research Institute, Coimbatore (Tamil Nadu) on black clay loam soil to study the effect of scheduling of drip irrigation on the growth, yield and water use efficiency of turmeric (cv. CO 2). The experiment included two intervals and three levels of irrigation with surface irrigation as control. Significantly higher rhizome yield was recorded in one day interval of irrigation at 80% PE (T_2) (42.79 t ha^{-1}) which was on par with two days interval of irrigation at 80% PE (T_3) (42.51 t ha^{-1}). Significantly higher number of leaves, leaf area, number of tillers, plant height and dry matter production were recorded in T_2 and T_3 compared to flood irrigation. Both one day and two days interval of irrigation and 40% PE recorded significantly higher WUE. The intervals and levels of irrigation were significantly superior for WUE, compared to surface irrigation.

Keywords: drip irrigation, growth, level of irrigation, turmeric, yield

Introduction

Turmeric (*Curcuma longa* L.) also known as the "golden spice" is an herbaceous perennial spice crop. India is the largest producer, consumer and exporter of turmeric with 80% of world production and contributing about 45% of trade. In India, it is mainly grown in the states of Andhra Pradesh, Odisha, Tamil Nadu, Assam, Maharashtra and Karnataka. Turmeric is cultivated in an area of 2.19 lakh hectares with an annual production of 11.67 lakh tonnes (Anon. 2012). India is endowed with vast water resources. These resources however are not equally shared among regions. This together with irregular distribution of rainfall makes some parts of India fully exploited and opportunity for surface irrigation is limited in many areas of peninsular states especially in Tamil Nadu. The time and intensity of moisture stress during the sensitive phase decreases the photosynthesis with stunted growth resulting in drastic reduction in biological yields. Water is the major limiting factor for turmeric production in Tamil Nadu. Adoption of micro irrigation may help to increase the irrigated area, productivity of crop and water use efficiency (Sivanappan 1995). Drip irrigation has proved its superiority over other methods owing to direct application of water in the root zone. Hence, it is worthwhile to find out optimum water requirement of turmeric through drip irrigation system under particular agro-climatic conditions which could help to bring additional area under irrigation and improve yield of turmeric.

Materials and methods

The field experiments were conducted at College Orchard, Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 2012–13 and 2013–14. The field is located at 11.00 N latitude, 77.00 E longitude with an altitude of 411 m above mean sea level. The mean annual rainfall was 453.50 mm and mean temperature was 28.5^{o}C for two consecutive years. The soil of the experimental area belongs to black clay loam in texture. The experiment was laid out in a Randomized Block Design with seven treatments and replicated thrice. Seven irrigation regimes based on irrigation water requirement and pan evaporation values were fixed with a view to study the effect of moisture stress and to optimize the irrigation requirements for turmeric. The details of the treatments are as follows,

Experiment code	Details
T_1	Surface irrigation, 0.09 Irrigation water/Cumulative Pan Evaporation (IW/CPE) ratio to 5 cm depth
T_2	Drip once in a day at 80% Pan Evaporation (PE)
T_3	Drip once in two days at 80% Pan Evaporation (PE)
T_4	Drip once in a day at 60% Pan Evaporation (PE)
T_5	Drip once in two days at 60% Pan Evaporation (PE)
T_6	Drip once in a day at 40% Pan Evaporation (PE)
T_7	Drip once in two days at 40% Pan Evaporation (PE)

The land was ploughed thoroughly and brought fine tilth. At the time of last ploughing, FYM was applied at 20 t ha^{-1}. After leveling, raised beds were prepared with dimension of 20 m length, 1 m width, 30 cm height and 60 cm path between two raised beds. Finger rhizomes of turmeric var. CO-2 weighing about 25 g were selected for planting. Planting was taken during the month of June 2012 and 2013. The treatments receiving drip irrigation, drip laterals were laid along the length of each bed at the centre. Three rows of plants per raised bed were laid out with a spacing of 45 cm between rows and 15 cm between plants within row. Irrigation to each individual plot in each replication was controlled by providing a manual regulating valve fixed to the lateral lines to ensure precise delivery of the required amount of water thus enabling full control of experimental setup. In control plot, instead of raised bed, ridges and furrows were prepared and provision for surface irrigation was provided. A dosage of 150:60:108 kg NPK ha^{-1} was taken as 100% as per the recommendation of the crop production manual (TNAU 2013). Harvesting was done during the month of February 2013 and 2014.

The length of the leaf was noted from the leaf base to the tip of leaf along the midrib and width was recorded at the widest point of the leaf lamina. The average length and breadth measurement from ten standard leaves in a plot were used for computation of leaf area by adopting the following method as suggested by Praveen *et al*. (1994). The leaf area was recorded at 225 days after sowing and expressed in cm^2.

Leaf area = Leaf length × Leaf breadth × K

Where, K is a constant that equals to 0.6454

The constant (K) was worked out by dividing the actual leaf area recorded on a graph sheet by computed leaf area (length × breadth). Two plants from each treatment were collected randomly and kept in hot air oven (55°C) till complete drying was achieved and constant weight was obtained. The dry weight of the plant was weighed and expressed in g plant^{-1}. The estimated fresh rhizome yield per hectare was calculated from plot yield of each treatment and expressed as t ha^{-1}.

After harvesting, the fingers were separated from mother rhizomes and fresh weight was recorded. A sample of two kg of fresh rhizomes from each plot was boiled in the perforated trough containing sufficient quantity of alkaline solution (0.1% sodium carbonate), so as to immerse the turmeric fingers. The whole mass was boiled till the rhizomes became soft to finger pressing and froth came out with white fumes giving out a typical odour. The boiling lasted for 45-60 minutes. After boiling, rhizomes were dried under the sun. Curing percentage was worked out by using the following formula and expressed as %. Cured rhizome yield was worked out and expressed as percentage.

Curing percentage = [Fresh weight of rhizome (kg) - Dry weight of rhizome after curing (kg)] /

[Fresh weight of rhizome (kg)] × 100

The water requirement for daily dripping was based on daily pan evaporation and for alternate day dripping was based on cumulative pan evaporation of two days reading from USDA Class-A pan evaporimeter. In case of surface irrigation, irrigation was scheduled at weekly interval. The water received through natural rain was compensated in successive days. The water requirement of the crop was computed on daily basis by using the following equation as suggested by Shukla *et al.* (2001).

$$WR = CPE \times Kp \times Kc \times A \times Wp - Re$$

Where, WR=Water requirement (L pl^{-1}); CPE=Cumulative Pan evaporation (mm); Kp=Pan constant (0.8); Kc=Crop coefficient; A=Area to be irrigated $plant^{-1}$ / spacing (0.45 m × 0.15 m); Wp=Wetting percentage (0.8) and Re=Effective rain fall

The values of the crop factor at different stages of the turmeric crop were selected based on the values suggested by Chauhan (2015). The crop factor values are as follows,

Growth stage	No. of days	Crop factor
Planting to germination	15	0.4
Initial growth	15-60	0.4-0.5
Mid growth	61-120	0.6-0.7
Rhizome initiation	121-150	0.8-0.9
Rhizome development	151-240	1.0-1.1
Maturity to harvest	241-270	0.9-1.0

The quantity of water to be applied was computed every day as explained in the above formula. For the known discharge rate of emitters, the duration of irrigation water application was calculated using the following formula.

Duration of irrigation (hours) = (Water requirement $plant^{-1}$) / (No. of emitters $plant^{-1}$ × Discharge rate of emitter $hour^{-1}$)

In each treatment ten plants were selected at random and recording observation at 225 days after planting. Observations on water requirement, growth character and yield of turmeric were analyzed statistically following the standard procedures (Panse & Sukhatme 1985). The water use efficiency (WUE) of the crop was determined by dividing the yield with water requirement of the crop.

Result and discussion

The important growth traits like plant height, number of leaves and number of tillers influence the growth and productivity of the crop (Table 1). These growth parameters were differentially influenced by the water regimes which contribute to the growth, yield and quality of the crop. Drip irrigation once in two days at 80% PE recorded the highest plant height (95.65 cm) followed by drip irrigation once in a day at 80% PE (95.65 cm). In case of number of leaves, the treatments T_2 and T_3 (drip irrigation at 80% PE once in a day and once in two days) recorded the highest number of leaves (8.92 and 8.87 respectively). The data on number of tillers per plant was recorded highest in drip irrigation daily at 80% PE (4.16).

Table 1. Effect of drip irrigation regimes on growth characters at 225 days after planting of turmeric

Treatments	Plant height (cm)			No. of leaves plant^{-1}			No. of tillers plant^{-1}			Leaf area plant^{-1} (cm^2)			Dry matter production (g plant^{-1})		
	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean
T_1	91.87	89.65	90.76	6.72	7.40	7.06	3.83	3.10	3.47	211.19	222.33	216.76	57.06	76.56	66.81
T_2	86.17	100.59	93.38	8.84	9.00	8.92	4.22	4.10	4.16	348.77	389.26	369.01	75.20	101.68	88.44
T_3	96.3	94.99	95.65	8.93	8.80	8.87	4.08	4.00	4.04	331.2	332.18	331.69	73.60	99.27	86.43
T_4	87.55	80.78	84.17	8.97	8.20	8.59	4.09	3.90	4.00	282.53	322.53	302.53	65.68	88.03	76.85
T_5	87.18	85.25	86.22	6.87	7.90	7.39	4.11	3.70	3.91	264.48	282.7	273.59	63.61	85.50	74.55
T_6	79.52	79.08	79.30	7.04	7.60	7.32	3.86	3.40	3.63	254.23	217.17	235.7	61.61	83.05	72.33
T_7	93.15	93.76	93.46	7.29	7.50	7.40	3.54	3.10	3.32	260.8	258.68	259.74	60.11	79.03	69.57
SEd±	7.643	1.680	4.662	0.67	0.270	0.470	0.248	0.240	0.244	37.18	25.53	31.355	3.506	5.692	4.599
CD ($P<0.05$)	16.652	3.650	10.151	1.43	0.600	1.015	0.546	0.520	0.533	78.12	54.13	66.125	7.639	12.402	10.020
CV %	6.20	8.85	6.67	13.43	7.91	10.29	5.87	11.57	8.40	16.91	21.68	18.95	10.44	10.98	10.74

The maximum plant height, number of leaves and number of tillers were recorded under drip irrigation given at more frequently (daily) and higher schedule *i.e.*, 80% PE. Similar results were obtained by Annappa (2010) in onion. Growth parameters decreased with decrease in drip irrigation schedules on both daily and alternate day basis and least growth parameters were recorded in furrow irrigation. Crops irrigated with drip daily at 80% PE irrigation regime performed better for all the growth parameters. This indicates that the crop's need was satisfied at 80 % PE. The excess irrigation might have resulted in poor soil aeration, poor root development and heavy loss of nutrients through leaching which might have resulted in lower growth attributes in furrow irrigation. The enhanced growth under drip system might be due to better turgidity of the cells, leading to cell enlargement and better cell wall development. Such increments may be due to the increasing water supply which improves root function, consequently enhance nutrient uptake and metabolic processes in olive (Andria & Morelli 2002). The increased growth attributes might be due to adequate availability and supply of water and nutrients in proportion, which ultimately resulted in triggering the production of plant growth hormones namely Indole Acetic Acid (IAA) which helped in maintaining a higher number of leaves throughout the cropping period (Sankar *et al*. 2008).

Total leaf area at any stage of the crop growth is an important aspect of turmeric as it has a close association with photosynthetic efficiency, reflecting on biomass production. Drip irrigation daily at 80% PE recorded the highest leaf area (369.01 cm^2 plant^{-1}) and dry matter production (88.44 g plant^{-1}) which might be due to sufficient availability and utilization of moisture resulting in greater photosynthetic area facilitating for higher accumulation of the photosynthates and also due to more cells and their enlargement because of hydrostatic pressure needed for cell expansion which eventually increased the dry matter. Kannan (2006) and Behera *et al.* (2012) have made similar observations in coleus and ashwagandha. Channagoudra (2009) also reported higher dry matter production at higher irrigation schedule in onion.

Among various treatments, the highest fresh rhizome yield (42.79 t ha^{-1}) was recorded under treatment T_2, which increased by 29% over surface irrigation. The low yield was recorded under surface irrigation method (30.96 t ha^{-1}). Irrigating the turmeric at 80% PE through drip irrigation both on daily and alternate day basis have recorded significantly higher rhizome yield over lower irrigation regimes (drip irrigation at 60 and 40% PE) and furrow irrigation. This may be due to the higher amount of applied irrigation with minimum crop exposure to water stress in higher irrigation regimes (80% PE) than lower irrigation regimes (60 and 40% PE) and furrow irrigation. These results are in agreement with the earlier findings of Rathod *et al.* (2010) who recorded the highest green turmeric yield of 433.30 q ha^{-1} with application of 84.24 cm of water. Drip irrigation at 60% and

Table 2. Influence of irrigation levels on number of mother, primary and secondary rhizomes plant^{-1}

Treatments	Number of rhizomes plant^{-1}								
	2012-13			2013-14			Mean		
	Mother	Primary	Secondary	Mother	Primary	Secondary	Mother	Primary	Secondary
T_1	2.10	8.30	12.61	2.43	7.85	11.55	2.27	8.08	12.08
T_2	3.30	12.50	16.06	3.90	11.83	18.29	3.60	12.17	17.18
T_3	3.00	12.20	15.96	3.59	11.79	17.75	3.30	12.00	16.86
T_4	2.80	10.70	14.28	2.76	9.17	15.79	2.78	9.94	15.04
T_5	2.50	10.33	12.37	2.88	9.06	14.73	2.69	9.70	13.55
T_6	2.40	10.07	13.17	2.16	8.64	13.89	2.28	9.36	13.53
T_7	2.40	9.40	12.13	2.07	8.11	13.54	2.24	8.76	12.84
SEd±	0.116	0.228	1.330	0.340	0.900	0.391	0.228	0.564	0.861
CD (P<0.05)	0.254	0.496	2.820	0.730	1.920	0.853	0.492	1.208	1.837
CV (%)	15.57	14.12	12.07	24.66	17.40	15.86	20.12	15.51	13.68

Table 3. Influence of irrigation levels on weight of mother, primary and secondary rhizomes plant^{-1}

Treatments	Number of rhizomes plant^{-1}								
	2012-13			2013-14			Mean		
	Mother	Primary	Secondary	Mother	Primary	Secondary	Mother	Primary	Secondary
T_1	68.68	137.91	67.94	66.37	130.33	89.18	67.53	134.12	78.56
T_2	89.18	168.89	90.05	88.85	183.41	87.74	89.02	176.15	88.89
T_3	87.74	166.07	83.98	85.93	181.94	84.05	86.84	174.01	84.02
T_4	84.05	151.91	83.24	82.63	148.99	80.48	83.34	150.45	81.86
T_5	80.48	148.88	78.92	78.08	134.10	77.14	79.28	141.49	78.03
T_6	77.14	142.40	72.17	75.99	120.52	73.80	76.57	131.46	72.99
T_7	73.80	139.91	70.09	74.14	130.33	68.68	73.97	135.12	69.38
SEd±	1.756	1.885	4.853	2.137	15.450	1.756	1.947	8.668	3.305
CD (P<0.05)	3.827	4.107	10.3435	4.655	32.750	3.827	4.241	18.429	7.085
CV (%)	9.33	8.21	10.55	9.70	17.50	9.33	9.49	12.69	8.34

Table 4. Influence of irrigation levels on yield parameters of turmeric

Treatments	Fresh rhizome yield plant^{-1} (g)			Fresh rhizome yield plot^{-1} (20 m^2) (kg)			Estimated fresh rhizome yield (t ha^{-1})			Estimated cured rhizome yield (t ha^{-1})			Curing (%)
	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean	
T_1	250.35	269.40	259.88	61.23	62.60	61.92	30.62	31.30	30.96	5.34	5.46	5.40	17.44
T_2	350.76	362.97	356.87	87.03	84.15	85.59	43.52	42.07	42.79	7.78	7.52	7.65	17.87
T_3	340.47	337.08	338.78	84.44	85.60	85.02	42.22	42.80	42.51	7.46	7.56	7.51	17.67
T_4	330.22	294.22	312.22	82.17	79.79	80.98	41.09	39.89	40.49	7.24	7.03	7.13	17.62
T_5	310.59	269.40	290.00	76.60	79.48	78.04	38.30	39.74	39.02	6.72	6.97	6.85	17.55
T_6	300.62	287.82	294.22	74.20	71.16	72.68	37.10	35.58	36.34	6.51	6.24	6.38	17.55
T_7	280.18	321.47	300.83	68.46	79.48	73.97	34.23	39.74	36.99	5.98	6.94	6.46	17.47
SEd±	14.990	36.720	25.855	2.212	0.593	1.402	-	-	-	-	-	-	-
CD ($P<0.05$)	31.010	77.840	54.425	4.819	1.292	3.055	-	-	-	-	-	-	-
CV %	11.46	11.63	10.48	9.21	8.01	8.27	-	-	-	-	-	-	-

40% PE recorded significantly lower yield because the crop experienced stress just before the next irrigation and in between moisture fluctuates from field capacity to different degrees of dryness. Being a major constituent of the protoplasm of a cell and primary component of photosynthesis, water aids in maintaining the turgor pressure and firmness of tissue. Water plays a functional role acting as solvent for transporting the mineral nutrients into the plant and moving carbohydrates to their site of use or storage throughout the plant. Thus supplementing water with minimum crop stress resulted in the higher yield by virtue of greater accumulation of the carbohydrates in irrigation at 80% PE unlike other irrigation regimes which resulted in the varying degree of crop water stress.

The significant difference in the yield as influenced by different irrigation regimes might be due to significant differences in number and weight of mother rhizomes, primary and secondary fingers which are the important yield attributes. Number of mother, primary and secondary fingers contributed more towards the yield than any other yield attributes. The daily drip irrigation at 80% PE recorded significantly higher number and weight of mother, primary and secondary rhizomes as compared to other treatments (Tables 2, 3 & 4). Optimum moisture availability in daily drip irrigation at 80% PE might have contributed to effective absorption and utilization of nutrients in turn increased photosynthesis, biomass partitioning and more proliferation of roots resulting in higher number of roots. The increase in weight of mother, primary and secondary fingers in daily drip irrigation at 80% PE might be due to higher moisture content in the fingers which would have determine the rhizome weight and that in turn have decided the rhizome yield. These results are in agreement with the earlier findings of Nair *et al.* (1996) in sweet potato, Kannan (2006) in coleus, Obafemi *et al.* (2011) in cassava, Fakhrodin *et al.* (2012) in potato, and Mahesh (2013) in turmeric.

The total quantity of water applied was ranged from 348.15 ha^{-1} mm in drip irrigation once in

Table 5. Influence of irrigation levels on water use efficiency (WUE) through drip irrigation

Treatments	Total water applied (ha.mm)	Estimated cured rhizome yield (t ha^{-1})	Water use efficiency (kg ha^{-1} mm)	% increase over control
T_1	630.02	5.35	8.48	0.00
T_2	538.40	7.79	14.47	70.48
T_3	536.46	7.47	13.93	64.16
T_4	443.51	7.23	16.31	92.23
T_5	442.06	6.72	15.20	79.12
T_6	349.12	6.50	18.63	119.57
T_7	348.15	5.98	17.18	102.53

two days at 40% PE to 630.02 ha^{-1} mm in furrow irrigation (Table 5). Water use efficiency (WUE) was increased with decrease in drip irrigation levels applied either on daily basis or alternate day basis over control (furrow irrigation). It was slightly higher with irrigation given at daily than alternate day basis. Higher WUE was noticed in drip irrigation every day at 40% PE but there was a marked reduction in yield at minimum water applied through drip irrigation and furrow irrigation recorded the least. Higher consumptive use of water without corresponding increase in turmeric yield in furrow irrigation resulted in lower water use efficiency. Though furrow irrigation treatment received more irrigation water than drip irrigation treatments it was not reflected in the yield due to unfavorable condition resulted from wide fluctuation in soil moisture and lesser availability of nutrients and leaching. These parameters led to the advantages of using the drip system in agriculture to ensure increased efficiency in water use. Similar findings were reported in potato (Rab & Willatt 1987; Saif *et al.* 2002). In the present investigation obviously the rhizome yield has not kept the pace with the increased consumptive use resulted in lower water use efficiency in higher irrigation regimes *i.e.*, 60% and 80% PE. The results are in line with the findings of the Kadam *et al.* (2006) in onion, Sankar *et al.* (2008) in garlic and Priyanka *et al.* (2012) in potato.

It can be concluded that drip irrigation significantly improved growth, yield and water use efficiency of turmeric (var. CO 2) under Coimbatore condition. Among the various methods of irrigation, drip irrigation at 80% PE was superior in terms of improved growth characters, higher marketable rhizome yield and water use efficiency than surface irrigation method.

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