Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com
Journal of Pharmacognosy and Phytochemistry

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(2): 1822-1829
Received: 25-01-2019
Accepted: 28-02-2019

Amandeep Kaur
Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab, India

Ajmer Singh Brar
Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab, India

Amandeep Singh Brar
Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab, India

Correspondence
Amandeep Kaur
Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab, India

To evaluate the effect of mulch, Irrigation methods and schedules on yield and quality of turmeric (*Curcuma longa*)

Amandeep Kaur, Ajmer Singh Brar and Amandeep Singh Brar

Abstract
A study was carried out at PAU, Ludhiana (Punjab) to evaluate the effect of mulch, Irrigation methods and schedules on yield and quality of turmeric (*Curcuma longa*). The experiment was laid out in split plot design keeping, combination of mulch levels (straw mulch @ 6 t/ha and no mulch) and irrigation methods (drip and check basin) in main plots and irrigation schedules (0.6 IW: CPE, 0.8 IW: CPE, 1.0 IW: CPE and 1.2 IW: CPE) in sub plots with three replications. Application of straw mulch resulted in significantly higher curcumin and oil yield as compared to no mulch treatment. Drip irrigation resulted in 41.1 and 42.2; 43.2 and 35.7 per cent higher curcumin and oil yield than check basin, respectively, in 1st, 2nd year. Crop raised with 1.2 IW: CPE schedule produced significantly higher growth and yield attributes than 0.6, 0.8 and 1.0 IW: CPE schedules. Drip irrigation at 1.2 IW: CPE schedule gave maximum curcumin and oil yield, which was at par with drip irrigation at 1.0 IW: CPE but significantly better than all other combinations of methods of irrigation and irrigation schedule. Curcumin and oil content did not differ significantly with application of mulch, irrigation methods and schedules.

Keywords: Turmeric, mulch, irrigation methods, irrigation schedules, yield, quality

Introduction

Turmeric (*Curcuma longa* L.), an annual herbaceous plant having a short stem with large oblong leaves and bearing ovate, pyriform or oblong rhizomes, which are often branched and brownish-yellow in colour. It belongs to order *Zingiberales* and family *Zingiberaceae*, commonly known as haldi in Hindi, turmeric in English and ukon in Japanese. Turmeric is a native of tropical South-East Asia and mainly cultivated in India, Bangladesh, China, Thailand, Malaysia, Indonesia, Philippines, Sri Lanka, Taiwan, Peru and Pakistan. India is the largest producer, consumer and exporter of turmeric in the world and accounts for 80 per cent of the world's turmeric production. Turmeric is cultivated on an area of 234.1 thousand hectares with a production of 1228.9 thousand metric tonnes in Andhra Pradesh, Tamil Nadu, Odisha, Kerala, Maharashtra, West Bengal and north-eastern states of India (Anonymous 2014) [4].

Turmeric powder contains 6.3 per cent protein, 2.5-7.2 per cent of essential oil (turmerol), 5 per cent fat, 3.5 per cent minerals, 13.1 per cent moisture and 69.4 per cent carbohydrates (Barrero and Carreno 1999) [5]. Turmeric is a medicinal plant extensively used in Ayurveda, Unani and Siddha medicine as home remedy for various diseases (Ammon and Wahl 1991; Eigner *et al.* 1999) [2, 8]. In old Hindu medicine, turmeric is used for the treatment of sprains, swelling caused by injury, (Ammon and Wahl 1991) [2] biliary disorders, anorexia, coryza, cough, sinusitis (Ammon *et al.* 1992) [3] and dissolving urinary calculus (Leskovan 1983) [18]. Turmeric is largely used as spice or condiment, preservative and colouring agent in Asian countries, including China and South East Asia (Sastry 1970) [18]. Turmeric considered as auspicious and is a part of religious rituals and used to provide a temporary dye for cotton, woollen and silk fabrics. Turmeric turns red on mixing with alkali and is utilized as an indicator for detecting alkaline conditions. Turmeric increases the shelf-life of oils (Rimpler *et al.* 1970) [25].

Curcumin is a crystalline substance (Diferuloylmethane, $C_{21}H_{20}O_6$), which makes up approximately 90 per cent of the total curcuminoid content followed by demethoxycurcumin and bisdemethoxycurcumin (Maheshwari *et al.* 2006) [19]. Curcumin possesses anti-cancerous properties (Kuttan *et al.* 1985; Aggarwal *et al.* 2003) [17, 1] and is used for the cure of AIDS (Cohly *et al.* 2003) [7]. Curcumin has anti-oxidant, anti-septic, anti-bacterial and anti-inflammatory properties and is useful in treating diabetes, jaundice, arthritis, cold, sore throat, dropsy, wounds and inflammation (Khanna 1999; Mani *et al.* 2002) [15, 21]. Turmerol contains 1 per cent a-phellandrene, 0.6 per cent sabinene, 1.0 per cent cineol, 0.5 per cent borneol, 25.0

per cent zingiberene and 53.0 per cent sesquiterpenes (Kapoor 1990) [13].

Turmeric demand is increasing in the national and international market. Despite having excellent export potential the production of turmeric has not kept pace with the increasing domestic and export demand, for many reasons i.e. marginal farming, unscientific techniques of cultivation, post-harvest operations and lack of high yielding varieties. The productivity of a crop can be enhanced by introducing high yielding varieties and modifying the existing package of practices which are location specific. Turmeric cultivation in state will be helpful not only to meet its own demand but also to help the country to boost export. In Punjab, rice-wheat is the predominant cropping system, but due to rise in cost of inputs and monoculture limitations, there is need to diversify some area from this cropping system in the state. Turmeric offers good scope in diversification of cereal based cropping system. The climatic and edaphic conditions of Punjab are suitable for cultivation of turmeric.

In Punjab, turmeric is planted in hot summer months from end of April to first week of May and remains in the field up to end of November. Thus, turmeric is not only a long duration crop but also runs through high evaporative demand period, which make its water requirement quite high (Chela and Brar 1976) [6]. Among agronomic practices, irrigation scheduling is of paramount importance and application of straw mulch may influence water retention and availability to crop (Swain *et al.* 2007) [32]. The application of mulch reduces evaporation losses, suppresses weeds, regulates soil temperature and helps to protect the germinating rhizomes from desiccation especially during early growth period in hot and dry months (May and June). Mulching reduced the weed growth considerably and enhanced sprouting of rhizomes by conserving soil moisture (Philip *et al.* 1981; Kumar *et al.* 2008) [23, 16]. The application of straw mulch had favourable effect on growth parameters, yield and yield attributing characters as compared to no mulch and these favourable effects of mulch might be due to early emergence, quick establishment of crop and higher interception of light (Singh and Randhawa 1988) [30]. Mulch also improves soil water retention, micro-flora and fauna in soil and reduces wind velocity at the soil surface in arid regions (Kay 1978; Jalota and Prihar 1998) [14, 11] besides, improving the water penetration by impeding runoff and protecting the soil from raindrop splash (Munshower 1994) [22].

Irrigation application is one of the most important factors influencing the yield of any crop and accounts for about 50 per cent of total energy invested in the agricultural sector. Moreover water table is declining at an alarming rate in the state of Punjab because of marked increase in the acreage under rice raised with tube well irrigation (Gupta *et al.* 1995) [10]. So the efficient use of irrigation water is a basic requirement to attain a higher level of production per unit of water. Drip irrigation is one of the most important irrigation method in which water used efficiently because drip irrigation provides precise and site-specific water application near the root zone of plant. Yield of crops can be improved by using drip irrigation, under limited water applications by decreasing the amount of water that leaches beneath the root zone (El-Hendawy *et al.* 2008) [9]. Drip irrigation reduces or eliminates runoff, deep percolation, evaporation and reduces weed growth. Additionally, water delivery with drip irrigation can be scheduled based on evapotranspiration, allowable soil water depletion and target soil water tension (Sammis 1981) [26]. Water saving from drip irrigation system varied from 12 to 84 per cent for different crops besides increasing the productivity of crops (Ramah 2008) [24]. No research work has so far been done to study the combined effect of mulch and drip irrigation in turmeric under Punjab conditions. Hence, taking the above facts in view the present study was planned, to check the quality and productivity of turmeric with straw mulching and irrigation schedules using drip and check basin irrigation methods.

Materials and Methods

Weather and climate

A field study was conducted at the Research Farm of Punjab Agricultural University, Ludhiana (30° 56' N and 75° 52' E at 247 m above sea level) during 2013 and 2014. It comes under central plain region of Punjab in trans-gangetic plain agro-climatic zone of India. The area is under sub-tropical to semi-arid climate with hot and dry summer (April to June), hot and humid monsoon period (July to September), mild winter (October to November) and severe winter from December to February. The mean minimum and maximum temperatures show considerable fluctuation during summer and winter. Maximum air temperature above 38 ºC is common during summer and frequent frosty spells are experienced in December-January. The average annual rainfall lies between 500-750 mm out of which 75 per cent is received in summer monsoon (July to September) complemented by a few showers in winter.

The meteorological data recorded at the meteorological observatory of Punjab Agricultural University, Ludhiana during the crop growing season are presented in Fig. 1. Total amount of rainfall received during crop growing season of 2013 and 2014 was 755.8 mm and 546.9mm, respectively. The mean monthly temperature ranged between 13.7-31.9 ºC and 12.3-33.8 ºC, whereas relative humidity remained 38.0-79.5 per cent and 44.0-80.0 per cent during 2013 and 2014, respectively.

Soil of the experimental site and methodology

The soil of the experimental site was sandy loam in texture, low in organic carbon (0.32 per cent), available nitrogen (188.2 kg/ha), medium in available phosphorous (13.8 kg/ha) and available potassium (324.8 kg/ha) in 0-15 cm depth and the contents of these nutrients in soil decreased with increase in depth up to 90 cm of soil profile. The pH of soil was slightly alkaline and electric conductivity of soil was low. The experiment was laid out in split plot design keeping, combination of mulch levels (straw mulch @ 6 t/ha and no mulch) and irrigation methods (drip and check basin) in main plots and irrigation schedules (0.6 IW: CPE, 0.8 IW: CPE, 1.0 IW: CPE and 1.2 IW: CPE) in sub plots with three replications. Irrigations were applied by taking 40 mm cumulative pan evaporation (CPE) as a base for drip irrigation, however in check basin, irrigations were applied as per the IW: CPE keeping 75 mm depth of water application. Turmeric crop was planted on April 25, 2013 and April 28, 2014 by using 20 q/ha rhizomes in rows 30 cm apart with plant to plant spacing of 20 cm. The plots were irrigated immediately after planting of rhizomes and sprayed with pre-emergence herbicide (Stomp 30 EC @ 3250 ml/ha) next day. In mulch treatments, straw mulch @ 6 t/ha was spread immediately after application of Stomp. Morphological data were recorded at periodic interval upto 210 days after planting and yield was recorded after harvest. After harvesting the turmeric crop, the rhizomes were properly cleaned and weighed plot wise. One kilogram fresh rhizomes from each plot was washed with clean water and then boiled in vertical autoclave at 121 °C temperature and 15 lbs/inch^2 pressure for half an hour. After boiling, the rhizomes were dried in sun light for 2 to 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 then grounded with the help of grinder and processed/powder yield of turmeric in q/ha was obtained. For obtaining curcumin content 0.1g of moisture free turmeric powder was dissolved in 50ml dehydrated alcohol in 250 ml flask. Content was then refluxed in flask fitted with condenser over a heating mantle for 4-5 hours and then allowed to cool. Alcohol loss, if any due to evaporation was then compensated by adding fresh dehydrated alcohol into the flask to make up the volume 50ml. One ml of the aliquot was transferred in a 25 ml flask and volume was made up with dehydrated alcohol. Intensity of yellow colour was measured at a wavelength of 425nm by spectrophotometer (Thimmaiah 1999) [33].

$$\text{Curcumin content (\%)} = \frac{0.0025 \times A_{425} \times \text{volume made up} \times \text{dilution factor}}{0.42 \times \text{weight of sample (g)} \times 1000} \times 100$$

Since, 0.42 absorbance at 425 nm = 0.0025 g curcumin
25 g turmeric powder was dissolved in one litre of water and distilled in Clevenger's Apparatus (oil distillation assembly) for 4.5 hours at 50 ºC and the amount of essential oil was worked out.

Statistical analysis

Analysis of variance was performed to see the influence of mulch levels, irrigation methods and irrigation schedules on various parameters of turmeric and their interaction. The variance was analyzed using Proc GLM (SAS software 9.1, SAS institute Ltd, USA) for both the years separately. The difference between means was compared with Fisher's least significant difference test (LSD) at 5% probability level. Since the trends in results were similar during both the years, the data was pooled, keeping years as main factor to increase the precision for main plots (mulch levels and irrigation methods).

Results

Effect of straw mulching

The data revealed that crop raised with straw mulch had significantly better on growth and yield attributes of turmeric as compared to no mulch (Table 1, 2 and 4). Leaf area index (LAI) increased with time till 180 DAP and thereafter there was reduction in leaf area index due to drying and withering of leaves on main stem. The data revealed that crop raised with straw mulch produced significantly higher leaf area index as compared to no mulch (Table 1). At 90, 150, 180 and 210 DAP crop raised with straw mulch had 211.1 per cent, 155.3 per cent, 74.6 per cent and 66.7 per cent; 168.9 per cent, 77.2 per cent, 73.3 per cent and 81.6 per cent; and 191.1 per cent, 115.2 per cent, 74.0 per cent and 72.9 per cent higher leaf area index as compared to crop raised without application of straw mulch, respectively during 2013, 2014 and as well as pooled data. Dry matter accumulation is good growth index to express the photosynthetic efficiency of the plant. Crop dry matter was recorded at 60, 90, 120, 150, 180 and 210 DAP (Table 2). Dry matter accumulation increased upto 210 DAP. Maximum increase in dry matter accumulation was reported between 90 to 150 DAP, which is considered to be grand growth stage of crop. The data revealed that crop raised with straw mulch produced significantly higher dry matter of above ground parts (stem plus leaves) as compared to no mulch (Table 2). At 90 and 150 DAP crop raised with straw mulch accumulated 82.9 per cent and 40.9 per cent; 92.7 per cent and 45.1 per cent; and 87.6 per cent and 43.0 per cent higher dry matter as compared to crop raised without mulch, respectively during 2013, 2014 and as well as pooled data. Junior *et al.* (2005) [12] also reported that mulch application is effective for increasing the above ground biomass.

The leaf area index and dry matter accumulation was significantly higher in mulched plot than no mulch, which resulted in significantly higher processed turmeric yield (122.9, 127.3 and 125.2 per cent), respectively during 2013, 2014 and as well as pooled data. Manhas *et al.* (2011) [20]; Verma and Sarnaik (2006) [35] was also reported higher fresh rhizome, dry rhizome and processed turmeric yield in mulched plots as compared to no mulch. Crop raised with straw mulch had non-significant effect on curcumin and oil content (Table 6). During both years, oil and curcumin content was non-significantly influenced by mulch application (Manhas *et al.* 2011; Sanwal *et al.* 2007) [20, 27] Crop raised with straw mulch produced 130.6, 141.8 and 136.7 per cent; and 126.1, 141.3 and 131.7 per cent higher curcumin and oil yield as compared to no mulch because of higher processed turmeric yield, respectively, during 1st, 2nd year and pooled data (Table 6).

Table 1: Effect of mulch levels, irrigation methods and irrigation schedules on leaf area index of turmeric

Treatments	Days after planting														
	90			120			150			180			210		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Mulch levels															
No mulch	0.45	0.45	0.45	1.18	1.22	1.20	1.70	1.71	1.71	2.37	2.17	2.27	1.65	1.52	1.59
Straw mulch (6t/ha)	1.40	1.21	1.31	3.39	2.99	3.19	4.34	3.03	3.68	4.14	3.76	3.95	2.75	2.76	2.75
CD (p=0.05)	0.11	0.05	0.05	0.28	0.18	0.15	0.38	0.17	0.18	0.38	0.31	0.22	0.26	0.13	0.13
Irrigation methods															
Check basin	0.87	0.70	0.79	2.03	1.75	1.89	2.78	2.17	2.47	3.03	2.62	2.82	2.05	1.90	1.98
Drip	0.98	0.96	0.97	2.54	2.45	2.50	3.27	2.57	2.91	3.48	3.31	3.40	2.35	2.38	2.36
CD (p=0.05)	0.11	0.05	0.05	0.28	0.18	0.15	0.38	0.17	0.18	0.38	0.31	0.22	0.26	0.13	0.13
Irrigation schedules															
0.6 IW:CPE	0.83	0.66	0.74	2.03	1.68	1.85	2.60	2.05	2.33	2.73	2.41	2.57	1.83	1.77	1.80
0.8 IW:CPE	0.88	0.73	0.81	2.18	2.00	2.09	2.87	2.25	2.56	3.22	2.76	2.99	2.04	2.02	2.03
1.0 IW:CPE	0.92	0.87	0.89	2.30	2.16	2.23	3.08	2.43	2.75	3.38	3.13	3.26	2.33	2.23	2.28
1.2 IW:CPE	1.08	1.08	1.08	2.63	2.58	2.60	3.54	2.74	3.14	3.69	3.56	3.63	2.62	2.53	2.58
CD (p=0.05)	0.13	0.11	0.08	0.27	0.25	0.17	0.25	0.24	0.17	0.35	0.27	0.21	0.33	0.15	0.18

Table 2: Effect of mulch levels, irrigation methods and irrigation schedules on dry matter accumulation (g/m^2) by turmeric crop

Treatments	Days after planting																	
	60			90			120			150			180			210		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Mulch levels																		
No mulch	22.6	20.6	21.6	51.4	45.2	48.3	149.3	137.6	143.4	222.8	208.2	215.5	326.7	306.4	316.5	369.0	342.8	355.9
Straw mulch (6t/ha)	44.4	42.4	43.4	94.0	87.1	90.6	300.9	280.0	290.5	314.0	302.2	308.1	581.4	552.0	566.7	576.6	539.1	557.8
CD (p=0.05)	4.5	1.4	2.1	7.9	3.4	3.8	20.8	11.5	10.6	24.2	25.1	15.5	44.2	31.0	24.0	55.3	29.5	27.9
Irrigation methods																		
Check basin	30.3	28.1	29.2	65.7	58.1	61.9	194.4	177.9	186.1	231.0	219.5	225.2	428.6	403.5	416.1	441.1	421.5	431.3
Drip	36.7	34.8	35.7	79.7	74.1	76.9	255.9	239.7	247.8	305.8	290.9	298.3	479.5	455.0	467.2	504.5	460.3	482.4
CD (p=0.05)	4.5	1.4	2.1	7.9	3.4	3.8	20.8	11.5	10.6	24.2	25.1	15.5	44.2	31.0	24.0	55.3	29.5	27.9
Irrigation schedules																		
0.6 IW:CPE	28.5	26.0	27.3	56.8	50.6	53.7	180.2	165.3	172.7	229.4	215.2	222.3	352.5	331.1	341.8	366.4	334.7	350.5
0.8 IW:CPE	30.4	28.3	29.4	66.7	60.2	63.5	212.1	198.0	205.1	255.6	243.6	249.6	456.6	423.9	440.2	474.6	433.0	453.8
1.0 IW:CPE	36.3	33.9	35.1	79.0	72.1	75.6	243.9	224.0	234.0	270.3	258.5	264.4	477.6	458.5	468.0	501.2	467.9	484.5
1.2 IW:CPE	38.9	37.6	38.2	88.2	81.6	84.9	264.3	247.8	256.1	318.2	303.4	310.8	529.6	503.4	516.5	549.0	528.2	538.6
CD (p=0.05)	3.5	1.5	1.8	7.6	4.3	4.3	15.9	9.0	8.9	39.3	29.3	23.9	61.7	38.9	35.5	71.2	42.8	40.5

Table 4: Effect of mulch levels, irrigation methods and irrigation schedules on processed yield (q/ha) of turmeric

Treatments	Processed Yield		
	2013	2014	Pooled
Mulch levels			
No mulch	26.2	23.1	24.6
Straw mulch (6t/ha)	58.4	52.5	55.4
CD (p=0.05)	4.5	4.1	2.7
Irrigation methods			
Check basin	36.0	32.2	34.1
Drip	48.6	43.3	46.0
CD (p=0.05)	4.5	4.1	2.7
Irrigation schedules			
0.6 IW:CPE	33.6	28.6	31.1
0.8 IW:CPE	40.2	35.0	37.6
1.0 IW:CPE	45.6	40.6	43.1
1.2 IW:CPE	49.9	47.0	48.4
CD (p=0.05)	3.4	4.0	2.6

Table 6: Effect of mulch levels, irrigation methods and irrigation schedules on Curcumin content (%), Curcumin yield (kg/ha), Oil content % (v/w) and Oil yield (l/ha) of turmeric

Treatment	Curcumin content (%)			Curcumin yield (kg/ha)			Oil content % (v/w)			Oil yield (l/ha)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Mulch levels												
No mulch	2.08	2.74	241	55.5	62.4	58.9	6.08	4.03	5.05	160.3	93.5	126.9
Straw mulch (6t/ha)	2.19	2.84	2.52	128.0	150.9	139.4	6.18	4.30	5.24	362.4	225.6	294.0
CD (p=0.05)	NS	NS	NS	11.7	15.0	8.5	NS	NS	NS	34.2	21.9	18.1
Irrigation methods												
Check basin	2.08	2.71	2.39	76.1	87.7	81.9	6.11	4.07	5.09	221.8	131.3	176.5
Drip	2.19	2.88	2.53	107.4	125.6	116.5	6.15	4.26	5.20	300.9	187.9	244.4
CD (p=0.05)	NS	NS	NS	11.7	15.0	8.5	NS	NS	NS	34.2	21.9	18.1
Irrigation schedules												
0.6 IW:CPE	1.94	2.78	2.36	65.9	81.5	73.7	5.85	3.92	4.88	196.1	113.3	154.7
0.8 IW:CPE	2.12	2.97	2.54	86.0	102.0	94.0	6.03	4.37	5.20	243.9	154.7	199.3
1.0 IW:CPE	2.22	2.70	2.46	101.9	111.2	106.6	6.21	4.02	5.11	284.1	167.0	225.6
1.2 IW:CPE	2.25	2.72	2.48	113.1	132.0	122.5	6.43	4.35	5.39	321.3	203.2	262.3
CD (p=0.05)	NS	NS	NS	15.0	18.3	11.5	NS	NS	NS	29.0	33.6	21.6

Effect of irrigation methods and schedules

Methods of irrigation had significant effect on leaf area index at all growth stages of crop. Drip irrigation resulted in 12.6, 37.1 and 22.8 per cent; 17.6, 18.4 and 17.8 per cent; and 14.6, 25.3 and 19.2 per cent higher leaf area index as compared to check basin at 90, 150 and 210 DAP, respectively, during 1st, 2nd year and as well as pooled data (Table 1).

Among the irrigation schedules, maximum leaf area index was reported in crop raised with 1.2 IW: CPE which was statistically at par with 1.0 IW: CPE but significantly higher than all other irrigation schedules at 180 and 210 DAP during 1st year (Table 1). In 2nd year significantly higher leaf area index reported in 1.2 IW: CPE schedule than 1.0, 0.8 and 0.6 IW: CPE schedule, whereas similar trend found in pooled data. However, at 90, 120 and 150 DAP leaf area index was significantly higher in crop raised with 1.2 IW: CPE than 1.0, 0.8 and 0.6 IW: CPE schedule during both years and as well as pooled data. Crop raised with 1.2 IW: CPE gave 17.4, 24.1 and 21.3 per cent; 14.3, 19.4 and 16.6 per cent; and 14.9, 12.8 and 14.2 per cent higher leaf area index as compared to 1.0 IW: CPE at 90, 120 and 150 DAP, respectively, during 1st, 2nd year and pooled data. Lower values of leaf area index in 0.6

IW: CPE schedule resulted from reduced transpiration and photosynthetic activities because of less frequent irrigation application.

Methods of irrigation also had significant bearing on dry matter accumulation at all growth stages (Table 2). Drip irrigation resulted in 21.3, 27.5 and 24.3 per cent; 32.4, 32.5 and 32.5 per cent; and 14.4, 9.2 and 11.8 per cent higher dry matter accumulation as compared to check basin at 90, 150 and 210 DAP, respectively, during 1st, 2nd year and as well as pooled data. Higher dry matter accumulation in drip irrigated crop resulted from significantly higher leaf area index as compared to check basin. Drip irrigation resulted favourable soil moisture conditions because of application of frequent and light irrigation beneath the root zone. Lesser dry matter accumulation in check basin irrigated crop resulted from less frequent irrigation application at longer interval, which resulted in close of stomata and hence less carbon dioxide diffusion for photosynthesis.

Among the irrigation schedules, maximum dry matter accumulation was reported in crop raised with 1.2 IW: CPE schedule which was statistically at par with 1.0 IW: CPE but significantly better than other schedules at 60, 180 and 210 DAP during 1st year (Table 2). However, at 90, 120 and 150 DAP dry matter accumulation was significantly higher in crop raised with 1.2 IW: CPE than 1.0, 0.8 and 0.6 IW: CPE during 2nd year and as well as pooled data. Crop raised with 1.2 IW: CPE gave 11.6, 13.2 and 12.3 per cent; 8.4, 10.6 and 9.4 per cent; and 17.7, 17.4 and 17.5 Per cent higher dry matter accumulation than 1.0 IW: CPE at 90, 120 and 150 DAP, respectively, during 1st, 2nd year and as well as pooled data.

Drip irrigation resulted in significantly higher processed yield of turmeric as compared to check basin (Table 4). Drip irrigated crop produced 35, 34.5 and 34.9 per cent higher processed yield of turmeric as compared to check basin, respectively, in 1st, 2nd year and as well as pooled data. Curcumin and oil content did not differ significantly in drip irrigated crop as compared to check basin (Table 6). Drip irrigated crop produced 41.1, 43.2 and 42.2; and 35.7. 43.1 and 38.5 per cent higher curcumin and oil yield as compared to check basin, respectively, in 1st, 2nd year and as well as pooled data. Irrigation schedules had significant effect on growth and yield attributes. Crop raised with 1.2 IW: CPE schedule produced significantly higher processed turmeric yield than 0.6, 0.8 and 1.0 IW: CPE schedules (Table 4). Irrigation application at more frequent scheduling at 1.2 IW: CPE kept soil moist and enhance nutrient availability to crop and resulted in significantly higher yield of turmeric than other schedules. Singte *et al.* (1997) [31] at Maharashtra reported that higher number of tillers/plant and yield of turmeric in 100% evaporation replenishment treatment than 80% and 60% evaporation replenishment treatment. Curcumin and oil content did not differ significantly with different irrigation schedules (Table 6). 1.2 IW: CPE schedule gave significantly higher oil and curcumin yield than other irrigation schedules.

Interactive effects

Interaction between methods of irrigation and irrigation schedules was significant for dry matter accumulation at 60 and 120 DAP (Table 3). The data revealed that the maximum dry matter accumulation was observed in crop irrigated with drip irrigation at 1.2 IW: CPE schedule, which was statistically at par with drip irrigation at 1.0 IW: CPE schedule but significantly better than all other combination of method of irrigation and irrigation schedules. It is worth to mention here that crop irrigated with check basin method at 1.2 IW: CPE schedule gave statistically at par dry matter accumulation to that irrigated with drip at 0.6 IW: CPE schedule. Thus, drip irrigation gave statistically at par dry matter accumulation at 120 DAP in 1st year. In 2nd year crop irrigated with check basin at 1.2 IW: CPE schedule gave statistically at par dry matter accumulation to that irrigated with drip at 0.8 IW: CPE schedule. Similar trend observed in pooled data at 120 DAP; and 2nd year and pooled data at 60 DAP.

Interaction between irrigation methods and irrigation schedules was significant for processed yield of turmeric (Table 5). Drip irrigation at 1.2 IW: CPE schedule gave maximum processed yield of turmeric, which was at par with drip irrigation at 1.0 IW: CPE but significantly better than all other combinations of methods of irrigation and irrigation schedule in both years. Drip irrigation at 1.2 IW: CPE provided frequent and site specific moisture near the root zone of plant and produced more leaf area index and higher dry matter accumulation. Drip irrigation at 1.2 IW: CPE schedule gave maximum curcumin and oil yield of turmeric, which was at par with drip irrigation at 1.0 IW: CPE but significantly better than all other combinations of methods of irrigation and irrigation schedule (Table 7).

Table 3: Interactive effects of irrigation methods and irrigation schedules on dry matter accumulation (g/m^2) by turmeric crop

Irrigation schedules	60 days after planting			
	Irrigation methods			
	2014		Pooled	
	Check basin	Drip	Check basin	Drip
0.6 IW: CPE	21.1	31.0	22.4	32.2
0.8 IW: CPE	23.8	32.9	24.9	33.8
1.0 IW: CPE	32.0	35.9	33.4	36.8
1.2 IW: CPE	35.6	39.5	36.3	40.2
CD (p=0.05)	2.1		2.6	

120 days after planting						
Irrigation schedules	2013		2014		Pooled	
0.6 IW: CPE	136.2	224.2	120.6	210.0	128.4	217.1
0.8 IW: CPE	181.8	242.5	165.3	230.7	173.5	236.6
1.0 IW: CPE	216.9	270.8	198.1	250.0	207.5	260.4
1.2 IW: CPE	242.5	286.1	227.8	267.9	235.1	277.0
CD (p=0.05)	22.4		12.7		12.6	

Table 5: Interactive effects of irrigation methods and irrigation schedules on processed yield (q/ha) of turmeric

Processed Yield (q/ha)						
Irrigation schedules	Irrigation methods					
	2013		2014		Pooled	
	Check basin	Drip	Check basin	Drip	Check basin	Drip
31.7	35.5		27.6	29.5	29.7	32.5
0.8 IW: CPE	32.5	47.9	27.7	42.2	30.1	45.1
1.0 IW: CPE	36.8	54.3	32.6	48.5	34.7	51.4
1.2 IW: CPE	43.1	56.7	40.9	53.0	42.0	54.9
CD (p=0.05)	4.8		5.7		3.6	

Table 7: Interactive effects of irrigation methods and irrigation schedules on Curcumin yield (kg/ha) and Oil yield (l/ha) of turmeric

Irrigation schedules	Irrigation methods			
	Pooled			
	Check basin		Drip	
0.6 IW:CPE	69.1		78.3	
0.8 IW:CPE	72.7		115.3	
1.0 IW:CPE	82.0		131.1	
1.2 IW:CPE	103.7		141.4	
CD (p=0.05)	16.3			
Oil yield (l/ha)				
Irrigation schedules	2013		Pooled	
0.6 IW:CPE	183.0	209.2	141.1	168.3
0.8 IW:CPE	194.4	293.4	161.8	236.8
1.0 IW:CPE	228.5	339.8	179.5	271.7
1.2 IW:CPE	281.2	361.4	223.6	300.9
CD (p=0.05)	40.9		30.5	

Discussion

The positive effect of straw mulch application on leaf area index and dry matter accumulation resulted early achieving of uniform crop stand than no mulch plots. The higher leaf area Index and dry matter accumulation realization in mulched plots resulted from quick emergence because of favourable moisture and temperature conditions, which ultimately resulted in higher processed turmeric yield. Vanlalhluna and Sahoo (2010) [34] reported that early emergence in mulched plot resulted from favourable temperature and moisture retention conditions, because mulch application conserves soil moisture through reduced evaporation by offering resistance to water flow from soil surface to atmosphere. Sidhu (1992) [29] also observed beneficial effects of mulch on early sprouting of turmeric, which resulted in early and better emergence count than no mulch. The higher plant growth parameter observed under drip irrigated crop resulted from favourable soil moisture conditions because of application of frequent and light irrigation beneath the root zone. Lesser leaf area index in check basin might be resulted from less frequent irrigation application at longer interval. The growth and yield attributes of turmeric were significantly higher in drip irrigated crop as compared to check basin because of favourable moisture regimes. Drip irrigation has beneficial effect through providing light and frequent irrigation near the root zone of plant, reduces evaporation and weed growth.

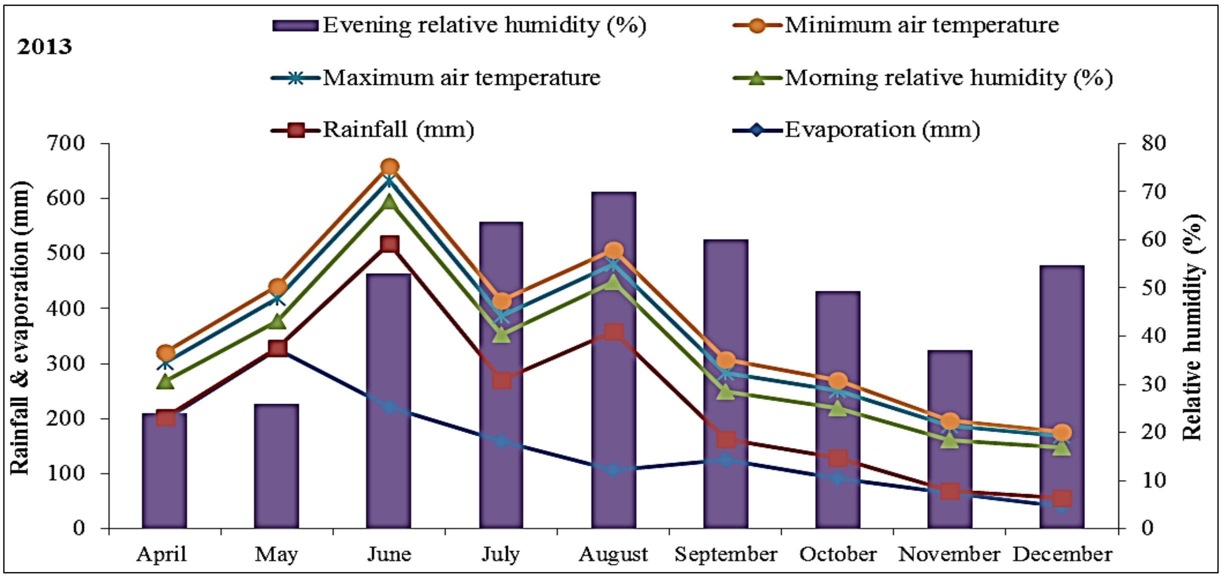

Fig 1: Meteorological data recorded during 2013 and 2014 at the experimental site

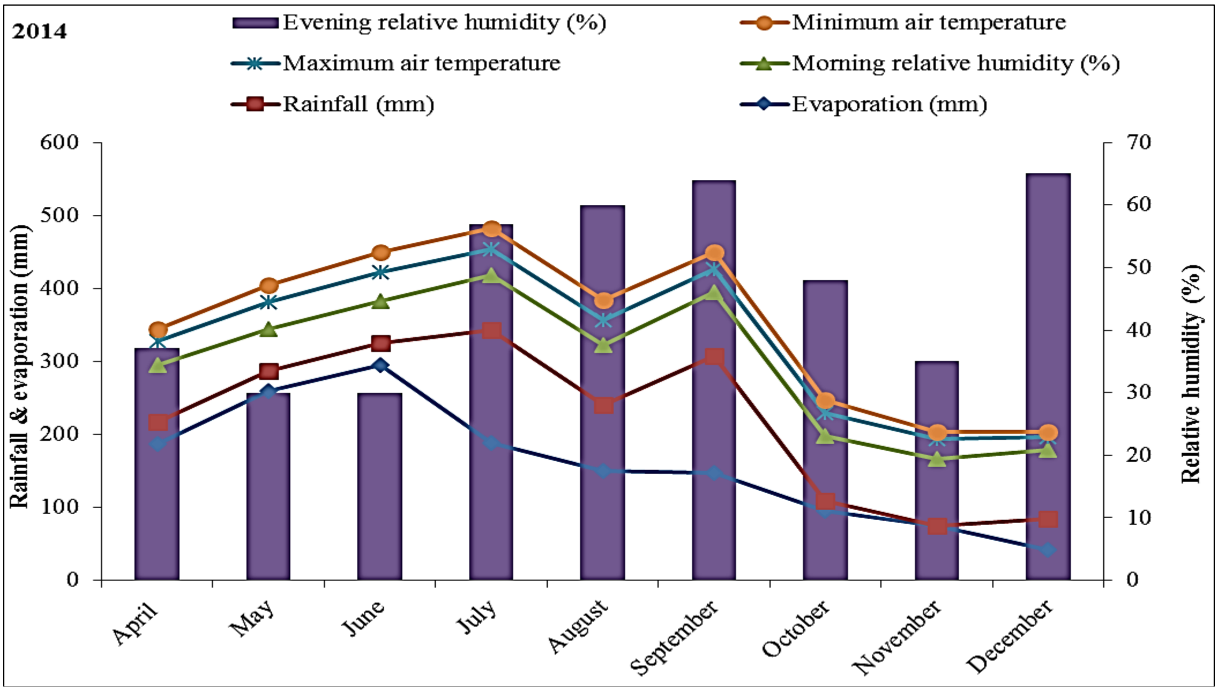

Fig 2: Effect of method of irrigation and mulch levels on production functions of turmeric (pooled mean of 2013 and 2014)

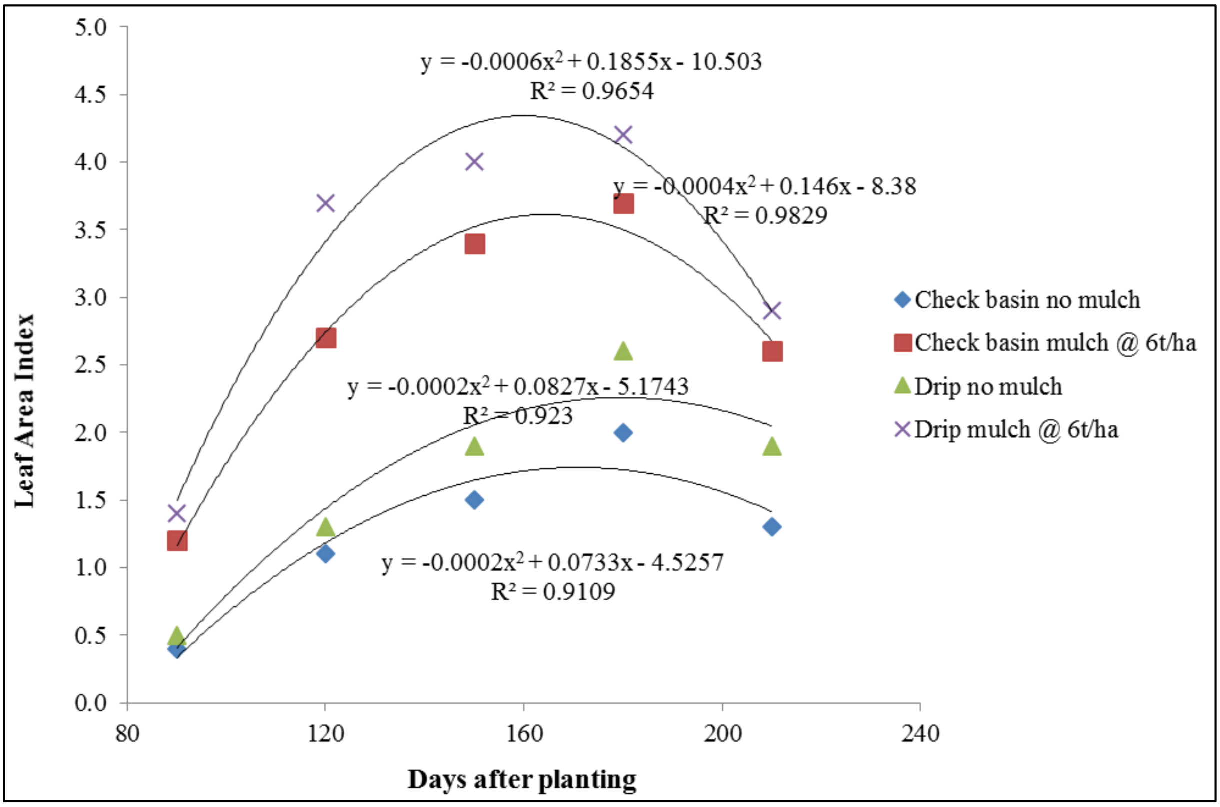

Fig 3: Effect of method of irrigation and mulch levels on production functions of turmeric (pooled mean of 2013 and 2014

Conclusion

Application of straw mulch resulted in significantly higher curcumin and oil yield as compared to no mulch treatment. Drip irrigation resulted in 41.1, 42.2 and 43.2; and 35.7, 43.1 and 38.5 per cent higher curcumin and oil yield than check basin, respectively, in 1st, 2nd year and as well as pooled data. Crop raised with 1.2 IW: CPE schedule produced significantly higher growth and yield attributes than 0.6, 0.8 and 1.0 IW: CPE schedules. Drip irrigation at 1.2 IW: CPE schedule gave maximum curcumin and oil yield, which was at par with drip irrigation at 1.0 IW: CPE but significantly better than all other combinations of methods of irrigation and irrigation schedule. Curcumin and oil content did not differ significantly with application of mulch, irrigation methods and irrigation schedules.

References

1. Aggarwal BB, Kumar A, Bharti AC. Anticancer potential of curcumin: Preclinical and clinical studies. Anticancer Res. 2003; 23(1A):363-368.
2. Ammon HPT, Wahl MA. Pharmacology of *Curcuma longa*. Planta Med. 1991; 57:1-7.
3. Ammon HPT, Anazodo MI, Safayhi H, Dhawan BN, Srimal RC. Curcumin: a potent inhibitor of leukotriene

B4 formation in rat peritoneal polymorphonuclear neutrophils (PMNL). Planta Med. 1992; 58:26.
4. Anonymous. Area and production of turmeric in India, 2014. (http//www.indiastat.com)
5. Barrero MM, Carreno RJ. Histochemical evaluation of turmeric rhizomes grown in Venezuela. Agron Trop Maracay. 1999; 49:349-359.
6. Chela KS, Brar JS. You can also grow turmeric. Prog Farm. 1976; 12:24.
7. Cohly HHP, Asad Das SK, Angel MF, Rao M. Effect of antioxidant (Turmeric, Turmerin and Curcumin) on human immune deficiency viruses. Int J Mol Sci. 2003; 4:22-23.
8. Eigner D, Scholz D. Ferula asa-foetida and *Curcuma longa* in traditional medicinal treatment and diet in Nepal. J Ethnopharmacol. 1999; 67:1-6.
9. El-Hendawy SE, El-Lattief EA, Ahmed AS, Schmidhalter U. Irrigation rate and plant density effects on yield and water use efficiency of drip irrigated corn. Agric Water Manage. 2008; 95:836-844.
10. Gupta RD, Mahajan G, Goel BR. Availability and quality of ground water in Punjab state. Proceeding of Symposium on Water Management, Punjab Agricultural University, and Ludhiana, 1995, 18-42.
11. Jalota SK, Prihar SS. Reducing soil water evaporation with tillage and mulching. Iowa State University Press, Ames. 1998; IA:142.
12. Junior MA, Borella JC, Franca SC, Masca MGCC. Effects of type of rhizome used to proliferation and mulching on growth and productivity of turmeric (*Curcuma longa* L.). Revista Brasileira- de- plantas medicinais. 2005, 2006; 8:30-34. (Original not seen. Abstr. In CAB Abstracts, AN20063014434).
13. Kapoor LD. Handbook of Ayurvedic Medicinal Plants, CRC Press, Boca Raton, Florida, 1990, 185.
14. Kay BL. Mulch and chemical stabilizers for land reclamation in dry regions. In F.W. Schaller and P. Sutten, editors. Reclamation of Drastically Disturbed Lands. American Society of Agronomy, Madison WI, 1978; 467-483.
15. Khanna NM. Turmeric-Nature’s precious gift. Curr Sci, 1999; 76:1351-1356.
16. Kumar D, Pandey V, Nath V. Effect of organic mulches on moisture conservation for rainfed turmeric production in mango orchard. Indian J Soil Cons, 2008; 36:188-191.
17. Kuttan R, Bhanumathy P, Nirmala K, George MC. Potential anticancer activity of turmeric (*Curcuma longa* L.). Cancer Lett. 1985; 29:197-202.
18. Leskovan P. Medicament for dissolving urinary calculus. Chem. Abstract 83590q, 1983.
19. Maheshwari RK, Singh AK, Gaddipatti J, Srimal RC. Multiple biological activities of cucumin: A short review. Life Sci. 2006; 78:2081-2087.
20. Manhas SS, Gill BS, Khajuria V, Kumar S. Effect of planting material, mulch and farmyard manure on growth, yield and quality of turmeric (*Curcuma longa* L.). Indian J Agron. 2011; 56(4):393-399.
21. Mani H, Sidhu GS, Kumari R, Gaddipatti JP, Maheshwari RK. Curcumin differentially egulates TGF-β1, its receptors and nitric oxide synthase during impaired wound healing. Bio Factors. 2002; 16:29-43.
22. Munshower FF. Pracitical Handbook of Disturbed Land Revegetation. Lewis Publishers, Boca Raton. FL, 1994.
23. Philip J, Sethumadhavan P, Vidhyadharan KK. Turmeric cultivation- an appraisal of agronomic practices. Indian Farmer Dig. 1981; 14:19-21.
24. Ramah K. Study on drip fertigation in maize based cropping system. Ph.D. Dissertation, Tamil Nadu Agricultural University, Coimbatore, 2008.
25. Rimpler H, Hansel R, Kochendoerfer L. Xan- thorrhizol, ein neues sesquiterpene aus Curcuma xanthorrhiza. Z. Naturforsch. 1970; 256:995.
26. Sammis TW. Yield of alfalfa and cotton as influenced by irrigation. Agronomy J. 1981; 73:323-329.
27. Sanwal SK, Laxminarayan K, Yadav RK, Rai N, Yadav DS, Bhuyan M. Effect of organic manures on soil fertility, growth, physiology, yield and quality of turmeric. Indian J Hort. 2007; 64:444-449.
28. Sastry BS. Curcumin content of turmeric. Res Industry. 1970; 15:258-260.
29. Sidhu SS. The effect of partial shading on growth and yield of turmeric. M. Sc. thesis, Punjab Agricultural University, Ludhiana, India, 1992.
30. Singh J, Randhawa GS. Effect of intercropping on yield and quality of turmeric. Acta Hort. 1988; 18:183-186.
31. Singte MB, Yamger VT, Kathmale DK, Gaikwad DT. Growth, productivity and water use of turmeric (*Curcuma longa* L.) under drip irrigation. Indian J Agron. 1997; 42:547-549.
32. Swain SC, Rath S, Ray DP. Effect of NPK levels and mulching on growth, yield and economics of turmeric in rainfed uplands. The Orissa J Hort. 2007; 35:58-60.
33. Thimmaiah SK. Standard Methods of Biochemical Analysis. Kalyani Publishers, 1999, 307-308.
34. Vanlalhluna PC, Sahoo UK, Lalremruati JH. Relative efficacy of different mulch types on soil moisture conservation and performance of rainfed turmeric in an agroforestry system of Mizoram. Range Manage Agroforestry. 2010; 31(1):31-35.
35. Verma A, Sarnaik DA. Effect of different types of mulches on growth and yield of turmeric (*Curcuma longa* L.). Int J Agric Sci. 2006; 2:425-426.