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RESEARCH ARTICLE

Crop geometry and dripper spacing in turmeric (*Curcuma longa* L.) raised with single bud transplants

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Abstract

Field experiments were carried out to explore the impact of crop geometry and dripper spacing on the growth, yield and water-use-efficiency (WUE) in turmeric (*Curcuma longa*) raised with single bud transplants at ARS, TNAU, Bhavani Sagar, Erode district, Tamil Nadu, India. The treatment structure includes 2 drippers spacing viz., 60 cm and 40 cm with combination of four crop geometry viz., 30 × 15 cm, 30 × 20 cm, 30 × 25 cm and 45 × 15 cm and with conventional (surface) irrigation method as control. The trials were laid out in a randomized block design (RBD) and repeated thrice. The irrigation is being applied once in 3 days through drip at 80 % Pan Evaporation (PE) which is common for all the treatments except the conventional method. The fertigation is being given once in 10 days by following the fertigation schedule developed for turmeric. The findings disclosed that drip irrigation (DI) at 80 % PE with 60 cm spacing of dripper and crop geometry of 30 × 20 cm recorded higher turmeric yield as well as high income and B:C ratio. Significantly the lowest yield was obtained in the control treatment (conventional method). Hence the cultivation of turmeric utilizing the drip irrigation system demonstrated a reduction in water consumption by 48 % in comparison to conventional irrigation method, with a WUE varying from 19.4 to 26.5 kg ha^{-1} mm^{-1}.

Keywords

crop geometry; drip fertigation; dripper spacing; single bud transplants; turmeric; water use efficiency

Introduction

One of the most significant spice crops is turmeric, which is extensively cultivated in the tropical and subtropical regions of our country. Since ancient times, India has cultivated turmeric, recognized as the third most significant spice crop and holds a leading position in its production (1). Turmeric (*Curcuma longa* L.) belongs to the family Zingiberaceae, is an herbaceous perennial plant. This crop is regarded as an exceptionally significant and sacrosanct spice cultivar in India, comprising a substantial proportion of proteins (6.3 %), lipids (5.1 %), carbohydrates (69.4 %), minerals (3.5 %) and other essential constituents when assessed on a dry weight basis (2).

In India, the production of turmeric (*C. longa*) accounts for approximately 6 % of the overall area designated for the cultivation of spices and condiments. The worldwide production of turmeric is approximately 11 lakh tons per year. India is the largest producer (80 % of world production), consumer and exporter (45 % of trade) of turmeric. India occupies a preeminent position in the global agricultural landscape, accounting for 80 % of cultivation output, succeeded by China (8 %), Myanmar (4 %), Nigeria (3 %) and Bangladesh (3 %) (3).

Primary cultivation of turmeric occurs in the regions of Andhra Pradesh, Odisha, Tamil Nadu, Assam, Maharashtra and Karnataka. In Tamil Nadu, Erode, Salem and Dharmapuri are the major turmeric cultivating districts. In Tamil Nadu, around 20771 ha area is under turmeric cultivation with a production of 97830 tonnes and the average productivity was 4710 kg/ha. The cultivated area of spread dedicated to turmeric in the Erode district encompassed an area of 4259 ha, resulting in a total yield of 24118 tonnes. The productivity of the Erode district was recorded at 5663 kg/ha for the agricultural year 2020-21 (4).

Turmeric is mostly grown in places where guaranteed source of water supply is available including command area supported with well irrigation. The irregular and heterogeneous distribution of rainfall renders water scarcity a significant issue that adversely influences the consistent availability of water in the canal regions. Thus, water emerges as the principal limiting factor for the cultivation of turmeric in Tamil Nadu. Therefore, the implementation of drip irrigation may contribute to the expansion of cultivated land, enhancement of agricultural productivity and improvement of water use efficiency in crop production (5). Drip irrigation, owing to its superior water-use-efficiency (WUE), diminishes the water demand for turmeric cultivation by 20-60 % within the states of Tamil Nadu and Maharashtra (6, 7). Consequently, it is advisable for the agricultural producers in Tamil Nadu to adopt the drip irrigation method by making use of the existing drip irrigation infrastructure associated with either sugarcane or banana cultivation that they currently possess. Generally, turmeric is propagated through the planting of both mother rhizomes and finger rhizomes as the primary planting materials, utilizing a seeding density of 2000 kg ha^{-1}. Hence, reduce the quantity of seed materials, a simplified form of raising healthier seedlings of turmeric is needed. Consequently, this research was undertaken to ascertain the optimal and economically viable dripper spacing and crop configuration that would enhance the productivity and conserve water in turmeric cultivated with single bud transplants.

Materials and Methods

Field experiments were carried out for 2 years at Agricultural Research Station, Bhavanisagar, Erode district of Tamil Nadu, India to detect the impact of dripper spacing and crop geometry on growth, yield and wue of turmeric raised with single bud transplants. The procedure (8) for producing the single bud transplants is given below

Turmeric plug transplant production stepwise procedure

- Drying of rhizomes (1 – 1 ½ months)
- Rhizomes were cut into small pieces with single bud (5 to 7 g)
- Rhizome pieces with single bud were placed in palm mat
- Entire buds were covered with humic acid treated cocopeat
- Water was sprinkled over the beds and kept for 4 days
- Rhizome treatment (Carbendazin at 2 g/L + Monocrotophos at 2 mL/L)
- After sprout emergence, the rhizome buds were sown in protray (Cocopeat (100 g) + *Pseudomonas fluorescens* (5 g))
- The trays were covered with polythene sheets up to 7 days
- Covers were removed (sprouting was completed)
- Portrays were kept under shade net and watered regularly
- Spraying of humic acid (0.5 %) at 15 DAS and 19:19:19 (1 %) at 20 and 25 DAS
- Transplants were ready for transplanting (30 - 35 days after sowing)

The treatment details are furnished below

- T_1-Drip irrigation (DI) at 80 % PE with 60 cm dripper spacing + 30 cm x 15 cm crop geometry
- T_2-DI at 80 % PE with 60 cm dripper spacing + 30 cm × 20 cm crop geometry
- T_3-DI at 80 % PE with 60 cm dripper spacing + 30 cm × 25 cm crop geometry
- T_4-DI at 80 % PE with 60 cm dripper spacing + 45 cm × 15 cm crop geometry
- T_5-DI at 80 % PE with 40 cm dripper spacing + 30 cm × 15 cm crop geometry
- T_6-DI at 80 **%** PE with 40 cm dripper spacing + 30 cm × 20 cm crop geometry
- T_7-DI at 80 % PE with 40 cm dripper spacing + 30 cm × 25 cm crop geometry
- T_8-DI at 80 % PE with 40 cm dripper spacing + 45 cm × 15 cm crop geometry and
- T_9-Conventional (surface) irrigation at 0.9 IW / CPE with 45 cm x 15 cm crop geometry (Control)

Irrigation was given once in 3 days through drip irrigation system at 80 % Pan Evaporation (PE) which is common for all the treatments under drip irrigation. Every 10 days fertigation was given by following the fertigation schedule of turmeric (Table 1, Fig. 1). The RDF followed for turmeric was 150: 60: 108 kg NPK per ha. The fertilizers

Table 1. Fertigation schedule for turmeric under drip.

Months	Fertilizer form	Fertilizer grade			Dosage Kg/ha/10 days	Nutrient content in Kgs		
		N	P	K		N	P	K
	Urea	46	0	0	8.3	11.5	0.0	0.0
June	MAP	12	61	0	3.3	1.2	6.1	0.0
	White Potash	0	0	60	1.7	0.0	0.0	3.0
	Urea	46	0	0	16.1	23.0	0.0	0.0
July	MAP	12	61	0	4.8	1.8	9.2	0.0
	White Potash	0	0	60	6.5	0.0	0.0	12.0
	Urea	46	0	0	24.2	34.5	0.0	0.0
Augt	MAP	12	61	0	6.5	2.4	12.2	0.0
	White Potash	0	0	60	8.1	0.0	0.0	15.0
	Urea	46	0	0	25.0	34.5	0.0	0.0
Sep	MAP	12	61	0	6.7	2.4	12.2	0.0
	White Potash	0	0	60	11.7	0.0	0.0	21.0
	Urea	46	0	0	16.1	23.0	0.0	0.0
Oct	MAP	12	61	0	5.8	2.2	11.0	0.0
	White Potash	0	0	60	12.9	0.0	0.0	24.0
	Urea	46	0	0	6.7	9.2	0.0	0.0
Nov	MAP	12	61	0	3.3	1.2	6.1	0.0
	White Potash	0	0	60	11.7	0.0	0.0	21.0
	Urea	46	0	0	1.6	2.3	0.0	0.0
Dec	MAP	12	61	0	1.6	0.6	3.1	0.0
	White Potash	0	0	60	6.5	0.0	0.0	12.0
	Total Recommendation					150	60	108

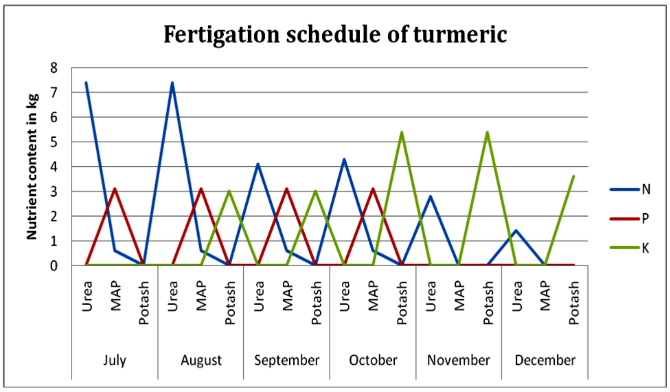

Fig. 1. Fertigation schedule for turmeric seedlings under drip irrigation.

used for fertigation were urea (46:0:0); MAP (12:61:0) and MOP (0:0:60). The experiments were laid out in a RBD and repeated thrice. The data on growth parameters were recorded on 120 DAT, 180 DAT and harvest stage. The observations on yield parameters and yield were noted during harvest stage. The data documented during the trials were analysed statistically (9).

Results and Discussion

Growth attributes of turmeric

The growth attributes of turmeric were significantly influenced by different dripper spacings and crop geometries at all the growth phases during the 2 years and as presented in Table 2. During harvest stages of the first and second years, maximum plant heights of 103.6 cm and 112.1 cm respectively, were obtained under emitter spacing of 40 cm combined with a closer crop geometry of 30 × 15 cm (T_5), which was superior to other spacings. However, during first year, this treatment was statistically comparable with same emitter spacing with crop geometry of 30 × 20 cm. Similar findings of higher plant heights or taller plants with closer crop spacing (10, 11). This might be due to the fact that under closer crop geometry, the competition for resources among the plants, such as light, nutrients and space, is high, causing the plants to allocate their resources towards vertical stem growth by increasing internodal length. This occurs because lateral expansion is restricted due to the lack of adequate space between plants. This is consistent with the findings of other studies in turmeric (12, 13).

Significantly maximum number of tillers per plant was obtained inwider crop geometry of 30 × 25 cm and 45 × 15 cm with both the dripper spacing of 40 cm and 60 cm (T_7, T_3, T_8 and T_4) during both the years. Wider plant spacing or lesser plant density had lesser competition and better utilization for resources which might have contributed to greater horizontal spreading resulting in a greater number of tillers per plant (12, 14, 15). Even though the plant height was observed to be higher in closer crop geometry the number of tillers per plant tends to decrease in high density planting. Lower number of tillers per plant of 3.7 were observed in closer crop geometry of 45 cm × 15 cm.

Table 2. Effect of dripper spacing and crop geometry on growth parameters of turmeric during harvest stage.

Treatment	First year		Second year		Pooled data	
	Plant height (cm)	No. of tillers plant^{-1}	Plant height (cm)	No. of tillers plant^{-1}	Plant height (cm)	No. of tillers plant^{-1}
T_1 - 60 cm dripper + 30 cm × 15 cm	93.2	3.5	98.8	4.0	96.0	3.7
T_2 - 60 cm dripper + 30 cm × 20 cm	93.4	4.0	103.0	4.4	98.2	4.2
T_3 - 60 cm dripper + 30 cm × 25 cm	92.6	4.7	96.0	4.8	94.3	4.7
T_4 - 60 cm dripper + 45 cm × 15 cm	83.5	4.3	94.2	4.5	88.9	4.4
T_5 - 40 cm dripper + 30 cm × 15 cm	103.6	3.8	112.1	4.0	107.9	3.9
T_6 - 40 cm dripper + 30 cm × 20 cm	94.0	4.0	103.0	4.2	98.5	4.1
T_7 - 40 cm dripper + 30 cm × 25 cm	93.0	5.3	97.7	5.0	95.3	5.1
T_8 - 40 cm dripper + 45 cm × 15 cm	86.1	4.3	94.7	4.8	90.4	4.5
T_9 - Conventional irrigation at 0.9 IW/CPE with 45 cm x 15 cm	74.4	3.7	88.7	3.7	81.6	3.7
SEd	4.6	0.4	4.3	0.3	3.2	0.2
CD (p=0.05)	9.7	0.8	8.1	0.5	6.8	0.5

Similarly, it was stated that the tiller per plants decreased in closer crop geometry in turmeric (11).

Yield of turmeric

Regarding the yield of turmeric (Table 3), dripper spacing of 40 cm and crop geometry of 30 x 15 cm (T_5) obtained higher turmeric yield of 16800 kg ha^{-1} and 17498 kg ha^{-1} during first and second year respectively but was comparable to 40 cm emitter spacing and crop geometry of 30 cm × 20 cm (T_6), 60 cm emitter spacing and plant geometry of 30 × 15 cm (T_1) and 30 × 20 cm (T_2) during both the years. This result revealed that closer spacing or increase in plant population produced significantly higher rhizome yield than the wider spaced crops. The higher rhizome yield recorded in the closer crop geometry might be due to a greater number of plants or higher plant density. Plant population plays a major factor which determines the rhizome yield of turmeric. Higher turmeric yields under closer geometry of turmeric obtained by several studies (11, 16, 17). Significantly the lowest yield of 7956 kg ha^{-1} and 9014 kg ha^{-1} were observed in the conventional method (surface irrigation) of irrigation and crop geometry of 45 cm × 15 cm (T_9) which might be due to the leaching of added nutrients and runoff which became unavailable to crops for growth and development when irrigated under 50 % soil moisture depletion condition and hence crop does not produce maximum yield. Results are in acceptance with the findings of (14, 18, 19), who acquired higher yields in drip irrigation over surface irrigation in turmeric.

Table 3. Effect of dripper spacing and crop geometry on yield of turmeric.

Treatments	Rhizome Yield (kg ha^{-1})		
	I year	II year	Pooled
T_1 – 60 cm dripper + 30 cm × 15 cm	15644	16323	15984
T_2 - 60 cm dripper + 30 cm × 20 cm	16178	17400	16789
T_3 - 60 cm dripper + 30 cm × 25 cm	10489	14644	12567
T_4 - 60 cm dripper + 45 cm × 15 cm	12711	12422	12567
T_5 - 40 cm dripper + 30 cm × 15 cm	16800	17498	17149
T_6 - 40 cm dripper + 30 cm × 20 cm	16089	17161	16625
T_7 - 40 cm dripper + 30 cm × 25 cm	12356	13686	13021
T_8 - 40 cm dripper + 45 cm × 15 cm	14756	15533	15145
T_9 - Conventional irrigation at 0.9 IW/CPE with 45 cm x 15 cm)	7956	9014	8485
SEd	1155	1335	740
CD (p=0.05)	2449	2037	1570

Economics of turmeric under drip irrigation with single bud transplants

The economics of turmeric cultivation (mean of 2 years) by using single bud transplants with different spacing are presented in Table 4. Though the plots with 40 cm emitter spacing with a closer crop geometry of 30 × 15 cm (T_5) obtained higher yield and higher gross income; it has obtained lower cost benefit ratio of 1.45 which might be due to seedling cost involved for higher number of seedlings. However, the highest B:C ratio of 1.80 was obtained in 60 cm emitter spacing with a crop geometry of 30 × 20 cm (T_2). Similar finding of drip irrigation at 80 % ETo resulted in higher net income along with saving of 311.1 mm irrigation water than the control treatment was observed in turmeric (20).

Table 4. Influence of dripper spacing and crop geometry on yield and economics of turmeric (Mean data of 2 years).

Treatments	Yield of Rhizome (kg ha^{-1})	Cost of cultivation (Rs)	Gross income (Rs)	Net income (Rs)	B:C ratio
T_1	15984	134201	191802	57601	1.43
T_2	16789	111979	201468	89489	1.80
T_3	12567	98645	150798	52153	1.53
T_4	12567	104571	150798	46227	1.44
T_5	17149	141701	205788	64087	1.45
T_6	16625	119479	199500	80021	1.67
T_7	13021	106145	156249	50104	1.47
T_8	15145	112071	181734	69663	1.62
T_9	8485	104346	101820	-2526	0.98

Cost of turmeric seedling: Rs. 0.40/no. Sale price of turmeric rhizome is Rs. 12.0/ per kg. Drip fertigation system cost of Rs.100000 is included at Rs.12500/ per year for 8 years.

Water use studies of turmeric under drip irrigation with single bud transplants

The total irrigation water consumed and water-use-efficiency (WUE) of turmeric under drip as per the treatment schedule are presented in the Table 5. For the drip irrigated treatments at 80 % PE, the amount of irrigation water consumed by drip were 459 and 415 mm and the effective rainfall received during the cropping period was 143 mm and 279 mm contributing to total water usage of 602 and 694 mm respectively for first and second year.

Table 5. Effect of drip irrigation on total water usage and WUE of turmeric raised with single bud transplants.

Treatments	I season			II season			Mean value		
	Rhizome Yield (kg ha^{-1})	Total water used (mm)	WUE (kg ha^{-1} mm^{-1})	Rhizome Yield (kg ha^{-1})	Total water used (mm)	WUE (kg ha^{-1} mm^{-1})	Rhizome Yield (kg ha^{-1})	Total water used (mm)	WUE (kg ha^{-1} mm^{-1})
T_1 – 60 cm dripper + 30 cm x 15 cm	15644	602	26.0	16323	694	23.5	15984	648	24.7
T_2 - 60 cm dripper + 30 cm x 20 cm	16178	602	26.9	17400	694	25.1	16789	648	25.9
T_3 - 60 cm dripper + 30 cm x 25 cm	10489	602	17.4	14644	694	21.1	12567	648	19.4
T_4 - 60 cm dripper + 45 cm x 15 cm	12711	602	21.1	12422	694	17.9	12567	648	19.4
T_5 - 40 cm dripper + 30 cm x 15 cm	16800	602	27.9	17498	694	25.2	17149	648	26.5
T_6 - 40 cm dripper + 30 cm x 20 cm	16089	602	26.7	17161	694	24.7	16625	648	25.7
T_7 - 40 cm dripper + 30 cm x 25 cm	12356	602	20.5	13686	694	19.7	13021	648	20.1
T_8 - 40 cm dripper + 45 cm x 15 cm	14756	602	24.5	15533	694	22.4	15145	648	23.4
T_9 - Conventional irrigation at 0.9 IW/CPE with 45 cm x 15 cm)	7956	1251	6.4	9014	1235	7.3	8485	1243	6.8
SEd	1155	-	1.92	1335	-	2.02	740	-	1.94
CD (p=0.05)	2449	-	4.07	2037	-	4.23	1570	-	4.09

Under conventional (surface) irrigation method, irrigation was given immediately after transplanting the seedlings followed by life irrigation at 5 cm depth and there after irrigation was given as per the IW / CPE ratio of 0.9. A total of 1050 mm and 900 mm of water were applied during I and II year respectively. An effective rainfall of 201 mm and 335 mm were received and totally 1251 mm and 1235 mm of water were consumed by surface irrigated crop with an average of 1243 mm. The average quantity of water used by turmeric for 2 years under drip irrigation was 648 mm, which was 48 % lower than surface irrigation method. Therefore, under drip irrigation method we can be able to save 595 mm of water. Regarding the WUE of turmeric, the 40 cm emitter spacing and crop geometry of 30 × 15 cm (T_5) obtained higher WUE of 27.9 kg ha^{-1} mm^{-1} and 25.2 kg ha^{-1} mm^{-1} during first and second years respectively, but was comparable with 40 cm emitter spacing and crop geometry of 30 × 20 cm (T_6) and 45 × 15 cm (T_8) and 60 cm emitter spacing and crop geometry of 30 × 15 cm (T_1) and 30 × 20 cm (T_2) during both years. Significantly lowest WUE of 6.4 kg ha^{-1} mm^{-1} and 7.3 kg ha^{-1} mm^{-1} were observed in the conventional treatment (T_9). Similar finding of 21.6 % higher WUE with saving of 311.1 mm irrigation water than control was observed in turmeric under drip irrigation at 80 % ETo (20).

Conclusion

Drip irrigation at 80 % PE with dripper spacing of 60 cm and crop geometry of 30 × 20 cm recorded higher rhizome yield as well as high income and B:C ratio. Significantly the lowest yield was observed in the conventional method (control). Turmeric cultivated under drip irrigation system resulted in saving of 48 % of water when compared to conventional method with a WUE ranging from 19.4 to 26.5 kg ha^{-1} mm^{-1}

Authors' contributions

All authors contributed to the study conception and design. Field trials and manuscript preparation were performed by KR. Assistance in taking up field trials by TS and RC Data analysis was performed by MPK and SS. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript

Compliance with ethical standards

Conflict of interest: The authors have no relevant financial or non-financial interests to disclose.

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