Journal of Spices and Aromatic Crops
Vol. 19 (1 & 2) : 42–49 (2010)

Indian Society for Spices

Growth, yield and quality of turmeric (*Curcuma longa* L.) as influenced by planting method, plant density and planting material

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Received 19 July 2009; Revised 5 May 2010; Accepted 26 August 2010

Abstract

A study was carried out at Ludhiana (Punjab) to evaluate the effect of planting method, plant density and planting material on growth, yield and quality of turmeric (*Curcuma longa*). The experiment consisted of two planting methods (flat and ridge), three plant densities (1,66,667; 1,11,111 and 83,333 plants ha^{-1}) and three types of planting material (mother, primary and secondary rhizomes). Fresh rhizome yield of 164.8 and 160.3 q ha^{-1} (pooled data) was produced in flat and ridge method of planting but the differences were non-significant. Closer plant spacing or higher plant density produced highest fresh, dry and processed turmeric yield and it decreased with decrease in plant density; whereas, number and weight of rhizomes increased with decrease in plant density. Use of mother rhizome as planting material resulted in better emergence (86.6% and 83.1%), taller plants (49.6 and 50.0 cm) with more number of leaves and leaf area index (4.4 and 3.8), more tillers $plant^{-1}$ (2.7 and 3.1), higher number (17.09 and 23.89) and weight (136.96 and 227.66 g) of total rhizomes $plant^{-1}$ as compared to use of primary and secondary fingers as planting material during 2003-04 and 2004-05, respectively. Planting of mother rhizomes produced highest fresh (207.7 q ha^{-1}), dry (46.0 q ha^{-1}) and processed (44.1 q ha^{-1}) turmeric yield and it decreased significantly with decrease in seed size. Curcumin content did not change due to different planting methods, plant densities and planting materials.

Keywords: *Curcuma longa*, growth, planting material, planting method, plant density, turmeric, yield, quality.

Introduction

Turmeric (*Curcuma longa* L.) offers good scope in diversification of cereal based cropping system in Punjab. Increased cultivation of turmeric in the state will help not only to meet its own requirements but also help the country to boost its export. Planting method is a soil management tool which affects plant growth and yield (Chattopadhayay *et al.* 1993). Gill *et al.* (2002) reported that plant height, number of leaves $plant^{-1}$, tillers $plant^{-1}$,

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number and weight of rhizome and fresh rhizome yield was significantly higher in ridge than flat planting method at Ludhiana (Punjab). Optimum plant density of a crop varies considerably depending upon climatic conditions of the growing area and fertility status of the soil. Plant distance is an important factor for higher production and gives equal opportunity to the plants for their survival and best use of other inputs. The full yield potential of an individual plant is achieved when sown at wider spacing, whereas yield per unit area is maximum when individual plants are subjected to severe competition (Holliday 1960). Kaur (2001) reported non-significant effect of two spacings (60 cm x 10 cm and 60 cm x 15 cm) on growth, yield and quality characters of turmeric at Ludhiana. Turmeric is propagated vegetatively using both mother as well as finger rhizomes. The type and weight of planting material used affects the vigour of the plant and crop yield per unit area as well as the cost of production (Philip 1985). Randhawa & Mishra (1974) while studying the effect of seed size in turmeric reported that large sized rhizome weighing approximately 100 g gave significantly higher yield (61 q ha^{-1}) than small sized rhizomes (53.3 q ha^{-1}) of 50 g weight. The present study was hence planned to study the effect of plant density and planting material on growth, yield and quality of flat and ridge planted turmeric.

Materials and methods

The investigation was carried out at Students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (Punjab) during 2003-04 and 2004-05. The experiment was carried out in a randomized block design (factorial) with four replications on loamy sand soil, with normal pH (8.0) and EC (dS/m at 25^0C), low in organic carbon (0.23 %) and available nitrogen (210 kg ha^{-1}), medium in available phosphorus (17 kg ha^{-1}) and potash (207 kg ha^{-1}). The treatments constituted of two planting methods (flat and ridge), three plant densities (1,66,667 plants ha^{-1}; 1,11,111 plants ha^{1} and 83,333 plants ha^{-1}) and three types of planting materials (mother rhizome 25-30 g, primary finger rhizome 15-20 g and secondary finger rhizome 5-10 g). For plant density of 1,66,667 plants ha^{-1}, the crop was sown at 60 cm x 10 cm in ridge planting method and at 30 cm x 20 cm in flat planting method; for plant density of 1,11,111 plants ha^{-1}, the crop was sown at 60 cm x 15 cm in ridge planting method and at 30 cm x 30 cm in flat planting method and in plant density of 83,333 plants ha^{-1}, the crop was sown at 60 cm x 20 cm in ridge planting method and at 30 cm x 40 cm in flat planting method. PCT-8 variety of turmeric was sown on May 7 during both the years; 30 t ha^{-1} farmyard manure was thoroughly mixed at the time of seed bed preparation. Nitrogen @ 30 kg ha^{-1} was applied after emergence of the crop. To keep the weeds under check, pendimethalin @ 2.5 l ha^{-1} was sprayed 3 days after planting and four hand weedings were also given. After hoeing (last two), earthing up was done in ridge planting treatment. The crop was harvested during the third week of January. The essential oil content (% V/W) in turmeric was determined using Clevenger's apparatus in which 25 g of turmeric powder was distilled for 4.5 h and the amount of essential oil was measured. The curcumin content was determined by the method of Thimmaiah (1999).

Results and discussion

Plant emergence was significantly higher in flat planting method than ridge planting method during both the years (Table 1). Plant height was significantly higher in flat planting during 2003-04 though the differences were not significant during 2004-05 (Table 1). The effect of different planting methods on tillers $plant^{-1}$, leaf area index (at 200-210 days after planting) and number as well as weight of mother, primary and secondary rhizomes $plant^{-1}$ was non-significant (Tables 1, 2 & 3).

The differences in fresh, dry and processed rhizome yield of turmeric (pooled data) due to different planting methods were not significant. Fresh rhizome yields of 164.8 and 160.3 q ha^{-1} were recorded in flat and ridge planting methods, respectively. Dry and

Table 1. Effect of planting methods, plant densities and planting materials on plant emergence*, plant height, tillers plant^{-1} and leaf area index of turmeric

Treatment	2003-04				2004-05			
	Plant emergence* (%)	Plant height (cm)	Tillers plant^{-1}	Leaf area index	Plant emergence (%)	Plant height (cm)	Tillers plant^{-1}	Leaf area index
Planting method								
Flat	88.1	46.0	2.4	3.7	86.4	42.6	2.7	3.0
Ridge	80.0	43.3	2.3	3.6	74.3	43.5	2.8	3.1
SEm±	1.45	0.75	0.08	0.12	1.65	1.24	0.07	0.11
CD (P=0.05)	4.1	2.1	NS	NS	4.7	NS	NS	NS
Plant density (plants ha^{-1})								
1,66,667	80.7	48.4	2.3	4.2	77.8	47.1	2.6	4.2
1,11,111	85.9	44.5	2.3	3.2	80.3	42.1	2.8	2.7
83,333	84.1	40.9	2.4	2.4	77.6	39.9	2.8	2.2
SEm±	1.77	0.92	0.09	0.14	2.02	1.52	0.09	0.14
CD (P=0.05)	NS	2.6	NS	0.4	NS	4.3	NS	0.4
Planting material								
Mother rhizome	86.6	49.6	2.7	4.4	83.1	50.0	3.1	3.8
Primary finger	81.3	43.9	2.3	3.6	80.3	43.4	2.7	3.2
Secondary finger	82.9	40.4	2.1	2.9	78.0	36.0	2.4	2.2
SEm±	1.77	0.92	0.09	0.14	2.02	1.52	0.09	0.14
CD (P=0.05)	NS	2.6	0.3	0.4	NS	4.3	0.3	0.4

* Transformed data; Interactions: NS

processed turmeric yields were 36.4 and 35.2 q ha^{-1} in flat method and 35.1 and 33.7 q ha^{-1} in ridge planting method when the 2 year data was pooled (Table 4). Similar results were observed during 2004-05 in fresh, dry and processed yield though the differences were not significant. Flat planting method produced significantly higher fresh, dry and processed turmeric yield than ridge method during 2003-04 (Table 4). The non-significant differences in turmeric yield due to different planting methods might probably be attributed due to non-significant differences in growth and yield attributing characters. Planting methods might have failed to exert any influence on growth and yield attributing characters due to light nature of soil having low organic carbon content and available nitrogen. Ramachandran & Muthuswami (1984) while studying different planting methods (ridge and furrow, flat bed and broad ridge method) reported non-significant differences in yield of turmeric. The oil and curcumin contents in turmeric were not affected by planting methods (Table 5). Similar results were also reported by Singh (1983).

Plant density did not influence plant emergence in the experiment. Higher plant density or closer plant spacing produced significantly taller plants than wider plant spacing but tillers plant^{-1} tend to decrease in closer plant spacing though the differences were not significant (Table 1). Leaf area index (LAI) was maximum in closer plant spacing and it decreased significantly in wider plant spacing (Table 1). The effect of plant spacing or density on the number of mother, primary, secondary and total rhizomes plant^{-1} were significant during 2004-05 (Table 2). Increase in plant spacing increased the mother, primary and secondary rhizomes plant^{-1}. A similar trend was observed during 2003-04 though the differences were not significant.

Table 2. Effect of planting methods, plant densities and planting materials on yield of rhizomes in turmeric

Treatment	Number of rhizomes plant^{-1}							
	2003-04				2004-05			
	Mother	Primary	Secondary	Total	Mother	Primary	Secondary	Total
Planting method								
Flat	2.72	7.84	5.34	15.90	3.41	9.68	7.99	21.08
Ridge	2.70	7.60	5.11	15.41	3.30	10.13	7.72	21.15
SEm±	0.08	0.21	0.28	0.45	0.09	0.27	0.23	0.45
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Plant density (plants ha^{-1})								
1,66,667	2.60	7.51	4.72	14.83	3.07	8.96	7.00	19.03
1,11,111	2.80	7.55	5.36	15.71	3.46	10.06	8.02	21.54
83,333	2.70	7.60	5.69	15.99	3.54	10.70	8.53	22.77
SEm±	0.09	0.26	0.34	0.56	0.11	0.34	0.29	0.55
CD (P=0.05)	NS	NS	NS	NS	0.32	0.92	0.81	1.57
Planting material								
Mother rhizome	3.23	8.02	5.84	17.09	3.74	11.43	8.72	23.89
Primary finger	2.50	7.56	5.33	15.39	3.41	10.44	7.88	21.73
Secondary finger	2.35	7.07	4.50	13.92	2.91	7.86	6.96	17.73
SEm±	0.09	0.26	0.34	0.56	0.11	0.34	0.29	0.55
CD (P=0.05)	0.28	0.72	0.96	1.57	0.32	0.92	0.81	1.57

Interactions: NS

Table 3. Effect of planting methods, plant densities and planting materials on weight of rhizomes in turmeric

Treatment	Weight of rhizomes (g)							
	2003-04				2004-05			
	Mother	Primary	Secondary	Total	Mother	Primary	Secondary	Total
Planting method								
Flat	53.93	42.84	9.74	106.51	80.95	87.15	20.82	188.92
Ridge	52.44	44.47	8.06	104.97	83.10	89.80	18.45	191.35
SEm±	1.26	1.75	0.53	3.73	2.05	2.89	1.08	5.34
CD (P=0.05)	NS	NS	1.21	NS	NS	NS	NS	NS
Plant density (plants ha^{-1})								
1,66,667	50.87	39.78	7.34	97.99	72.84	75.85	15.79	164.48
1,11,111	51.62	41.77	8.12	101.51	86.56	91.82	20.87	199.25
83,333	57.06	49.42	9.74	116.22	86.87	97.76	22.83	207.46
SEm±	1.55	2.14	0.62	4.57	2.52	3.54	1.32	6.54
CD (P=0.05)	4.40	6.08	1.76	12.98	7.15	10.04	3.74	18.56
Planting material								
Mother rhizome	72.53	54.01	10.42	136.96	102.24	101.09	24.33	227.66
Primary finger	51.88	42.60	8.52	103.00	78.12	89.17	19.49	186.78
Secondary finger	35.15	34.36	6.25	75.76	65.74	75.17	75.68	156.59
SEm±	1.55	2.14	0.62	4.57	2.52	3.54	1.32	6.54
CD (P=0.05)	4.40	6.08	1.76	12.98	7.15	10.04	3.74	18.56

Interactions: NS

Table 4. Effect of planting methods, plant densities and planting materials on fresh, dry and processed yield of turmeric

Treatment	2003-04			2004-05			Mean of two years		
	Fresh rhizome yield (q ha^{-1})	Dry rhizome yield (q ha^{-1})	Processed rhizome yield (q ha^{-1})	Fresh rhizome yield (q ha^{-1})	Dry rhizome yield (q ha^{-1})	Processed rhizome yield (q ha^{-1})	Fresh rhizome yield (q ha^{-1})	Dry rhizome yield (q ha^{-1})	Processed rhizome yield (q ha^{-1})
Planting method									
Flat	158.9	38.0	36.9	170.7	34.7	33.4	164.8	36.4	35.2
Ridge	149.6	35.3	34.0	171.0	34.9	33.4	160.3	35.1	33.7
SEm±	3.17	0.88	0.88	5.73	1.26	1.23	3.68	0.89	0.86
CD (P=0.05)	9.0	2.5	2.5	NS	NS	NS	NS	NS	NS
Plant density (plants ha^{-1})									
1,66,667	189.0	46.2	44.3	207.7	42.6	40.8	198.3	44.4	42.5
1,11,111	145.2	34.7	34.3	167.1	34.2	32.6	156.2	34.5	33.4
83,333	128.4	29.2	27.9	137.7	27.7	26.7	133.1	28.4	27.3
SEm±	3.88	1.07	1.08	7.01	1.54	1.50	4.51	1.09	1.06
CD (P=0.05)	11.0	3.0	3.1	19.9	4.4	4.3	12.7	3.1	3.0
Planting material									
Mother rhizome	199.2	48.2	46.4	216.2	43.7	41.8	207.7	46.0	44.1
Primary finger	153.7	36.3	35.5	169.7	34.4	32.9	161.7	35.4	34.2
Secondary finger	109.8	25.5	24.5	126.6	26.4	25.4	118.0	26.0	25.0
SEm±	3.88	1.07	1.08	7.01	1.54	1.50	4.51	1.09	1.06
CD (P=0.05)	11.00	3.0	3.1	19.9	4.4	4.3	12.7	3.1	3.0

Interactions: NS

Chattopadhay *et al.* (1993) reported that plant spacing of 30 cm x 20 cm gave significantly more (17.1) fingers plant^{-1} in turmeric than plant spacing of 20 cm x 15 cm (10.40) at Cooch Behar, West Bengal. Rashid *et al.* (1996) at Barisal (Bangladesh) and Shashidhar & Sulikeri (1996) at Dharwad (Karnataka) also reported similar findings. The effect of plant density on weight of mother, primary and secondary rhizomes was significant. Increase in plant spacing increased the weight of mother, primary and secondary rhizomes during both the years (Table 3).

Increase in plant density increased the fresh, dry and processed yields of turmeric significantly (Table 4). A fresh rhizome yield (pooled data) of 198.3, 156.2 and 133.1 q ha^{-1} was recorded in plant population of 1,66,667; 1,11,111 and 83,333 plants ha^{-1}, respectively. Dry rhizome yield of 44.4, 34.5 and 28.4 q ha^{-1} was recorded in 1,66,667; 1,11,111 and 83,333 plants ha^{-1}, respectively and the differences among these treatments were significant. An increase of 9.9 q ha^{-1} and 16.0 q ha^{-1} with highest plant population was recorded as compared to 1,11,111 and 83,333 plants ha^{-1}, respectively. A similar trend was also observed in processed yield. Processed turmeric yield of 42.5, 33.4 and 27.3 q ha^{-1} was obtained in higher, medium and low level of plant density, respectively and the differences among these treatments were significant. Chattopadhayay

Table 5. Effect planting methods, plant densities and planting materials on oil content and curcumin content of rhizomes

Treatment	2003-04		2004-05	
	Oil content (%)	Curcumin content (%)	Oil content (%)	Curcumin content (%)
Planting method				
Flat	5.84	1.81	7.19	1.91
Ridge	5.73	1.86	6.93	1.79
SEm±	0.08	0.04	0.10	0.05
CD (P=0.05)	NS	NS	NS	NS
Plant density (plants ha^{-1})				
1,66,667	5.76	1.75	7.15	1.79
1,11,111	5.77	1.85	6.90	1.87
83,333	5.83	1.91	7.14	1.9
SEm±	0.10	0.06	0.11	0.06
CD (P=0.05)	NS	NS	NS	NS
Planting material				
Mother rhizome	5.84	1.87	7.43	1.80
Primary finger	5.83	1.82	7.17	1.93
Secondary finger	5.69	1.82	6.58	1.82
SEm±	0.10	0.06	0.11	0.06
CD (P=0.05)	NS	NS	0.32	NS

Interactions: NS

et al. (1993) at Cooch Behar (West Bengal) and Silva *et al.* (2004) at Goiania (Brazil) also obtained higher fresh rhizome yield under closer plant spacing than wider spacing.

Closer plant spacing or higher plant density produced significantly higher turmeric yield than low density of plants. The higher fresh, dry and processed yield of turmeric was mainly due to higher plant population per unit area although the growth and yield attributing characters (number and weight of mother, primary and secondary rhizomes) decreased in higher plant density. The possible reason for obtaining higher yield from closer spacing or higher plant densities is probably because more plants were accommodated per hectare. Although wider spacing had resulted in higher number as well as weight of mother, primary and secondary rhizomes plant^{-1}, apparently due to less plant competition, but higher plant population or density contributed more towards higher yield.

The higher rhizome weight in wider spacing may be due to better nourishment and availability of space, which leads to higher weight of mother, primary and secondary rhizomes. Govind *et al.* (1993) also reported that maximum yield plant^{-1} was recorded in 30 cm x 30 cm spacing and the lowest yield plant^{-1} was recorded in 30 cm x 10 cm at Barapani (Meghalaya). Similar results were also obtained by Singh *et al.* (1988), Rashid *et al.* (1996) and Shashidhar & Sulikeri (1996). The effect of different plant densities on oil content and curcumin content of turmeric was non-significant (Table 5).

Plant emergence in mother rhizome planting material was higher than primary and secondary finger planting material though the differences were not significant (Table 1). Plant height and tillers plant^{-1} were maximum in mother rhizome plant material and both characters decreased significantly with each decrease in plant material size from mother rhizome to primary finger and from primary finger to secondary finger plant material (Table 1). LAI was maximum in mother rhizome plant material and both decreased with each decrease in plant material size (Table 1). Rashid *et al.* (1996) also obtained significantly more number of leaves plant^{-1} in

turmeric with mother rhizome planting (27.2) as compared to primary (23.7) and secondary (23.0) rhizomes, respectively.

Different planting materials had significant effect on the number and weight of mother, primary, secondary as well as total fingers (Tables 2 & 3). Mother rhizome planting material produced plants with maximum number and weight of mother, primary and secondary rhizomes. The number and weight decreased in primary and secondary finger planting material. Tayde & Deshmukh (1986) recorded significantly more number of mother (3.82), primary (14.40) and secondary (13.71) rhizomes with mother rhizome planting as compared to primary (3.08, 10.41 and 11.34) and secondary rhizome (3.26, 7.64 and 9.45) at Maharashtra.

The effect of different planting materials on fresh rhizome yield of turmeric was significant. Use of mother rhizome planting material produced significantly higher fresh rhizome yield than the primary finger rhizome and rhizome yield of primary finger plant material was also significantly superior to secondary finger planting material (Table 4). The mother, primary and secondary finger planting material produced fresh rhizome yield of 199.2, 153.7 and 109.8 q ha^{-1} during 2003-04 and 216.2, 169.7 and 126.6 q ha^{-1} during 2004-05, respectively (Table 4). The use of primary and secondary finger planting material resulted in 22.8% and 44.8% reduction in fresh rhizome yield during the first year and 25.2% and 41.4% during the second year as compared to mother rhizome planting material. A similar trend was observed in pooled analysis of data (Table 4). Decrease in planting material size/weight decreased the fresh rhizome yield of turmeric significantly giving a maximum fresh rhizome yield of 207.7 q ha^{-1} in mother rhizome planting material. The primary and secondary finger planting material produced a fresh rhizome yield of 161.7 and 118.0 q ha^{-1}, respectively.

The effect of different planting materials on dry turmeric yield was significant. With increase in seed size, turmeric rhizome yield increased significantly during both the years. Dry rhizome yields of 48.2, 36.3 and 25.5 q ha^{-1} were produced by planting of mother, primary and secondary fingers during 2003-04 and 43.7, 34.4 and 26.4 q ha^{-1} during 2004-05, respectively (Table 4). The mean data revealed that 46.0, 35.4 and 26.0 q ha^{-1} of dry rhizome yield was produced by planting of mother, primary and secondary rhizomes, respectively (Table 4). A similar trend was also observed in processed yield. Dry turmeric yield was 21.99% of fresh turmeric yield and processed turmeric yield was 21.1% of fresh turmeric yield.

Each increase in plant material size/weight increased the processed rhizome yield significantly. Mother rhizome plant material recorded an increase of 47.0% and 39.2% in processed yield during 2003-04 and 2004-05, respectively, over primary finger rhizomes. Similarly, primary finger rhizomes gave 30.9% and 22.6% higher processed yield than secondary finger rhizomes during the first and second years, respectively. Mother rhizome as planting material produced 76%-77% higher turmeric yield as compared to secondary finger rhizome planting material. Philip (1983) and Meenakshi *et al.* (2001) also recorded significantly higher cured yield of turmeric by planting mother rhizomes.

Essential oil content was higher in mother rhizome plant material and it tend to decrease with decrease in plant material size though the differences were not significant during 2003-04. Curcumin content did not change significantly due to different planting materials (Table 5).

Increased rhizome yield in mother rhizome planting material might be attributed to better crop growth in terms of quick emergence, higher plant height, more leaf area index and tillers $plant^{-1}$ which intercepted more photosynthetically active radiation and resulted in higher values of yield attributing characters which ultimately contributed towards higher yield of the crop. Differences in performance of different sizes of rhizomes can be relied on the source-sink relationship,

as the mother rhizomes constitute a stronger sink than the fingers. Translocation and mobilization of assimilates and nutrients are more in mother rhizome thereby making the mother rhizomes qualitatively and quantitatively superior. Thus, the plants resulting from mother rhizomes are more vigorous and yield better as compared to finger plant material. Significantly higher fresh rhizome yield due to mother rhizome plant material was also recorded by Singh *et al.* (2000) and Alam *et al.* (2003). Philip (1983) recorded significantly higher yield of turmeric (51.62 q ha^{-1}) with whole mother rhizome planting as compared to primary (42.24 q ha^{-1}) and secondary finger rhizomes (39.19 q ha^{-1}), respectively.

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