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Varieties and planting dates affect the growth, yield and quality of turmeric (*Curcuma longa* L.) in mild-tropical environment

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Abstract: The present field experiment was carried out to evaluate the performance of 11 released varieties in three planting dates under mild-tropical climatic conditions at ICAR-RC-NEH Region, Mizoram Centre, Kolasib, Mizoram. The planting of turmeric at last week of April in Mizoram result in better plant growth, higher fresh and dried rhizome yield, and greater curcumin content. Any delay in planting significantly affects the yield as well as quality of rhizomes. The fresh rhizome yield was harvested highest in Megha Turmeric-1 and Duggirala (430 q/ ha) followed by IISR Pratibha (400 q/ ha) and Roma (396 q/ ha). Further, dry matter yield potential was maximum in Duggirala (118.2 q/ ha) followed by Roma (114.0 q/ ha), IISR Pratibha (112.7 q/ ha) and Megha Turmeric-1 (105.7 q/ ha). The most promising quality trait, curcumin content was analysed to be higher in Megha Turmeric-1 (7.09%) followed by IISR Allepy Supreme (6.16%), Rajendra Sonia (6.16%), IISR Pratibha (6.03%) and Roma (5.98%). In conclusion, four varieties such as Megha Turmeric-1, Duggirala, IISR Pratibha and Roma were excelled with respect to better plant growth, enhanced fresh rhizome yield and dry matter yield, and higher curcumin content.

Keywords: Turmeric (*Curcuma longa*), planting date, curcumin, split plot design (SPD).

Introduction

Turmeric (*Curcuma longa* L.), a rhizomatous herbaceous plant of the Zingiberaceae family, is usually used as a spice, cosmetic, coloring agent, flavourant and preservative, and also ascribed universally to its aromatic, stimulative and carminative properties. Commercially, it is traded as a spice, dye, oleoresin and source of industrial starch. It is an ancient spice and being used dates back nearly 4000 years to the Vedic culture in India as a culinary spice and dye, and had a wide range of spiritual significance of Hindu religion. India is the largest producer, consumer and exporter of turmeric that accounts about 80%, 90% and 60% share, respectively of the world's total (Anonymous 2012). In India, Andhra Pradesh, Tamil Nadu, Orissa, Karnataka, West Bengal, Gujarat, Maharashtra, Assam and Meghalaya are some of the important states cultivates turmeric extensively.

The distinctive yellow-orange curcuminoids (curcumin, demethoxycurcumin and bisdemethoxycurcumin) found in the rhizomes are basic bioactive substances for its virtue. Recently, it has attracted much attention due to its significant medicinal potential. Turmeric has been reported to possess anti-inflammatory, hepatoprotective, antitumor, antiviral and anticancerous properties, and used in treating gastrointestinal and respiratory disorders (Polasa *et al*. 1991, and Anwarul *et al*. 2006). Curcuminoids exhibit free-radicals scavenging properties, i.e. antioxidant activity (Ammon *et al*. 1993, Selvam *et al*. 1995, and Masuda *et al*. 1999), and act as inhibitors of human immune deficiency virus type 1 (HIV-1) integrase (Mazumder *et al*. 1995). Turmeric oil is composed of several monoterpene and sesquiterpene compounds such as zingiberene, ar-turmerone, α-turmerone and β-turmerone (Apisariyakul *et al*. 1995). The main biological activities of the oil are carminative, antiflatulence, antifungal and as an antiplatelet agent. Free radicals were a major interest for early physicists and radiologists; and much later, the free radicals were found to be a product of normal as well as stress metabolism. Today, it is well known that the free radicals cause molecular transformations and gene mutations in many types of organisms. Recent data also suggest that curcumin and other antioxidant products from the dried

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rhizome may be useful in the prevention or treatment of some age-related degenerative processes (Miquel *et al*. 2002).

The use and demand of turmeric is spreading worldwide, hence production of turmeric rich in curcuminoid content, especially curcumin, must be promoted to meet out the domestic and international demand by increase in both the area of cultivation and the productivity per unit area. In order to introduce turmeric cultivation into non-traditional areas, cultivars that are adapted to specific agro-climates and give high yields need to be identified. The geo-climatic conditions of North-eastern states of India, especially Assam, Meghalaya and Mizoram, favour the existence of a wide genetic variability of turmeric as well as higher accumulation of curcumin in their rhizomes (Singh et al. 2013 a, Singh et al. 2013 b). Although the North-eastern regions possess one of the best agro-climatic conditions for production of quality turmeric, yet the potential of turmeric production yet to be realize. Therefore, the present study was undertaken to evaluate the performance of 11 released varieties under three planting dates on plant growth, yield and curcumin content in mild-tropical climatic conditions of Mizoram.

Materials and Methods

The field experiment was carried out at the Research Farm, ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram during 2008-09. The experimental Farm lies at 24º12' N latitude and 92º40' E longitude with an altitude of 650 m above mean sea level, and has a mild-tropical climate. Following was the range of variation for monthly mean temperature and monthly mean relative humidity (RH) during the crop growth period (April-January), Tmin-max 15.6-31.4 ºC and RH 50.7-90.9 %. Cumulative rainfall during the growth period was 2190 mm (86 rainy days) which was ranged from 0-665 mm/ month (0-20 days/ month). The soil type is an Alfisol and acidic in nature (pH 5.8). The plot size was kept as 3×1 m in terraced bed. Thirty seed-rhizomes were planted in each plot at the spacing of 33×30 cm. The experiment was laid-out in split plot design (SPD) with three replications. The experiment comprised 11 released varieties (Megha Turmeric-1, Suranjana, Narendra Haldi-1, IISR Allepy Supreme, IISR Kedaram, IISR Pratibha, Duggirala, BSR-2, Rajendra Sonia, Rasmi and Roma) in the main-plots, and three planting dates each at 15 days interval (8th April, 22nd April and 6th May 2008) in the sub-plots. The uniform dose of FYM @ 5.0 t/ ha and lime @ 2 t/ ha was applied at last tilling. The fertilizers such as N:P_2O_5:K_2O @ 80:60:40 kg/ ha were supplied by urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. The half dose of N, and full dose of P_2O_5 and K_2O was applied as basal at final plot dressing; and rest half N was top dressed in standing crop at 90 days after planting.

The growth parameters like shoot length, leaf length, leaf width, leaf area, shoot thickness near base and numbers of tillers/ plant were taken after 120 days after planting. The observations pertaining to growth parameters were recorded on 15 randomly chosen plants in each plot. Third leaf from top was chosen to measure the leaf length, leaf width and leaf area. Days to maturity was counted at 50 % neck fall stage. The rhizomes were dug out at maturity, physically cured by keeping under ventilated-shade for a week and finally weighed to determine rhizome weight/ plant and yield (q/ ha). The cleaned rhizomes were cured by boiling and sun drying. The rhizomes boiled in galvanized iron vessel having water just enough to soak. Boiling was stopped when froth comes out and white fumes appear, and rhizomes soften. It took around 50-60 minutes. Thereafter, the boiled rhizomes were sun dried by spreading on threshing/ drying floor during day for 10-15 days. The curcumin content in turmeric powder was estimated by following the ASTA method (ASTA 1997). The mean data were subjected to analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) using IRRISTAT software (Version 3/93, Biometrics Unit, International Rice Research Institute, Manila, Philippines) to identify homogeneity of data between various combinations.

Results and Discussion

The mean square estimates were partitioned into main-plot [varieties (V)], sub-plot [planting dates (P)], interaction between V×P and their errors (Table 1). Highly significant mean squares of varieties and planting dates for all the traits studied (Shoot length, leaf length, leaf width, leaf area, shoot thickness, numbers of tillers/ plant, days to maturity, rhizome weight, yield, dry matter content, dry matter yield and curcumin content) indicate that genetic architecture of varieties and various planting dates affecting the plant growth, yield and curcumin accumulation of turmeric. In addition, varieties also interacted with planting dates (having difference of 30 days) significantly for shoot length, shoot thickness, rhizome weight, yield and dry matter yield. Ishimine *et al*. (2004) found significant effects of planting dates on rhizome yield.

The leaf length, leaf breadth, shoot thickness, number of tillers/ plant and rhizome weight/ plant were estimated maximum when planting was done on 22nd April (last

Table 1: Response of varieties to different date of sowing on plant growth, maturity and rhizome yield of various varieties of turmeric

Variety/ date of planting	Leaf length (cm)	Leaf breadth (cm)	Shoot thickness (mm)	No. of tillers/ plant	Days to maturity	Rhizome weight (g/plant)
Megha Turmeric-1	52.9	14.5	21.2	4.9	233.0	516.3
Suranjana	36.9	11.0	15.9	3.8	213.6	393.2
Narendra Haldi-1	39.8	10.6	15.1	4.0	205.9	329.7
IISR Allepy Supreme	55.0	14.3	20.1	5.3	230.0	398.8
IISR Kedaram	46.7	13.2	18.6	5.5	231.0	389.1
IISR Pratibha	51.3	13.8	19.3	5.3	227.6	480.6
Duggirala	46.1	13.1	20.2	4.2	229.1	515.5
BSR-2	46.4	12.1	16.0	4.1	213.9	326.0
Rajendra Sonia	41.2	11.3	15.9	3.8	204.3	365.5
Rasmi	52.8	13.6	21.5	4.8	231.9	348.7
Roma	51.7	13.5	19.8	4.7	231.7	474.8
SEm ±	1.2	0.4	0.6	0.3	3.0	19.1
LSD at $P < 0.05$	3.6	1.1	1.8	1.0	8.6	54.4
8th April planting	48.9	11.9	17.5	4.4	233.8	423.9
22nd April planting	57.5	14.3	23.0	4.9	220.3	498.1
6th May planting	35.7	12.3	15.0	4.4	214.6	315.7
SEm±	0.8	0.2	0.3	0.1	0.6	9.2
LSD at $P < 0.05$	2.3	0.6	0.9	0.3	1.8	27.3

week of April) indicates the best time of planting of turmeric to realize the better plant growth as well as rhizome yield potential (Table 2). The longest leaf was measured for IISR Allepy Supreme (55.0 cm) followed

Table 2: Effect of planting dates on plant growth and yield of various cultivars of turmeric

Variety	Shoot length (cm)				Leaf area (cm^2/ leaf)				Yield (q/ ha)			
	8th April planting	22nd April planting	6th May planting	Mean	8th April planting	22nd April planting	6th May planting	Mean	8th April planting	22nd April planting	6th May planting	Mean
Megha Turmeric-1	103.8ab	135.4abc	87.8a	109.0	513.2ab	758.4ab	462.5a	578.0	416a	490a	384a	430
Suranjana	75.9c	90.1e	66.9abc	77.6	269.0d	379.5c	280.2bc	309.6	324b	381b	278b	328
Narendra Haldi-1	90.2bc	106.0de	65.2bc	87.1	302.6cd	409.5c	253.0bc	321.7	255b	302b	268b	275
IISR Allepy Supreme	121.0a	151.0a	72.7abc	114.9	620.9a	792.4a	381.3ab	598.2	320b	374b	303b	332
IISR Kedaram	113.0a	127.4bc	67.3abc	102.6	429.3bc	630.9b	347.2abc	469.2	335b	388b	250bc	324
IISR Pratibha	114.0a	140.7ab	69.3abc	108.0	539.9ab	726.4ab	362.6abc	543.0	424a	512a	265b	400
Duggirala	104.0ab	125.2bcd	62.7bc	97.3	453.4b	638.4b	291.5bc	461.1	489b	564a	236bc	430
BSR-2	109.0ab	128.9bc	56.3c	98.1	460.6b	625.5b	228.3c	438.1	297b	346b	172c	272
Rajendra Sonia	102.2ab	118.9cd	66.0bc	95.7	322.0cd	465.4c	275.1bc	354.2	303b	381b	230bc	305
Rasmi	117.7a	137.3abc	79.2ab	111.4	487.1ab	689.2ab	440.9a	539.1	291b	333b	248bc	291
Roma	123.2a	146.0ab	74.8abc	114.7	499.4ab	781.2a	344.8abc	541.8	432a	495a	260b	396
Mean	106.7	127.9	69.8	101.5	445.2	627.0	333.4	468.5	353	415	263	344
Estimate				LSD at $P < 0.05$				LSD at $P < 0.05$				LSD at $P < 0.05$
A (Variety)				11.9				64.1				45
B (Variety)				22.6				143.6				91
C (Planting date)				5.3				40.2				23
D (Planting date)				17.1				128.7				73

A: estimate between two main-plots (Variety) treatment means
B: estimate between two main-plots (Variety) treatment means at the same or different levels of sub-plot treatment (Planting date)
C: estimate between two sub-plots (Planting date) treatment means
D: estimate between two sub-plots (Planting date) treatment means at the same level of main-plot treatment (Variety)
In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

by Megha Turmeric-1 (52.9 cm), Rashmi (52.8 cm), Roma (51.7 cm) and IISR Pratibha (51.3 cm), and smallest for Suranjana (36.9 cm). Moreover, leaf lamina was measured wider (=13.5 cm) in five varieties such as Megha Turmeric-1 (14.5 cm), IISR Allepy Supreme (14.3 cm), IISR Pratibha (13.8 cm), Rashmi (13.6 cm) and Roma (13.5 cm), and narrower leaf was measured for Narendra Haldi-1 (10.6 cm) and Suranjana (11.0 cm). The shoot thickness at base was maximum in Rashmi (21.5 mm) which was at par with five cultivars: Megha Turmeric-1, Duggirala, IISR Allepy Supreme, Roma and IISR Pratibha. Significantly more number of tillers was counted in six varieties (IISR Kedaram, IISR Allepy Supreme, IISR Pratibha, Megha Turmeric-1, Rashmi and Roma). The highest rhizome yield per plant was harvested in Megha Turmeric-1 (516.3 g) which was at par with Suranjana, IISR Pratibha and Rashmi.

As like leaf length, leaf breadth, shoot thickness, number of tillers, days to maturity and fresh rhizome weight; shoot length, leaf surface area and yield were also found to be significantly higher in 2nd planting date (last week of April) over 1st and 3rd planting dates which again signifies the importance of planting the turmeric during last week of April to harness the yield potential of cultivars efficiently. Ishimine *et al*. (2004) also reported significant reduction in rhizome yield in late plantings. Significantly higher shoot length and leaf area were recorded in five varieties, namely IISR Allepy Supreme, Roma, IISR Pratibha, Rashmi and Megha Turmeric-1. Irrespective of planting dates, fresh rhizome yield (q/ ha) was harvested maximum in Megha Turmeric-1 and Duggirala (430) which was at par with IISR Pratibha (400) and Roma (396), and minimum in BSR-2 (272) and Narendra Haldi-1 (275). Moreover, maximum yield potential (>475) was realized in 22nd April planting by Duggirala (564) followed by IISR Pratibha (512), Roma (495) and Megha Turmeric-1 (490), and 8th April planting of Duggirala (489). Among these five high yielding varieties, Megha Turmeric-1 showed more stable performance over all three planting dates. The stable performance of Megha Turmeric-1 (selection from Lakadong, a local land race of Jayantia Hill, Meghalaya) is only due to climatic similarity of ICAR Kolasib, Mizoram and Jayantia Hill, Meghalaya.

Unlike various plant growth parameters and yield, the dry matter content was realized minimum in 22nd April planting that might be due to higher mobilization and translocation of photosynthetic metabolites for plant growth and rhizome development. Higher dry matter accumulation was recovered in 8th April planting with maximum in IISR Pratibha followed by IISR Kedaram, Rashmi, Roma, IISR Allepy Supreme and Megha Turmeric-1. The dried turmeric rhizomes are mostly processed into powder and oleoresin (40-55 % curcuminoid and 15-20 % volatile oil). Considering the economic importance and commercial value of dried

Table 3: Effect of planting dates on quality of various cultivars of turmeric

Variety	Dry matter (%)				Dry matter yield (q/ ha)				Curcumin content (%)			
	8th April planting	22nd April planting	6th May planting	Mean	8th April planting	22nd April planting	6th May planting	Mean	8th April planting	22nd April planting	6th May planting	Mean
Megha Turmeric-1	24.1bc	21.6ab	23.3bc	23.0	100.3ab	105.7a	89.4a	98.5	6.96a	7.09a	6.93a	6.99
Suranjana	18.6d	16.1c	17.0d	17.3	60.0ef	61.8cde	47.3cde	56.4	5.43d	5.52e	5.38e	5.44
Narendra Haldi-1	12.3f	10.7d	11.3e	11.4	31.4g	32.3e	29.5e	31.1	5.90b	5.94bc	5.84bcd	5.89
IISR Allepy Supreme	25.2abc	22.0ab	22.1c	23.1	80.5cd	81.8b	67.3b	76.5	6.02b	6.16b	6.04b	6.08
IISR Kedaram	26.6a	21.9ab	26.0a	24.8	89.5bc	86.0b	64.8bc	80.1	5.66c	5.76cd	5.65d	5.69
IISR Pratibha	26.8a	21.9ab	26.0a	24.9	113.6a	112.7a	69.1b	98.5	5.94b	6.03b	5.82bcd	5.93
Duggirala	23.6c	20.9b	21.7c	22.1	115.3a	118.2a	51.0bcd	94.9	5.36d	5.52e	5.34e	5.41
BSR-2	23.2c	20.6b	21.2c	21.6	68.7de	71.1bc	36.5de	58.8	5.32d	5.40e	5.21e	5.31
Rajendra Sonia	15.4e	12.5d	13.1e	13.7	46.9fg	47.8de	30.2e	41.7	6.00b	6.16b	5.92bc	6.02
Rasmi	25.9ab	23.7a	24.6ab	24.7	75.6cde	79.0bc	60.8bc	71.8	5.44d	5.58de	5.41e	5.48
Roma	25.9ab	22.9ab	25.4ab	24.7	111.7a	114.0a	66.2bc	97.3	5.89bc	5.98bc	5.77cd	5.88
Mean	22.5	19.5	21.1	21.0	81.2	82.8	55.7	73.2	5.81	5.92	5.76	5.83
Estimate				LSD at $P < 0.05$				LSD at $P < 0.05$				LSD at $P < 0.05$
A (Variety)				1.1				9.1				0.19
B (Variety)				2.5				20.0				0.30
C (Planting date)				0.7				5.5				0.04
D (Planting date)				2.2				17.7				0.13

A: estimate between two main-plots (Variety) treatment means
B: estimate between two main-plots (Variety) treatment means at the same or different levels of sub-plot treatment (Planting date)
C: estimate between two sub-plots (Planting date) treatment means
D: estimate between two sub-plots (Planting date) treatment means at the same level of main-plot treatment (Variety)
In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

rhizome, dry matter yield was calculated which is simply a factor of percent dry matter content and total yield to find out the actual quantity of economic produce. In contrast to other studied traits, dry matter yield was not affected significantly in 8th and 22nd April plantings (81.2 and 82.8 q/ ha), nevertheless it was drastically reducing by late planting (55.7 q/ ha). Furthermore, the varietal mean performance over planting dates varied greatly and ranged from 31.1-98.5 q/ ha with the outstanding performance by Megha Turmeric-1 and IISR Pratibha (98.5 q/ ha) followed by Roma (97.3 q/ ha) and Duggirala (94.9 q/ ha). However, dry matter yield potential of cultivars was realized by planting in last week of April which was maximum in Duggirala (118.2 q/ ha) followed by Roma (114.0 q/ ha), IISR Pratibha (112.7 q/ ha) and Megha Turmeric-1 (105.7 q/ ha). As like the traits related to plant growth and yield, the accumulation of curcumin was maximum in last week of April planting. Its content was maximum in Megha Turmeric-1 (7.09 %) followed by IISR Allepy Supreme (6.16 %), Rajendra Sonia (6.16 %), IISR Pratibha (6.03 %) and Roma (5.98 %). In conclusion, the planting of turmeric at last week of April in Mizoram result in better plant growth, higher fresh and dried rhizome yield, and greater curcumin content. Any delay in planting greatly affects the yield and quality of economic produce. Four varieties, namely Megha Turmeric-1, Duggirala, IISR Pratibha and Roma were found to be the most potential with respect to higher economic yield as well as better curcumin content. In a genotype x environmental trial at 11 locations across India, three cultivars (Megha Turmeric-1, IISR Pratibha & IISR Kedara were recommended as good genetic source for stability in breeding for high dry yield and curcumin content (Anandaraj et al. 2014).

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