Int.J.Curr.Microbiol.App.Sci (2020) *9*(10): 1202-1213

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 10 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.910.144

Influence of Drip irrigation with Deficit Irrigation Levels and Planting Layouts on Performance of Turmeric (*Curcuma longa* L.)

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Keywords

Deficit irrigation, Drip Irrigation, Irrigation levels, Planting layout, Turmeric yield and Economics

Article Info

Accepted:
10 September 2020
Available Online:
10 October 2020

A B S T R A C T

Field experiments were conducted at Agricultural Research Station, Mahatma Phule Krishi Vidyapeeth, Kasbe Digraj, Dist. Sangli, Maharashtra, India during 2014-15 to 2016-17 to study the influence of drip irrigation with deficit irrigation levels and planting layouts on yield of turmeric. Three planting layout {D_1: 2 crop lines (30 x 30 cm) on raised beds of 1.2m spacing and 0.6 m top width, D_2: 3 crop lines (22.5 x 30 cm) on raised beds of 1.2m spacing and 0.6m top width and D_3: 2 crop lines (37.5 x 30 cm) on both sides of 0.75 m spaced ridges and furrows}as main factor and six irrigation levels based on cumulative pan evaporation (CPE) {I_1: 40% CPE, I_2: 35% CPE, I_3: 30% CPE, I_4: 25% CPE, I_5: 20% CPE and I_6: surface irrigation at 75 mm CPE (1.0 IW/CPE ratios)} as sub-factor in split plot design were included for achieving objectives. The results revealed that drip irrigation with scheduling at alternate day of 40% CPE and planting of two rows at 37.5 x 30 cm spacing on both sides of 0.75 m wide ridges and furrows resulted economically better production of fresh and dry rhizome yield with optimum use of water as it recorded significantly highest growth, yield and yield contributing parameters of turmeric. During water deficit condition, drip irrigation scheduled at alternate day of 35% and 30% CPE and planting of two rows at 37.5 x 30 cm spacing on both sides of 0.75 m wide ridges and furrows are also suggested for more turmeric production with less use of water.

Introduction

Turmeric is important spice crop cultivated for domestic consumption as well as export owing to its wide range of fields of utilities covering culinary to medicine. India ranks the first position in the world (Siddramappa, 2013) with an area of 1.90 lakh hectares and also produces 8.44 lakh tonnes (Anon., 2017). India accounts for about 80 per cent of world turmeric production and 60 per cent of world exports. Whereas, Maharashtra is the second largest turmeric producing state in India after Telangana. Most of studies in turmeric were focused on to evaluate the medicinal value of turmeric and very few studies have been conducted on turmeric cultivation (Hermann and Martin, 1991; Ishimine *et al.*, 2003).

Improvement of crop cultivation technology for local climatic and edaphic factors is important for successful production of turmeric (Akamine *et al.,* 1995; Ishimine *et al.,* 2003). In view to this, proper planting layout and planting distance plays very crucial role to increase the yield and to decrease interference with weeds (Baki *et al.,* 1995; Knezevic *et al.,* 2003; Murphy *et al.,* 1996). The optimum planting pattern for a specific root crop facilitates an optimum space to maximize vegetative parts, which subsequently receives higher solar energy and results in maximum yield. Adjusting raised beds and ridges-furrows along with row spacing is one of the important agronomic practices for increasing yield of a row crop and reducing the competition with weeds (Murphy *et al.,* 1996; Wicks *et al.,* 2003). Apart from planting layout, soil moisture also plays very important role for growing full potentiality of crop during the different growth stages. However, Indian farmers often over irrigate through increased irrigation frequency and subsequently high amount of applied water causing deleterious effect on the applied nutrients, water and soil properties. Considering water as the scarcest, yet a priceless farming resource, precision irrigation aims at prudent usage of water throughout the process of farming is important. Further, climate change and prevailing seasonal water deficit endeavours for improvement in agronomic practices for addressing the water deficit situation. Deficit irrigation is one such approach to reduce the water consumption. To apply deficit irrigation, drip irrigation system is the perfect method as it is used for precise application of water and nutrients directly at the plant's root zone at right time with right amounts to grow turmeric crop optimally. However, farmers reported feedback about problem of rhizome rot due to wet conditions maintained near rhizomes by frequent application of water through drip irrigation system. This might be due to the lack of proper irrigation scheduling and thereby applying excess quantity of water. These conditions emphasized the need of field trial for studying impact of both planting layout and different irrigation levels on yield of turmeric. Accordingly, an experiment was planned to conduct the "Influence of drip irrigation with deficit irrigation levels and planting layouts on performance of turmeric (*curcuma longa* L.)" at Agricultural Research Station (ARS), Turmeric Research Scheme (TRS), Kasbe Digraj, Tal. Miraj, Dist. Sangli (M.S.).

Materials and Methods

Experimental site was located at ARS, TRS, Kasbe Digraj, Sangli under Mahatma Phule KrishiVidyapeeth, Rahuriduring 2014-15 to 2016-17. Climatically this region falls under the semi-arid and plain zone with average annual rainfall of 380.28mm. The distribution of rain is uneven and is distributed over 22 to 49 rainy days. The annual mean maximum and minimum temperature ranges between 28.49^{0}C to 38.43^{0}C and 11.61 ^{0}C to 21.75 ^{0}C, respectively. The annual mean pan evaporation ranges from 3.04 to 6.68 mm day^{-1}. Soil type observed at the experimental site was medium deep black clayey soil with alkaline in pH (8.20), low in available nitrogen (188.71 kg ha^{-1}) and available phosphorus (9.90 kg ha^{-1}) and very high in available potassium (437.96 kg ha^{-1}). Experiment was laid in split plot design with three replications. The high yielding turmeric variety *Salem* was used for this experiment. Treatments were assigned as below:

Main-plot: Planting layout

D_1: 2 crop lines (30 x 30 cm) on raised beds of 1.20 m spacing and 0.60m top width

D_2:3 crop lines (22.5 x 30 cm) on raised beds of 1.20cm spacing and 0.60m top width

D_3: 2 crop lines (37.5 x 30 cm) on both sides of 0.75m spaced ridges and furrows

Sub-plot: Deficit Irrigation levels based on cumulative pan evaporation (CPE) through drip irrigation on alternate day

I_1: 40% CPE (Crop factors are not available for turmeric crops)
I_2: 35% CPE
I_3: 30% CPE
I_4: 25% CPE
I_5: 20% CPE
I_6: Surface irrigation at 75 mm CPE (1.0 IW/CPE ratios) i.e. IW/CPE means irrigation water/cumulative pan evaporation

The recommended dose of 25 ton farm yard manure ha^{-1}+ 200:100:100 NPK Kg ha^{-1}were applied for turmeric. Entire P_2O_5 and K_2O were applied as basal dose at the time of planting. While Nitrogen was applied in two equal splits at 6 and 12 weeks interval starting from planting. Fertilizer were applied with Urea, DAP and MOP as source of the nutrients. The irrigation was provided at alternate day as per treatments through drip irrigation system (Emitters @ 4 lph and 0.60 m spacing between two emitters) with one lateral placed at the middle of each raised beds and ridges. All standard agronomic practices were followed uniformly across the treatments during the conduct of the experiment. Growth parameters of turmeric observed during the conduct of the experiment is expressed as leaf area (cm^2 $plant^{-1}$), height of plant (cm), Number (No.) of tillers per plant, No. of leaves per tiller at 150 DAP (days after planting).The yield and yield contributing parameters of turmeric i.e., weight of mother rhizome (gm $plant^{-1}$), No. of primary rhizome per plant, weight of primary rhizome (gm $plant^{-1}$), No. of secondary rhizome per plant, weight of secondary rhizome (gm $plant^{-1}$), curcumin (%), fresh rhizomes yield (qha^{-1}) and dry rhizomes yield (qha^{-1}) were recorded at harvest. Fresh rhizomes were harvested at maturity by digging. Fresh rhizome yield and dry rhizome yield presented is cumulative of all rhizomes harvested (Mother, primary, secondary and tertiary rhizomes). The economic feasibility of different treatment combinations were evaluated by cost of cultivation (Rs ha^{-1}), gross returns (Rs ha^{-1}), net profit (Rs ha^{-1}) and B: C ratio. The split plot design with three main factors and six sub-factors with three replications were used for statistical analysis of growth, yield and economics of turmeric cultivation under different treatments (Panse *et al.*, 1976).

Results and Discussion

Effect of drip irrigation with deficit irrigation levels and planting layouts on growth parameters of turmeric

The pooled data for the years 2014-15, 2015-16 and 2016-17 pertaining to growth parameters of turmeric as influenced by deficit irrigation, planting layout and density are presented in Table 1. The significantly maximum pooled mean height of plant (116.93 cm) was observed in D_3 i.e. two crop lines on the ridges and furrows. The pooled mean of highest number of tillers per plant were observed in D_3 (2.98) layout which was at par with D_1 (2.44) i.e. 2 crop lines (30 x 30 cm) on raised beds of 1.2 m spacing and 0.6 m top width. The significantly higher pooled mean of number of leaves per tiller was observed in the D_3 (11.90) which were followed by D_1 (10.4). The effect of different deficit irrigation levels, planting layout and density on leaf area was found to be non-significant. Whereas, significantly lowest pooled mean of height of plant (94.04 cm), number of tillers per plant (1.86), number of leaves per tiller (9.0) and leaf area (188.87 cm^2) were observed under D_2 i.e. 3 crop lines (22.5 x 30 cm) on raised beds of 1.20m

spacing and 0.60m top width. This might be due to more density of plants under D_2 (83,333 plants ha^{-1}) than D_1 (55,555 plants ha^{-1}). Secondly, there were denser plant population due to three crop lines on just 0.6 m top width of raised bed as compare to two crop lines on 0.75 m ridges and furrows. Hence, growth parameters of turmeric were recorded highest under D_3.Hossain *et al.*, (2005) found that the significantly lowest No. of tillers per turmeric plant was observed at 20 cm plant spacing than larger plant spacings. The No. of tillers per plant under plant spacing of 30, 40, 50 and 60 cm were at par with each other. The lower plant height was observed under plant spacing of 20 cm and at par with plant spacings of 30, 40, 50 and 60 cm.

The scheduling of irrigation at 40% CPE recorded significantly maximum pooled mean height of plant (112.83 cm), number of tillers per plant (3.0), number of leaves per tiller (10.5) and leaf area (227.41 cm^2) followed by 35% CPE. Whereas, significantly lowest pooled mean height of plant (96.07 cm), number of tillers per plant (1.86), number of leaves per tiller (8.9) and leaf area (181.69 cm^2) were recorded under 20% CPE irrigation treatments. This might be due to that the fact that plants faced shortage of water (deficit water stress) in 20% CPE as it was 50 % less than the 40% CPE treatments. On the contrary drip irrigation at 40% CPE might had facilitated better root aeration, field capacity conditions, nutrient and water availability for better development of turmeric plants due to application of right amount of water at right time and near root zone. The growth parameters were recorded significantly lower in surface irrigation treatment as compare to 40%, 35% and 30% CPE irrigation treatments under drip irrigation. This might be due to the high irrigation interval as compare to drip irrigation, loss of added nutrients through leaching, soils taken 2 to 3 days for coming back to field capacity after heavy irrigation at a time, runoff and other factors. The interaction effect of different deficit irrigation levels, planting layout and density on growth characters was found to be non-significant.

Effect of drip irrigation with deficit irrigation levels and planting layouts on yield and yield contributing parameters of turmeric

The pooled data for the years 2014-15, 2015-16 and 2016-17 pertaining to yield contributing parameters of turmeric as influenced by deficit irrigation, planting layout and density are presented in Table 2 and 3. The interaction effect of different deficit irrigation levels, planting layout and density was found to be non-significant on pooled mean of yield attributing characters except number and weight of secondary rhizomes and fresh rhizomes yield. The significantly highest pooled mean weight of mother rhizome/plant (81.10 gm), weight of primary rhizomes per plant (86.19 gm), No. of secondary rhizome per plant (12.4), weight of secondary rhizome per plant (428 gm) were observed under D_3 i.e. i.e. two crop lines on the ridges and furrows followed by D_1 and D_2.The No. of primary rhizome per plant and curcumin (%) were found non-significant under different planting layout. The significantly highest fresh (295.92 q ha^{-1}) as well as dry (61.93 q ha^{-1}) rhizome yield were recorded in the two crop lines on the ridges and furrows followed by2 crop lines on raised beds of 1.20m spacing and 0.60 m top width. Hence, the ridges and furrows of 0.75 m with 0.375 x 0.30 m spaced turmeric treatment confirmed the previous recommendation given by Turmeric Research Station, Kasbe Digraj, Sangli. This might be due to the optimum plant density of 88,888 plants ha^{-1} in ridges and furrow system layout and lesser plant density of 55,555 plants ha^{-1} in 2 crop lines (0.30 x 0.30 m) on raised beds of 1.20m

spacing and 0.60 m top width. Hossain *et al.*, (2005) reported that when turmeric was planted at 20 cm spacing, rhizome could not expand properly, which ultimately resulted in the smaller rhizome compared with that planted with a larger spacing of 30 cm, 40 cm and 50 and 60 cm spacing. They further found that the yields recorded on ridges and furrows of 75, 100, 125 and 150 cm with two crop lines were 724, 619, 478 and 354 gm m^{-2}, respectively.

The largest shoot biomass and highest rhizome yield were obtained when turmeric was planted in two rows on the ridges with a 75 cm width followed by 100 cm width among the treatments (Hossain *et al.*, 2005).The similar results were also observed in present study.

Among the different levels of deficit irrigation, the significantly highest pooled mean weight of mother rhizome/plant(74.1 gm), No. of primary rhizome per plant (2.97), weight of primary rhizome per plant (86.61 gm), No. of secondary rhizome per plant (11.6), weight of secondary rhizomes per plant (416.88 gm), fresh as well as dry rhizome yield (264.79 q ha^{-1} and 55.14 q ha^{-1}, respectively) was recorded under scheduling of irrigation at 40% CPE which was followed by scheduling of irrigation at 35% CPE. Whereas, the significantly lowest pooled mean of fresh as well as dry rhizome yield (175.05 q ha^{-1} and 35.67 q ha^{-1}, respectively) was recorded under irrigation to 20% CPE treatment.

This might be due to 40% CPE facilitated optimum moisture, better field capacity conditions, nutrient and water availability for better development of turmeric plants due to application of right amount of water at right time and near root zone. Selvaraj*et al.*, (1997) also reported highest water use efficiency in the treatment irrigating with drip at 0.36 IW/CPE ratio daily (it mean 36% of pan evaporation or cumulative pan evaporation) with highest yield. Whereas, shortage of water might have resulted lesser rhizome yield in 20% CPE with drip irrigation. Drip irrigated treatments at 40%, 35% and 30% CPE recorded more yields as compare to surface irrigation with ridges and furrows. Sadarunnisa *et al.*, (2010) and Patel *et al.*, (2012) obtained higher yields in drip irrigation over furrow irrigation.

Effect of drip irrigation with deficit irrigation levels and planting layouts on water requirement and water use efficiency of turmeric

The treatment wise water requirement (mm), fresh rhizome yield (q ha^{-1}) and water use efficiency (kg/ha-mm) were shown in Fig. 1. It is observed from Fig. 1 that the water requirement of turmeric was recorded highest (1350 mm) under surface irrigation at 75 mm CPE (1.0 IW/CPE ratios) followed by scheduling of irrigation at 40% CPE (562 mm) on alternate day through drip irrigation.

The lowest water requirement (323 mm) and highest water use efficiency (54.15 kg/ha-mm) were observed under drip irrigation on alternate day at 20% CPE. Thiyagarajan *et al.*, (2011) also recorded 568.4 mm of water requirement for turmeric when drip scheduled daily at 40% PE. They also registered 1120 mm of water under surface irrigation. The lowest water use efficiency (15.65 kg/ha-mm) was recorded by surface irrigation at 75 mm CPE (1.0 IW/CPE ratios). The 40% CPE treatment recorded 562 mm of water requirement and 47.16 kg/ha-mm of water use efficiency. Thiyagarajan *et al.*, (2011) registered water use efficiency for turmeric of 22 and 47 kg/ha-mm under surface irrigation at 0.9 IW/CPE ratio and drip irrigation with 40% CPE, respectively.

Table.1 Effect of deficit irrigation and planting layout on growth of turmeric

Treatment	Height of plant (cm)				No. of tillers per plant				No. of leaves per tiller				Leaf area (cm^2 $plant^{-1}$)			
	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean
Layout																
D_1	98.16	97.44	108.27	101.29	2.4	2.68	2.22	2.44	8.6	9.38	10.4	9.5	199.27	194.81	208.32	200.80
D_2	93.50	91.69	96.93	94.04	1.7	2.16	1.76	1.86	8.5	9.08	9.5	9.0	194.39	188.61	183.62	188.87
D_3	118.63	105.76	126.39	116.93	2.5	2.95	3.44	2.98	8.6	9.96	11.9	10.2	187.42	202.70	244.87	211.66
S. E. ±	3.81	4.63	1.96	2.55	0.11	0.07	0.08	0.19	0.17	0.22	0.15	0.33	6.44	4.74	4.61	10.37
CD at 5%	11.65	13.39	5.65	7.38	0.34	0.21	0.23	0.54	NS	0.66	0.44	0.97	NS	13.69	13.32	NS
Irrigation																
I_1	112.47	105.80	120.21	112.83	2.9	2.98	3.10	3.00	9.4	10.5	11.4	10.5	228.56	220.92	232.76	227.41
I_2	107.38	101.47	117.50	108.78	2.6	2.80	2.88	2.77	8.8	10.0	11.2	10.0	200.42	201.95	229.42	210.60
I_3	103.33	98.60	113.38	105.10	2.2	2.69	2.62	2.51	8.5	9.6	10.8	9.6	188.14	192.90	213.56	198.20
I_4	99.71	95.44	105.58	100.24	1.9	2.42	2.26	2.20	8.0	9.1	10.2	9.1	184.97	187.20	202.38	191.51
I_5	96.58	92.07	99.56	96.07	1.5	2.27	1.82	1.86	8.3	8.7	9.6	8.9	171.83	182.89	190.33	181.69
I_6	101.11	96.40	106.96	101.49	2.1	2.42	2.18	2.22	8.4	8.9	10.3	9.2	188.23	186.36	205.18	193.26
S. E. ±	1.23	1.93	2.82	0.71	0.10	0.11	0.13	0.07	0.11	0.29	0.22	0.08	3.68	5.49	6.61	1.74
CD at 5%	3.56	5.56	8.14	2.06	0.29	0.31	0.39	0.20	0.32	0.87	0.66	0.24	10.65	15.85	19.10	5.01
Interaction Effects	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: D_1: 2 crop lines (30 x 30 cm) on raised beds of 1.20 m spacing and 0.60 m top width, D_2: 3 crop lines (22.5 x 30 cm) on raised beds of 1.20 cm spacing and 0.60 m top width, D_3: 2 crop lines (37.5 x 30 cm) on both sides of 0.75 m spaced ridges and furrows; I_1: 40% CPE, I_2: 35% CPE, I_3: 30% CPE, I_4: 25% CPE, I_5: 20% CPE and I_6: Surface irrigation at 75 mm CPE (1.0 IW/CPE ratios)

Table.2 Effect of deficit irrigation and planting layout on yield and yield contributing characters of turmeric

Treatment	Curcumin (%)				Weight of mother rhizome (gm plant^{-1})				No. of primary rhizomes per plant				Weight of primary rhizomes(gm plant^{-1})			
	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean
Layout																
D_1	3.63	3.64	3.63	3.63	61.7	65.84	66.8	64.8	2.4	2.08	2.33	2.28	70.8	71.84	88.30	76.99
D_2	3.64	3.62	3.63	3.63	57.1	49.02	62.0	56.1	2.0	1.82	1.93	1.90	54.1	52.73	78.24	61.70
D_3	3.67	3.65	3.69	3.67	84.0	84.91	74.3	81.1	2.0	2.68	3.64	2.77	75.6	80.02	102.99	86.19
S. E. ±	0.009	0.01	0.01	0.006	2.87	1.77	0.77	3.74	0.08	0.08	0.10	0.29	2.31	2.77	1.77	1.76
CD at 5%	NS	NS	NS	NS	8.70	5.13	2.21	10.79	0.25	0.24	0.30	NS	6.94	8.02	5.11	5.10
Irrigation																
I_1	3.69	3.68	3.67	3.68	77.8	72.8	71.8	74.1	2.6	3.0	3.34	2.97	82.0	79.7	98.16	86.61
I_2	3.65	3.64	3.64	3.64	72.4	70.6	70.6	71.2	2.2	2.5	3.07	2.60	70.3	75.2	95.87	80.48
I_3	3.66	3.63	3.67	3.65	69.6	66.3	68.8	68.2	2.1	2.1	2.71	2.32	68.7	68.5	91.53	76.24
I_4	3.62	3.60	3.64	3.62	63.6	63.4	65.8	64.3	2.0	1.9	2.37	2.09	62.8	63.4	85.24	70.49
I_5	3.61	3.63	3.65	3.63	58.2	62.4	63.1	61.2	1.8	1.8	1.91	1.83	52.0	60.0	81.20	64.40
I_6	3.65	3.64	3.61	3.63	64.0	64.1	66.1	64.8	2.0	1.9	2.40	2.10	65.2	62.3	87.07	71.54
S. E. ±	0.02	0.01	0.01	0.008	2.27	2.03	1.16	0.65	0.08	0.09	0.14	0.06	2.53	2.64	2.58	1.10
CD at 5%	NS	NS	NS	NS	6.57	5.92	3.35	1.87	0.26	0.26	0.40	0.18	7.60	7.62	7.46	3.17
Interaction Effects	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: D_1: 2 crop lines (30 x 30 cm) on raised beds of 1.20 m spacing and 0.60 m top width, D_2: 3 crop lines (22.5 x 30 cm) on raised beds of 1.20 cm spacing and 0.60 m top width, D_3: 2 crop lines (37.5 x 30 cm) on both sides of 0.75 m spaced ridges and furrows; I_1: 40% CPE, I_2: 35% CPE, I_3: 30% CPE, I_4: 25% CPE, I_5: 20% CPE and I_6: Surface irrigation at 75 mm CPE (1.0 IW/CPE ratios)

Table.3 Effect of deficit irrigation and planting layout on yield and yield contributing characters of turmeric

Treatment	No of secondary rhizomes per plant				Weight of secondary rhizomes per plant (gm plant^{-1})				Yield of fresh rhizomes (q ha^{-1})				Yield od dry rhizomes (q ha^{-1})			
	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean
Layout																
D_1	9.7	9.03	10.1	9.6	315	307.59	361	328	201.04	193.99	217.63	204.22	42.22	39.41	44.51	42.05
D_2	5.1	6.43	8.3	6.6	221	227.44	295	248	159.21	153.12	171.31	161.21	32.64	30.79	33.65	32.36
D_3	13.0	11.22	13.2	12.4	406	403.63	474	428	313.94	280.61	293.22	295.92	65.93	57.54	62.31	61.93
S. E. ±	0.22	0.30	0.26	0.55	15.48	11.08	9.62	4.51	10.95	5.52	6.93	6.16	2.29	1.13	1.27	1.14
CD at 5%	0.67	0.87	0.75	1.60	46.45	32.01	27.78	13.01	32.85	15.96	20.07	17.80	6.87	3.27	3.67	3.31
Irrigation																
I_1	11.6	11.2	12.1	11.6	411	402.31	437.22	416.88	277.63	248.41	268.32	264.79	57.98	50.77	56.67	55.14
I_2	10.2	10.0	11.6	10.6	340	336.93	419.56	365.35	242.38	236.79	256.12	245.10	50.63	48.30	53.56	50.83
I_3	9.2	9.1	10.9	9.7	316	314.42	390.33	340.10	233.02	208.83	235.51	225.79	48.67	42.56	48.76	46.67
I_4	8.3	7.7	10.0	8.7	276	275.53	352.78	305.14	193.40	197.06	211.66	200.71	40.38	40.09	43.39	41.29
I_5	7.6	7.4	8.7	7.9	251	275.67	325.67	287.85	177.35	166.80	180.98	175.05	37.03	33.82	36.16	35.67
I_6	8.5	7.9	9.9	8.7	290	272.47	334.78	291.67	224.57	197.55	211.72	211.28	46.87	39.96	42.39	43.07
S. E. ±	0.31	0.29	0.42	0.13	11.37	10.57	16.18	3.99	6.79	6.82	11.37	2.63	1.42	1.39	2.33	0.65
CD at 5%	0.91	0.86	1.22	0.38	34.11	30.54	46.72	11.51	30.37	19.70	32.84	7.61	4.26	4.01	6.73	1.88
Interaction Effects S.E. ±	NS	NS	NS	0.32	NS	NS	NS	9.76	NS	NS	NS	6.45	NS	NS	NS	NS
CD at 5%				0.99				30.08				19.88				

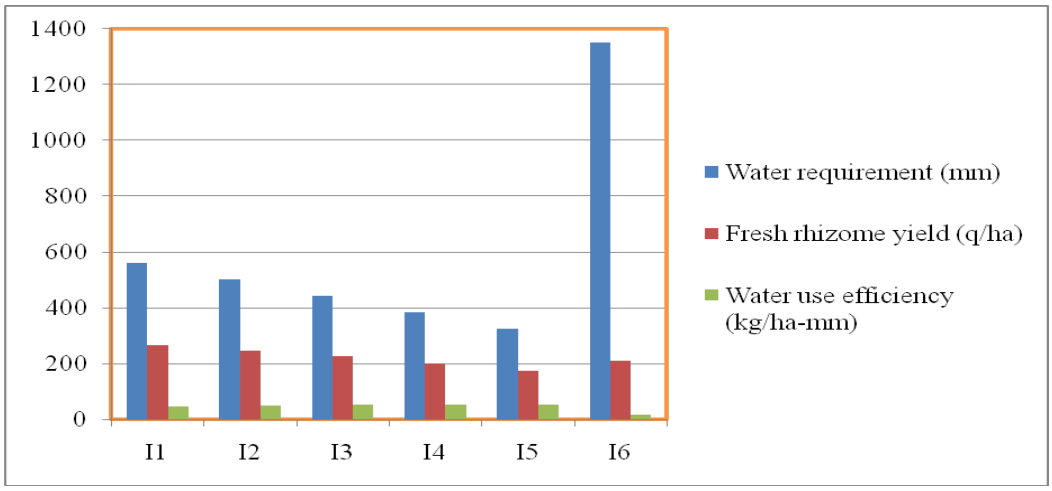
Note: D_1: 2 crop lines (30 x 30 cm) on raised beds of 1.20 m spacing and 0.60 m top width, D_2: 3 crop lines (22.5 x 30 cm) on raised beds of 1.20 cm spacing and 0.60 m top width, D_3: 2 crop lines (37.5 x 30 cm) on both sides of 0.75 m spaced ridges and furrows; I_1: 40% CPE, I_2: 35% CPE, I_3: 30% CPE, I_4: 25% CPE, I_5: 20% CPE and I_6: Surface irrigation at 75 mm CPE (1.0 IW/CPE ratios)

Table.4 Effect of deficit irrigation and planting layout on economics of turmeric cultivation

Treatment	Cost of cultivation (Rs. ha^{-1})				Gross returns (Rs. ha^{-1})				Net profit (Rs. ha^{-1})				B:C ratio			
	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean	2014-15	2015-16	2016-17	Mean
Layout																
D_1	275151	285722	295435	285436	295528	315277	400567	337124	20377	29555	105132	51688	1.07	1.10	1.35	1.17
D_2	297895	308158	308835	304963	228468	246346	302846	259220	-69426	-61812	-5990	-45743	0.77	0.80	0.97	0.85
D_3	340973	348066	355530	348190	461491	460355	560781	494209	120518	112289	205250	146019	1.35	1.32	1.57	1.41
S. E. ±	15633	10025	9329.9	1633.46	16023.1	9069.2	11441.1	7059.5	3185.3	1220.9	3770.8	5722.2	-	-	-	-
CD at 5%	NS	28951.5	26943.3	4717.15	62904.4	26190.4	33039.7	20386.7	12505	3525.8	10889	16524.6	-	-	-	-
Irrigation																
I_1	321359	328696	338506	329520	405837	406165	510030	440677	84478	77468	171524	111157	1.25	1.23	1.49	1.32
I_2	312028	324605	333008	323214	354441	386419	482037	407632	42413	61814	149029	84418	1.12	1.18	1.43	1.24
I_3	308975	316154	324985	316705	340721	340466	438876	373354	31746	24312	113891	56650	1.09	1.07	1.34	1.16
I_4	298532	312059	316102	308898	282668	320700	390551	331306	-15865	8641	74449	22408	0.93	1.02	1.23	1.06
I_5	293853	302902	304418	300391	259187	270536	325415	285046	-34666	-32366	20997	-15345	0.87	0.88	1.05	0.93
I_6	293290	299475	302583	298450	328121	319670	381478	343090	34831	20195	78895	44640	1.11	1.06	1.26	1.14
S. E. ±	9806.1	12006.4	19915.6	919.1	9916.2	11124	20984.3	5580	2973	2443.9	4070.9	4661.7	-	-	-	-
CD at 5%	NS	NS	NS	2654.24	28636.3	32124.2	60598.8	16114.1	8585.4	7057.6	11756	13462.2	-	-	-	-
Interaction S. E. ±	24020	29409.5	48783	2251.36	24289.7	27248.2	51400.7	13668.2	7282.3	5986.4	9971.5	11418.8	-	-	-	-
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	22441	18447	30728	NS	-	-	-	-

Note: D_1: 2 crop lines (30 x 30 cm) on raised beds of 1.20 m spacing and 0.60 m top width, D_2: 3 crop lines (22.5 x 30 cm) on raised beds of 1.20 cm spacing and 0.60 m top width, D_3: 2 crop lines (37.5 x 30 cm) on both sides of 0.75 m spaced ridges and furrows; I_1: 40% CPE, I_2: 35% CPE, I_3: 30% CPE, I_4: 25% CPE, I_5: 20% CPE and I_6: Surface irrigation at 75 mm CPE (1.0 IW/CPE ratios)

Fig.1 Water requirement, fresh rhizome yield and water use efficiency of turmeric influenced by different deficit irrigation levels through drip irrigation



Economic feasibility of turmeric under drip irrigation with deficit irrigation levels and planting layouts

The pooled data for the years 2014-15, 2015-16 and 2016-17 pertaining to cost of cultivation of turmeric (Rs.ha^{-1}) gross income (Rs.ha^{-1}), net profit (Rs.ha^{-1}) and B:C ratio induced under deficit irrigation, planting layout are presented in Table 4. The interaction effect of different deficit irrigation levels, planting layout on economic feasibility parameters was found to be non-significant. The maximum pooled mean of gross income (Rs.494209 ha^{-1}), net profit (Rs.205250 ha^{-1}) and B:C ratio (1.41) was observed in D_3 i.e. two crop lines on the ridges and furrows followed by D_1 i.e. 2 crop lines (0.30 x 0.30 m) on raised beds of 1.2 m spacing and 0.6 m top width. This might be due to optimum plant density, highest rhizome yield and thereby more gross and net income obtained under ridges and furrows. Whereas, the lowest pooled mean of gross income (Rs.259220 ha^{-1}), net profit (Rs.-45743 ha^{-1}) and B:C ratio (0.85) was observed in D_2 i.e. 3 crop lines on raised beds of 1.2 m spacing and 0.6 m top width. Three crop lines on just 0.6 m wider top of raised bed availed less space for rhizome growth under denser plant population as compare to two lines on raised bed as well as ridges and furrows. Consequently, D_2layout obtained lowest rhizome yield per plant, total rhizome yield per ha and thereby gained less gross and net income.

Among the different levels of deficit irrigation, significantly highest gross income (Rs.440677 ha^{-1}), net profit (Rs.111157 ha^{-1}) and B:C ratio (1.32) were recorded by scheduling of irrigation with drip at 40% CPE followed by 35% CPE. The irrigation amount of 40% CPE provided optimum and congenial condition to plant growth and produced highest fresh and dry rhizome yield and finally the highest economic returns than other deficit irrigation treatments. Drip irrigation with 20% CPE produced lowest rhizome yield and thereby lowest gross and net income due to more water deficit situation arised in root zone.

In conclusions, drip irrigation with scheduling at alternate day of 40% CPE and planting of two rows at 0.375 m x 0.30 m spacing on both sides of 0.75 m wide ridges and furrows is recommended for maximum yield of

turmeric, higher economic returns and efficient use of water over surface irrigation.

During water deficit condition, drip irrigation scheduled at alternate day of 35% and 30% CPE and planting of two rows at 37.5 x 30 cm spacing on both sides of 75 cm wide ridges and furrows is suggested for efficient use of water and higher yield of turmeric.

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How to cite this article:

Rathod, S. D., J. H. Kadam, D. K. Kathmale and Mali, M. D. 2020. Influence of Drip irrigation with Deficit Irrigation Levels and Planting Layouts on Performance of Turmeric (*Curcuma longa* L.). *Int.J.Curr.Microbiol.App.Sci.* 9(10): 1202-1213.
doi: https://doi.org/10.20546/ijcmas.2020.910.144