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Varietal performance of turmeric (*Curcuma longa* L.) with special reference to curcumin and essential oil content under climatic conditions of Indogangetic plains

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Abstract

The field experiments were conducted in the years 2011-14 in the climatic conditions of Indogangetic plains at Botanical garden, Department of Botany BHU, Varanasi, using 35 varieties of turmeric. Variety Rajendra Sonia recorded highest fresh rhizome mass (3550 g/plant) followed by Rajapuri and GL PurmI, while in oil content Suvarna (1.40 %), Sugandhum (1.20 %) and Ranga (1.09 %) were found to be superior followed by Suroma, Roma and Kasur. The yield related trait rhizome number was more in Suroma (129) followed by Rajendra Sonia (117) and RCT1 (101); while Rajendra Sonia, Rajapuri and GL PurmI were recorded as higher rhizome mass producing varieties. As curcumin is the most potent medicinal compound, Rajendra Sonia recorded significantly highest curcumin content (2.18 %) followed by RH -5 (1.55 %). Rhizomes harvested from each variety were also hydrodistilled for their essential oil. The oil content of rhizomes varied between 1.4 % and 0.05 % on a fresh weight basis. The essential oil of each variety was evaluated for its major terpenes: â-pinene, ñ-cymene, á-curcumene, â-curcumene, ar-turmerone, á-turmerone and â-turmerone. Cluster analysis revealed that high yielding varieties in terms of rhizome number and curcumin content can be clustered together viz, Vontimitra, GL Purm1, Rajapuri, Rajendra Sonia and Dindigram in cluster IIA. Interestingly the correlation between rhizome mass and curcumine showed positive and highly significant correlation. Curcumin also showed positive correlation with á-Turmerone. The rhizome of Rajendra Sonia variety was found rich in total Turmerone. The total oil content was also positively correlated with Ar-curcumene, linalool and zingiberene. Results suggest that Rajendra Sonia have greater medicinal potential than other tested varieties.

Key words: Turmeric, Performance, hydro-distilled oil, varieties, curcumin, Curcuma longa

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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; and is traded as a spice, dye, oleoresin and source of industrial starch (Chattopadhyay *et al*. 2004, Singh *et al*. 2013, Anandaraj *et al*. 2014). It is one of the important spice crops of India with tremendous medicinal value and plays a vital role in the farmers/national economy. India is the world's largest producer and exporter of turmeric in the world and accounts for more than 60% of the World trade (Philip 1983). It is an important aurvedic medicine due to its bioactive constituent curcumin. A bright yellow colour of turmeric comes mainly from fat-soluble, polyphenolic pigments known as curcuminoids. This crop can be grown on various types of soils including loamy and alluvial soils with pH range of 5.0-7.5 and is sensitive to water logging conditions. A temperature range of 30-35 ºC is optimum for tillering and rhizome initiation and temperature of 18-20 ºC has been found to be adequate at bulking stage (Panigrahi et al. 1987). Although wide genetic variability exists in this crop with regard to the yield, yield attributes, and curcumin content, however, much work has not been reported in terms of crop improvement through the selection of superior lines. Hence, the present study was carried out to evaluate the performance of different varieties with regard to yield

and quality related components of turmeric.

For traditional Ayurveda, turmeric is an excellent natural antiseptic, disinfectant, anti-inflammatory, and analgesic, while at the same time the plant has also been used to aid digestion, to improve intestinal flora, and to treat skin irritations. In South Asia it has been used as a readily available antiseptic for cuts, burns, and bruises. However, several other beneficial properties are reported in folk medicine. Although there is plenty of information about the use of turmeric powder as a spice in culinary and apart from its multiple medicinal uses, the plant is credited with interesting pesticidal properties against insects and fungi of agricultural significance, including repellent properties against some noxious mosquito species. Curcumin, most important bioactive constituent of turmeric has antioxidant (Sharma 1976, Toda *et al.* 1985, Masuda et al., 1999), antibacterial, anti-fungal (Negi *et al*. 1999), anti-inflammatory (Srimal and Dhawan 1973, Satoskar *et al*.1986), analgesic, and digestive properties. Moreover, other constituents of the plant are under investigation for possible benefits in the treatment of cancer, Alzheimer's disease, liver disorders, and certain other skin diseases. Studies have shown that curcumin is non toxic compound, exerts anti-inflammatory activity by inhibition of a number of different molecules that play an important role in inflammation. It has been also reported that turmeric especially the compound curcumin is effective in the treatment of various kind of cancers (Kuttan et al. 1985). The use of rhizome paste or powder has shown significant decrease in low-density lipoproteins and total cholesterol in human blood. Recently curcumin has been found to be antidepressive and hypolipidimic (Jang *et al.* 2008). Because the plant is used as an ingredient in various food supplements and has a tremendous therapeutic properties and is more convincingly used as an ingredient in Indian traditional Ayurvedic formulations in the present study thirty five different varieties of turmeric were evaluated for yield of rhizome, curcumin content and hydro-distilled essential oils of rhizomes/ leaves collected from different parts of India.

Materials and methods

The field experiment was conducted at Varanasi district of Uttar Pradesh during the year 2011-12, 2012-13 and 2013-14 in the climatic conditions of Indogangetic plains at Botanical garden, Botany Department, BHU. The trials were laid out in randomized block design (RBD) with four replications using thirty five varieties of turmeric. The rhizomes were planted 50 cm apart in the month of April in the experimental plot of the Botanical garden. Farmyard manure was applied in the turmeric plots at a concentration of 150 q/ha. There were five replications for each variety and they were harvested for rhizomes in December. Rhizomes were planted in ridge and furrow method with a spacing of 50 x 20 cm. The observations on yield and yield attributes were recorded in replicates and pooled analysis was done.

Extraction of essential oil: The harvested rhizomes / leaves (100 g each) were washed, crushed and hydro-distilled in a Clevenger type apparatus (Borosil) for 6 h. The distilled essential oil was collected and dried over anhydrous sodium sulphate for GC-MS analysis.

GC-MS Analysis: GC-MS was performed on a Shimadzu QP-2010 plus with thermal desorption system TD20, under the following conditions: carrier gas, hydrogen; injector and detector temperatures, 220 ºC and 225 ºC, respectively; using a capillary column (Supelcowax-10, 30m, 0.3 mm), with oven temperature programmed from 80 ºC to 150 ºC at 5 ºC/min, then at 7 ºC/min at 215 ºC. The MS was recorded in electron ionization (EI) mode at 70 eV with a capillary column (50 m, 0.25 mm) ULBON HR-1, with film thickness 0.25 ìm. The carrier gas helium was used at a row of 2 mL/min and the column was programmed at 100 ºC for 6 min and then heated at a rate of 10 ºC/min to 250 ºC.

Identification of the components: The identity of the components was assigned by comparing their GC retention times with those of authentic samples, as well as of the components of other essential oils which were identified earlier and by comparison of the fragmentation pattern of the mass spectra with those reported in the literature and the established library.

Estimation of curcumin content: The percent curcumin content was detected by using the method of Gupta et al. (1999) as described below. 100 mg rhizomes of *Curcuma longa* of each plant was grinded in 5 ml acetone and kept for overnight, filtered, evaporated and re-dissolved in 2 ml of acetone for its quantification through chromatography. HPTLC plates (60 F 254 10x10 cm) were pre-activated and samples and standards were applied to the plate as 6 mm wide bands with an automatic TLC applicator Linomate IV with N_2 flow (Camag, Muttenz, Switzerland), 10 mm from the bottom of the plate at a delivery speed of the syringe (10 S/µl). The detection of curcumin was done by developing the TLC plate using a Camag-twin trough glass tank which was presaturated with the mobile phase chloroform: methanol (95:5) for 1 h and each plate was developed to a height of about 8 cm. The composition of mobile phase was optimized by using different mobile solvents of varying polarity. The TLC runs were made under laboratory conditions of 25±2 ºC and 50 % to 55

% relative humidity. After development, the plate was removed and dried and the spots were visualized in UV light (UV cabinet, Camag, Switzerland).

Statistical analysis: Data were analyzed by simple variance analysis (ANOVA), and the differences with P d" 0.05 were considered signiûcant which were compared by t-test.

Results and discussion

The data collected from field experiments in the year 2011-12, 2012-13 and 2013-14 represented in figure 1 were analyzed statistically and presented in Table 1. The rhizome and leaves harvested from all the replications per year of different varieties were pooled and samples were used for the determination of yield of rhizome, quality of essential oils and curcumin content. Data reflects highly significant variations among the varieties tested for fresh yield of rhizome, leaves, essential oil and curcumin content. Further, it was noted that yield attributing characters such as rhizome no. and mass varied significantly among varieties. The most important yield contributing character in turmeric is the number of rhizomes and their mass. More number of rhizomes per plant were produced in Suroma (129) closely followed by Rajendra Sonia (117). However, Ranga and Krishna produced lesser number of rhizomes per plant in comparison to other tested varieties. The mass of rhizomes varied from 45 g to 3550 g. The variety Rajendra Sonia, Rajapuri and GL Puram I were yielded higher mass of rhizome whereas Krishna and Ranga showed less yield in terms of mass of rhizome.

The data presented in Table 1 showed wide range of variation among the turmeric varieties with regards to the oil yield from leaves and rhizome. The variety Alleppey Supreme and Amalapuram showed poor content of oil in their leaves (0.05 % and 0.15 % respectively). The superior varieties in terms of leaf oil content were Rajendra Sonia and Megha turmeric I. It was noted that varieties Rajendra Sonia, GL PuramI and Rajapuri produced higher leaf oil yield (24.1 - 28.0 g /100g leaf tissue) in contrast to these varieties Krishna, Salem Local, Alleppey Supreme and Erode Local have lowest oil yield (0.1-0.2 g).

Since, information regarding rhizoids essential oil are quite limited in literature so the present investigation ascertained on the yield and quality of essential oil of rhizome tissues also which may be useful for the plant breeders for sequestration of oil rich turmeric genotypes valuable for both nutritional and medicinal point of view (Bansal *et al*. 2002). The oil content in rhizome was

Table 1. Studies on yield and yield attributes of collected turmeric varieties and the essential oil content in their leaves/ rhizomes.

Sl. no	Varieties	Plant height (cm)	Leaves				Rhizomes				
			Number	Mass (g)	Oil content%	Oil yield (g)	Number	Mass (g)	Oil content %	Oil yield (g)	Curcumin content (g) in 100g of rhizome
1	Alleppey supreme	155±10.2	25±3.4	421±3.4	0.05±0.001	0.20±0.001	62±4.5	669±2.6	0.55±0.003	3.3±0.004	0.88±0.01
2	Amalapuram	200±8.9	44±5.2	2161±12.3	0.15±0.007	2.91±0.006	83±4.8	2000±6.2	0.25±0.002	4.5±0.005	0.68±0.01
3	Armour	184±7.5	33±2.1	2207±10.8	0.65±0.011	12.92±0.01	59±3.6	2315±7.0	0.33±0.002	6.9±0.007	1.05±0.02
4	BSR-1	186±5.8	28±2.8	1262±7.4	0.45±0.009	5.11±0.007	50±3.7	1320±4.1	0.60±0.003	7.1±0.006	0.75±0.01
5	CO-1	150±6.6	9±o.6	295±1.1	0.35±0.008	0.91±0.001	21±1.6	411±1.6	0.40±0.002	1.5±0.001	0.69±0.01
6	Dindigam	157±7.1	19±1.4	920±3.6	0.75±0.010	6.21±0.008	36±2.9	845±2.3	0.35±0.002	2.3±0.001	0.74±0.01
7	Erode Local	146±7.3	3±0.4	90±0.6	0.20±0.004	0.20±0.001	9±0.5	157±0.5	0.79±0.003	1.1±0.001	0.58±0.01
8	GL PurmI	182±8.2	56±5.6	3065±14.7	0.75±0.009	24.1±0.020	73±6.1	2690±7.4	0.36±0.001	8.7±0.010	1.01±0.02
9	GL PurmII	176±10.1	36±3.2	520±2.4	0.20±0.003	0.90±0.001	53±2.1	785±1.6	0.65±0.003	4.6±0.003	0.75±0.02
10	IISR Prabha`	100±4.7	28±1.6	402±1.8	0.55±0.007	2.0±0.002	12±1.2	525±2.8	0.36±0.002	1.7±0.002	1.15±0.03
11	IISR Pratibha	121±8.1	16±2.3	420±2.1	0.40±0.004	1.5±0.002	39±3.6	715±3.0	0.63±0.002	4.1±0.003	0.71±0.01
12	Kasur	200±9.3	17±1.7	1025±3.0	0.25±0.002	2.3±0.003	27±2.0	700±2.8	1.00±0.010	6.3±0.005	1.11±0.02
13	Kodur	183±5.8	29±2.8	1415±3.6	0.70±0.005	8.9±0.006	29±1.8	1010±3.7	0.05±0.001	3.2±0.002	0.87±0.02
14	Krishna	148±6.5	4±0.2	45±0.4	0.20±0.001	0.1±0.001	2±0.1	45±1.0	0.66±0.003	0.3±0.001	0.9±0.02
15	Lakadong	135±6.2	13±1.2	295±1.6	0.20±0.001	0.5±0.001	13±0.8	245±1.7	0.65±0.003	1.4±0.002	0.95±0.02
16	Megha Turmeric1	123±4.7	45±4.6	192±1.3	0.80±0.005	1.4±0.002	19±1.4	236±1.3	0.3±0.001	0.6±0.001	1.04±0.03
17	P317	117±7.5	7±0.6	162±1.1	0.65±0.006	1.0±0.001	3±0.2	185±1.1	0.36±0.001	0.6±0.001	0.63±0.02
18	PTS-10	100±5.1	11±1.1	145±2.3	0.55±0.004	0.7±0.001	12±0.6	304±2.3	0.58±0.002	1.6±0.002	0.91±0.03
19	Rajapuri	183±6.7	58±4.2	3665±14.5	0.79±0.010	24.5±0.004	72±6.4	2890±6.8	0.37±0.001	8.9±0.007	1.19±0.03
20	Rajendra Sonia	170±5.9	81±6.5	4145±17.4	0.85±0.009	28.0±0.003	117±8.6	4550±7.4	0.38±0.001	19.6±0.012	2.18±0.05
21	Ranga	100±4.0	7±0.3	45±0.8	0.63±0.005	0.3±0.001	1±0.2	45±0.6	1.09±0.007	0.4±0.001	0.95±0.01
22	Rasmi	92±3.1	28±2.4	840±2.5	0.32±0.003	2.4±0.002	23±2.4	330±1.3	0.90±0.006	2.7±0.002	1.19±0.02
23	RCT 1	205±10.6	34±3.6	3310±12.6	0.37±0.003	11.0±0.004	101±5.8	2380±4.8	0.73±0.004	15.6±0.010	0.80±0.02
24	RH10	110±5.1	8±0.8	165±1.3	0.70±0.006	1.0±0.001	6±0.4	193±1.2	0.32±0.002	0.6±0.001	0.62±0.01
25	RH2	162±7.2	42±5.2	1030±4.1	0.70±0.005	6.5±0.002	35±3.1	1277±3.7	0.35±0.002	4.0±0.003	1.02±0.03
26	RH5	147±3.9	13±1.0	185±2.3	0.40±0.003	0.7±0.001	12±0.8	239±1.4	0.96±0.005	2.1±0.001	1.55±0.05
27	Roma	180±6.2	58±5.2	2550±8.5	0.30±0.002	6.9±0.002	56±2.9	1475±3.9	1.05±0.006	13.9±0.009	0.85±0.02
28	Salem Local	157±5.7	7±0.2	125±1.1	0.20±0.002	0.2±0.001	12±1.0	114±0.9	0.53±0.002	0.5±0.001	1.09±0.03
29	Sonali	167±7.4	8±0.2	490±1.0	0.40±0.005	1.8±0.001	55±3.4	490±2.2	0.60±0.003	2.7±0.001	0.80±0.02
30	Sudarsana	155±4.8	5±0.1	62±0.8	0.50±0.004	0.7±0.001	21±2.7	303±1.6	0.7±0.003	1.9±0.001	1.01±0.02
31	Sugandham	175±9.0	39±3.2	2380±9.7	0.55±0.005	11.8±0.002	64±4.9	1845±4.3	1.20±0.009	19.9±0.014	0.77±0.02
32	Suguna	152±6.2	39±4.0	1010±3.5	0.60±0.006	5.5±0.001	33±3.1	839±2.5	0.35±0.002	0.9±0.001	0.81±0.03
33	Suroma	200±8.3	85±6.2	4300±16.7	0.40±0.003	15.5±0.004	129±8.9	1870±3.7	1.08±0.008	18.2±0.008	1.01±0.03
34	Suvarna	180±6.6	12±2.1	540±2.2	0.60±0.008	2.9±0.001	20±1.4	460±1.4	1.4±0.010	5.8±0.004	1.12±0.04
35	Vontimitra	151±5.1	62±5.8	2714±11.6	0.75±0.006	18.3±0.003	53±3.8	2495±4.8	0.35±0.001	7.9±0.005	0.83±0.02

highest in Sugandham (1.20 %) followed by Ranga (1.09 %). The varieties Kodur (0.05 %) and Amalapuram (0.25 %) were poor in rhizome oil content but in terms of total oil yield Sugandham (19.9 g) and Rajendra Sonia (19.6 g) were superior than the other varieties. Variations in essential oil content of rhizomes in different accessions were also reported by Sharma *et al.,* 1997.

Curcumin Content: Srimal (1993) reported the yield of curcumin from *C. longa* rhizome ranged from 3 % to 5 %. However in the present study the content of curcumin in the dried rhizomes varied between 0.58 % and 2.18 %. The rhizomes of fourteen varieties were observed to have a curcumin percentage higher than 1. Variety Rajendra Sonia (2.18 %) and RH5 (1.55 %) showed higher concentration of curcumin in their rhizome (Table 2). The variety Sugandham, whose rhizomes were rich in essential oil (1.20 %), contained only 0.77 % curcumin and on the other hand Rajendra Sonia and RH5, whose rhizomes were rich in curcumin (2.18 %, 1.55 % respectively), contained 0.30 % and 0.96 % essential oil, respectively. Rakhunde *et al.* (1998) in their study of six western Indian genotypes of turmeric, found total pigments in dry rhizomes in the range 2.94 ± 5.14 %. Since curcumin is one of the pigments contained in rhizomes, usually accounting for 40 ± 60 % of total pigments in turmeric cultivars, it appears that the presently examined genotypes are generally deficient in curcumin as compared to the western Indian genotypes.

Table 2: Range of curcumin content in tested 35 varieties of *C. longa*

	Curcumin content%			
	0.51-0.75	0.76-1.00	1.01-1.50	>1.50
Varieties	BSR1	Alleppy	Armour	Rajendra
	CO1	Supreme	GLpuram1	Sonia
	Dindigam	Kodur	IISR Prabha	RH5
	Erode local	Krishna	Kasur	
	GL Puram 2	Lakadong	Megha	
	Amalapuram	PTS10	turmeric1	
	IISR Pratibha	Ranga	Rajapuri	
	P317	RCT1	Rasmi	
	RH10	Roma	RH2	
		Sonali	Salem local	
		Suguna	Sudarsana	
		Sugandham	Suroma	
		Vontimitra	Suvarna	

Variability in the composition of the leaf essential oils: The leaf essential oil from the different varieties also differed widely in their composition (Table 3). The

Table 3: Variability in the composition of the essential oils distilled from the leaves of 35 accessions of *C. longa*.

S. No.	Varieties	% terpenoids							
		α-pine ne	α- terpenene	1,8-cineole	ρ- cymene	Ar-curcumene	Ar-turmerone	α-turmerone	ß-turmerone
1	Alleppey supreme	3.22	2.29	26.46	25.98	3.58	3.38	4.99	1.69
2	Amalapuram	2.70	1.18	4.13	0.10	1.55	3.14	1.90	0.85
3	Armour	1.65	4.04	11.39	31.16	4.95	7.92	0.37	2.86
4	BSR 1	1.49	2.92	15.92	28.30	5.25	9.18	1.85	3.78
5	CO 1	1.12	28.05	14.79	17.45	1.49	5.01	1.00	1.88
6	Dindigam	1.37	2.65	11.39	30.08	6.07	9.47	2.25	4.33
7	Erode Local	3.02	2.15	28.74	5.22	1.20	3.73	1.41	1.34
8	GL PurmI	1.80	6.00	0.01	31.25	4.84	9.19	1.95	3.80
9	GL PurmII	3.38	3.11	30.81	19.54	2.20	3.03	1.53	5.69
10	IISR Prabha	1.12	2.70	14.91	26.81	4.13	9.65	1.19	3.64
11	IISR Pratibha	0.88	32.78	13.11	8.74	1.53	3.07	0.92	0.66
12	Kasur	1.97	1.42	27.14	2.19	5.70	1.70	4.80	9.13
13	Kodur	1.71	3.60	12.82	32.33	5.20	8.09	0.34	2.96
14	Krishna	3.60	32.40	24.69	28.68	6.81	9.01	4.49	4.01
15	Lakadong	2.31	9.18	20.66	30.13	0.32	3.67	1.09	4.01
16	MeghaTurmeric1	2.53	35.15	11.21	12.06	1.66	2.82	0.41	0.67
17	P317	1.31	2.88	13.70	27.83	5.65	9.90	2.14	4.43
18	PTS 10	2.00	11.27	13.21	23.45	3.60	7.28	0.76	2.95
19	Rajapuri	1.85	6.09	0.05	31.24	4.83	9.10	1.90	3.81
20	Rajendra Sonia	3.63	33.73	25.09	32.01	6.92	9.82	4.85	4.90
21	Ranga	0.36	3.38	8.01	78.09	0.01	0.01	0.01	0.01
22	Rasmi	1.15	13.38	2.41	15.60	1.88	0.25	4.84	1.11
23	RCT 1	2.12	2.87	19.21	29.08	4.12	6.95	0.82	2.92
24	RH10	1.01	1.80	11.04	25.77	5.72	10.87	0.77	4.22
25	RH2	1.89	45.53	8.29	9.06	0.64	2.20	0.39	1.28
26	RH5	1.37	2.30	13.95	18.37	1.27	8.97	2.83	4.43
27	Roma	0.38	0.84	12.27	15.81	5.27	7.17	1.75	4.75
28	Salem Local	3.55	6.84	22.66	17.28	5.83	3.35	3.61	1.55
29	Sonali	1.03	2.74	16.05	27.49	4.59	8.90	2.11	4.36
30	Sudarsana	0.83	38.85	12.20	21.50	0.76	2.36	1.19	0.26
31	Sugandham	1.30	3.59	16.16	29.53	3.75	8.16	1.68	3.01
32	Suguna	1.37	3.88	11.43	29.13	5.77	9.88	2.14	4.39
33	Suroma	3.03	3.22	15.44	27.84	4.78	8.16	3.96	3.92
34	Suvarna	1.09	3.45	13.10	14.81	2.54	4.98	1.22	2.57
35	Vontimitra	1.33	3.06	9.57	27.61	5.81	8.62	2.57	4.80
	Mean	3.34	10.26	14.63	23.75	3.72	6.26	2.01	3.17

majorly known terpenoids of turmeric leaf oil sach as á-pinene, á-terpinene, 1,8-cineole, ñ-cymene, Ar-curcumene, Ar-turmerone, á-turmerone, â-turmerone were present in almost all the accessions, although to different extents. The contents of á-terpenene, 1,8-cineole and ñ-cymene have been demonstrated to have large variability, the range of the concentration of á-terpinene was from 0.84 to 45.53 %, 1,8-cineole was from 0.001 to 30.81 % and 0.10 to 78.09 % for ñ-cymene. The range of variability of á-pinene, Ar-curcumene and turmerone(s) was relatively lower. The concentrations of these terpenoids ranged from 0.010 % to 10.87 %. Their order of occurrence in terms of increasing concentrations was á pinene < á-turmerone < Ar-curcumene < â-turmerone < Ar turmerone. Leaf oil of the variety Rajendra Sonia showed highest content of á pinene (3.63 %) followed by Krishna (3.60 %). Variety RH2 and Sudarsana contain á-terpinene more than 38 % while 1,8-cineole was found more in GL Puram II and Erode Local. Among observed all the 35 varieties lowest composition of á-pinene, Ar-curcumene, Ar-turmerone, á-turmerone and â-turmerone was found in Ranga variety. The pooled concentration of the three turmerone(s) varied from 0.01 to 8.33 % among all the variety. It is noteworthy that the concentrations of the Ar-turmerone, á-turmerone, â-turmerone were very low (0.01 %) in the essential oil of the variety Ranga. The qualities of the essential oil of *C. longa* cv Roma were also reported by Bansal *et al*. 2002.

Variability in the composition of the rhizome essential oils: The varieties also demonstrated high level of variability for the rhizome essential oil composition. Previous reports work on rhizome essential oil component (Bahl et al. 2014) have already identified that the major component of hydro distilled essential oil of rhizome were ß-Pinene, p-cymene, ã-terpenene, Linalool, ar-turmerone, á-turmerone and ß—turmerone, zingi-berene in *C. longa*. In the present study tested varieties demonstrated enormous variability in the concentration of these compounds in the essential oils of rhizome (Table 4). The ß - pinene, myrcene, Ar-curcumene, Ar-turmerone and ß –turmerone concentrations varied from 0.01 to 45.1 %, 0.01 to 20.91 %, 0.30 to 21.03 %, 2.65 to 36.68 % and 0.51 to 19.97 %, respectively. The variation in the contents of á-pinene, 1, 8-cineole, linalool, ã-terpinene, ñ-cymene, and zingiberene was relatively lower. The percentage of ß – pinene was found highest in Vontimitra variety while in rhizome of Rasmi variety ñ-cymene, ar-curcumin and zingi-berene present in higher concentration. On the basis of results, it appears that in Indogangatic plain variety Rajendra Sonia whose rhizome was rich in curcumin also found rich in total turmerone, which is a major component of rhizome essential oil.

Table 4: Variability in the composition of the essential oils distilled from the rhizomes of 35 varieties

S. No.	Varieties	% terpenoids											
		α-pine ne	ß- pine ne	Myrc-ene	1,8-cine-o1	γ- terpene ne	p-cyme- ne	Lina-lool	Ar-curu mene	Zingi-berene	Ar-turm-erole	α-Turm-erone	ß Turm-erone
1	Alleppey supreme	0.20	6.38	0.01	2.86	0.70	0.47	1.18	2.16	2.29	5.59	7.96	5.18
2	Amalapuram	2.98	0.38	0.94	0.01	0.01	0.01	1.48	1.69	2.84	3.80	8.34	4.98
3	Armour	0.36	28.04	8.17	0.56	11.42	0.01	0.25	0.92	1.06	13.98	10.40	9.65
4	BSR 1	0.38	12.91	1.44	0.22	0.60	0.40	0.35	2.21	1.78	7.20	3.34	5.65
5	CO 1	4.44	0.01	0.01	0.01	0.01	0.01	0.20	2.56	8.94	7.15	7.62	6.96
6	Dindigam	1.01	32.96	0.01	7.72	0.95	1.61	0.40	1.10	1.66	5.77	10.81	6.91
7	Erode Local	0.07	1.05	0.01	0.01	0.01	0.50	6.89	11.29	7.07	19.64	5.51	3.38
8	GL PurmI	0.60	0.01	20.91	3.46	0.43	0.55	0.28	1.71	1.24	10.86	14.41	5.94
9	GL PurmII	0.05	0.01	0.01	1.41	0.01	0.33	8.03	12.88	7.75	5.42	2.41	2.63
10	IISR Prabha	0.28	16.52	3.22	0.01	0.45	0.67	0.26	1.50	1.02	5.96	7.79	3.39
11	IISR Pratibha	0.03	12.76	9.46	0.18	1.04	0.59	1.30	0.70	1.54	8.12	11.11	4.01
12	Kasur	0.02	0.01	2.50	0.01	0.01	1.10	7.42	10.52	6.54	2.65	3.91	1.51
13	Kodur	0.57	20.45	2.77	0.55	0.84	0.64	0.35	2.07	1.66	5.11	3.73	2.83
14	Krishna	0.01	0.01	0.65	0.01	0.01	2.07	0.80	7.83	7.46	4.44	6.68	4.64
15	Lakadong	0.05	0.79	0.01	0.01	0.01	0.34	6.24	12.30	8.26	12.98	2.99	2.94
16	MeghaTurmeric1	0.57	14.75	3.48	0.32	4.57	1.38	0.39	1.14	0.71	3.69	4.74	7.64
17	P317	0.46	19.23	3.73	0.01	0.47	0.76	0.02	1.77	1.83	5.48	4.13	3.81
18	PTS 10	0.32	14.13	2.13	0.04	0.01	0.17	1.08	4.08	1.93	36.68	14.45	4.81
19	Rajapuri	0.60	0.01	20.91	3.46	0.43	0.55	0.28	1.71	1.24	10.86	14.41	5.94
20	Rajendra Sonia	0.88	20.80	5.53	0.31	7.06	0.01	0.31	1.13	0.13	6.67	14.83	19.97
21	Ranga	2.54	0.01	0.16	0.01	0.01	7.22	0.35	3.13	4.18	5.28	6.51	5.50
22	Rasmi	0.43	1.56	0.01	0.01	0.01	10.10	3.22	21.03	14.38	5.95	6.01	1.55
23	RCT 1	0.01	0.01	1.00	0.01	0.01	0.18	6.29	10.51	6.99	15.31	3.79	2.73
24	RH10	0.28	13.76	0.01	3.16	0.42	0.63	0.11	1.90	1.17	5.87	4.06	3.83
25	RH2	0.33	10.98	0.01	4.36	8.66	0.01	0.29	0.30	1.21	18.96	15.01	19.52
26	RH5	0.01	1.16	1.03	0.01	0.01	0.12	5.85	9.58	6.13	24.90	7.70	3.59
27	Roma	2.27	7.21	2.57	0.01	0.52	0.37	2.01	3.18	2.88	4.82	2.75	3.36
28	Salem Local	0.38	4.04	0.01	0.01	0.01	0.33	5.14	4.33	7.58	3.32	7.46	2.12
29	Sonali	0.07	7.68	3.69	0.01	0.01	0.10	0.30	2.92	1.88	12.67	12.91	6.95
30	Sudarsana	0.19	0.01	4.46	3.01	0.01	0.44	1.16	1.89	2.40	29.00	13.98	12.91
31	Sugandham	0.17	0.01	6.78	2.33	0.33	0.14	2.05	2.97	2.83	6.33	12.82	4.15
32	Suguna	1.42	41.67	9.08	0.92	8.80	0.01	0.22	0.96	0.77	16.22	7.87	5.67
33	Suroma	0.16	4.86	1.18	0.01	0.01	0.01	1.83	2.85	2.72	7.25	13.34	3.86
34	Suvarna	0.01	0.01	0.01	0.07	0.01	2.62	3.73	8.46	6.24	12.67	14.29	4.84
35	Vontimitra	1.17	45.05	7.70	1.10	1.92	1.70	0.32	1.33	0.92	21.30	8.51	3.80
	Mean	0.73	8.73	3.36	1.06	1.43	1.14	2.06	4.84	3.84	9.71	7.60	5.66

Correlation analysis: Correlation coefficient between various compositions of essential oil of rhizome in 35 Turmeric varieties revealed significant positive correlation with linalool, Ar- turmerone and zingiberene (Table 5). The oil component á-Turmerone and ß-Turmerone showed significant negative correlation with linalool and Ar-curcumene , while Ar-curcumene and zingiberene showed significant positive correlation with p-cymene and linalool. Interestingly the correlation between rhizome mass with rhizome curcumin showed positive and significant correlation. Similar trend was observed in the oil yield with rhizome mass. Curcumin showed positive correlation with á-Turm-erone, on the other hand á-pinene, ß- pinene, 1, 8-cineol and zingiberene were negatively correlated with curcumin. The total oil content was positively correlated with linalool, Ar-curcumene and zingiberene.

Genetic variation analysis based on rhizome oil content and yield related traits: Genetic similarities measured through analysis of data including rhizome oil content, curcumin and yield related traits from 35 varieties of *C. longa* revealed varying degree of genetic relatedness. Jacord similarities coefficient (Jaccard 1908) ranged from 0.02-1.0. Using the Jaccard similarity coefficient a dendrogram was constructed which resulted in clustering of the varieties into four clusters, the first major cluster consists of 12 genotypes divided into two sub clusters IA and IB. Subcluster IA consists eight varieties viz: Alleppey Supreme, Erode Local, Salem Local, Krishna, Ranga, CO1, GL PurmII, Lakadong and subcluster IB consists of four varieties IISR Prabha, PTS-10, RH-5 and Sudarsana. The second major cluster also consists of two sub cluster IIA and IIB. The subcluster IIA consists of five varieties GL

Table 5: Correlation between curcumin content and other antioxidants

Trait	*α-pine ne*	*ß- pine ne*	*Myrc-ene*	*1,8-cine-ol*	*γ- terpene ne*	*p-cyme-ne*	*Lina-lool*	*Ar-curumene*	*Zingi-berene*	*Ar-turm-erole*	*α-Turm-erone*	*ß Turm-erone*	*Number*	*Mass (g)*	*Oil content %*	*Oil yield (g)*	*Curcumin content %*
α-pine ne	1.00																
ß- pine ne	0.05	1.00															
Myrc-ene	-0.05	0.15	1.00														
1,8-cine-ol	-0.08	0.20	0.24	1.00													
γ- terpene ne	0.02	0.57**	0.20	0.13	1.00												
p-cyme- ne	0.09	-0.13	-0.18	-0.10	-0.18	1.00											
Lina-lool	-0.33*	-0.48**	-0.34*	-0.28	-0.33*	0.00	1.00										
Ar-curumene	-0.28	-0.47**	-0.36*	-0.32	-0.36*	0.49**	0.77***	1.00									
Zingi-berene	0.02	-0.56***	-0.45**	-0.34	-0.42*	0.49**	0.67***	0.89	1.00								
Ar-turm-erole	-0.21	0.12	0.09	0.04	0.12	-0.19	0.06	0.02	-0.11	1.00							
α-Turm-erone	-0.09	0.03	0.44**	0.36	0.23	-0.14	-0.39*	-0.39**	-0.38**	0.40**	1.00						
ß-Turm-erone	0.08	0.18	0.11	0.34	0.64***	-0.20	-0.42**	-0.44**	-0.42	0.22	0.56***	1.00					
Number	0.03	0.02	0.32	0.08	0.18	-0.30	-0.07	-0.20	-0.28	-0.13	0.34	0.25	1.00				
Mass (g)	0.08	0.21	0.55***	0.15	0.37*	-0.26	-0.21	-0.30	-0.39**	-0.04	0.39**	0.41**	0.84***	1.00			
Oil content %	-0.17	-0.53**	-0.27	-0.28	-0.38*	0.32	0.48**	0.49**	0.45**	0.04	0.03	-0.28	-0.01	-0.20	1.00		
Oil yield (g)	-0.06	-0.06	0.27	0.00	0.09	-0.22	0.03	-0.09	-0.18	-0.11	0.29	0.18	0.83***	0.79***	0.31	1.00	
Curcumin content %	-0.16	-0.03	0.15	-0.11	0.29	0.09	0.03	0.07	-0.02	0.07	0.36**	0.47	0.25	0.43**	0.09	0.32*	1.00

*significant at 0.05 %, **significant at 0.01%, ***significant at 0.001%

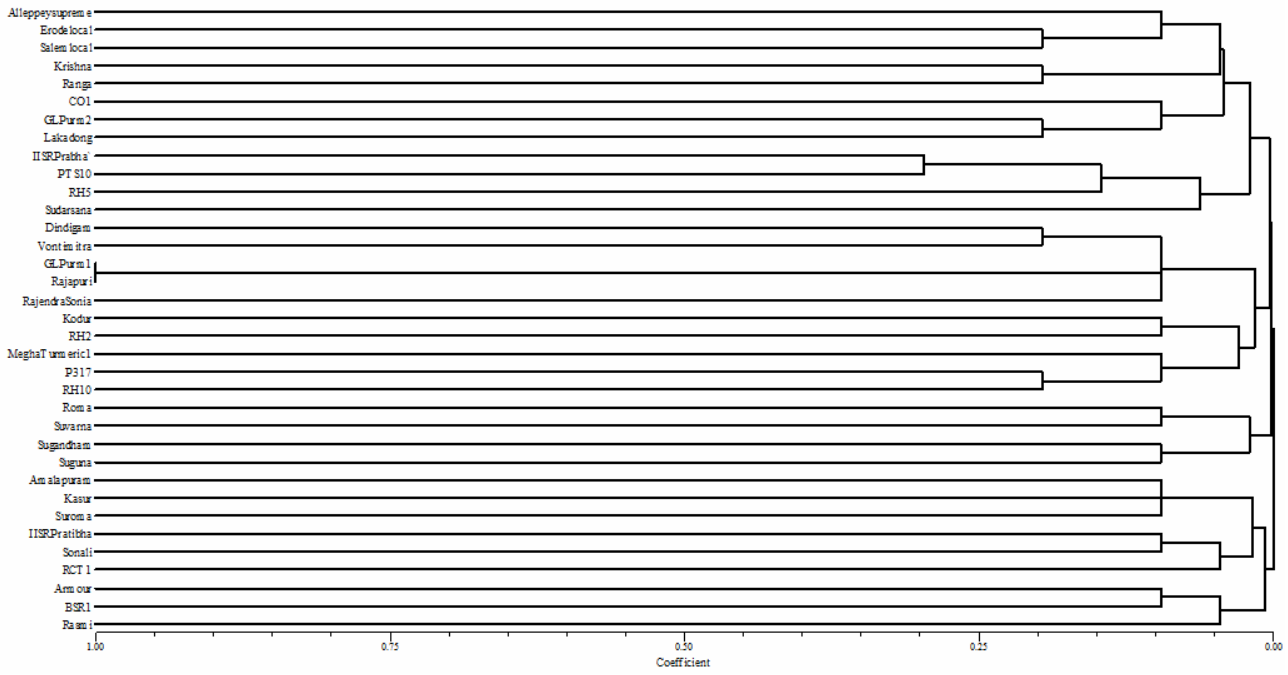

Figure 2: Dendogram showing clustering of 35 *C. longa* varieties based on similarity index

PurmI, Rajapuri, Rajendra Sonia, Dindigram and Vontimitra, while IIB includes Kodur, RH-2, Megha Turmeric1, P317 and RH-10. The cluster IInd includes higher yielding varieties in terms of rhizome yield and curcumin content.

The third major cluster consists of four varieties Roma, Suroma, Sugandham, Suguna and fourth major clusters consists of nine varieties; Amlapurm, Kasur, Suroma, IISR Pratibha, Sonali, RCT1, Armour, BSR1 and Rasmi. Subcluster IIA group contains high yielding varieties Rajendra Sonia, Rajapuri and GL PurmI in relation to rhizome yield and curcumin content.

Conclusion

Curcumin percentage is an important factor as the fresh rhizomes are to be cured to obtain marketable turmeric for spices and medicine. Maximum recovery of the cured produce is positively correlated with curcumin content was recorded high by Rajendra Sonia. Curcumin content (yellow colour) is also one of the important attributes in grading the turmeric produced for export and domestic market. The yield of cured produce per ha was found to be maximum in Rajendra Sonia (65.18 q/h) as calculated with the help of cured rhizome produce (data not shown here). The variation in rhizome yield and recovery percentage of curcumin and oil among various turmeric varieties could be due to genetic variations among the varieties as also reported Subbharayadu *et al*. (1976). Thus, it can be concluded that among the variety Rajendra Sonia and Rajapuri produced highest fresh rhizome yield and curcumin content. Further, the varieties Rajendra Sonia and Megha Turmeric I was found to be better in oil content than other tested varieties.

सारांश

वर्ष 2011–14 में पूर्वी उत्तर प्रदेश के, गंगा के मैदानी क्षेत्र में हल्दी की विभिन्न प्रजातियों में कुरकुमिन एवं जल आसवित तेल की मात्रा का अध्ययन किया गया। इसके लिए भारत में उत्पादित हल्दी की 35 भिन्न प्रजातियों का वनस्पति विज्ञान विभाग काशी हिन्दू विश्वविद्यालय के वनस्पति उद्यान में एक क्षेत्रीय प्रयोग किया गया। तीनों वर्षों में प्राप्त विवरण के औसत के अनुसार प्रजाति राजेन्द्र सोनिया का ताजा प्रकन्द द्रव्यमान सबसे ज्यादा पाया गया। उसके पश्चात् राजापुरी एवं जीएल पुरम–I का पाया गया। जबकि तेल की मात्रा सुवर्णा (1.40%), सुगन्धम (1.20%); रंगा (1.09%) तदोपरान्त सुरोमा, रोमा एवं कासूर प्रजातियों से अधिक पायी गयी। प्रकन्द संख्या के आधार पर देखा गया कि सुरोमा प्रजाति में सबसे अधिक 129 प्रकन्द थे, उसके उपरान्त राजेन्द्र सोनिया में 117 एवं आरसीटी-I में 101 प्रकन्द पाये गये जबकि प्रजाति राजेन्द्र सोनिया, राजापुरी एवं जीएल पुरम-I अधिक प्रकन्द द्रव्यमान के लिए अंकित की गयी। जैसा कि हम जानते हैं, कुरकुमिन एक अत्यधिक प्रभावी चिकित्सीय रसायन हैं, प्रजाति राजेन्द्र सोनिया में यह सबसे अधिक 2.18% पाया गया, फिर प्रजाति आरएच–5 में 1.55% पाया गया। सभी प्रजातियों के तेल में निम्नलिखित मुख्य टर्पीन पाये गयेः–बीटा – पाइनिन, रो – साइमीन, अल्फा – कुरकुमिन, बीटा – कुरकुमिन, एआर – टरमिरॉन, अल्फा – टरमिरॉन एवं बीटा – टरमिरॉन समूह का परीक्षण बताता है कि अधिक प्रकन्द उत्पादन एवं कुरकुमिन वाली प्रजातियाँ एक साथ एक समूह II-A में रखी गयी, जो क्रमशः वान्टीमित्रा, डिन्डीग्राम, राजापुरी, राजेन्द्र–सोनिया एवं जीएल पुरम–I हैं। ये तथ्य रूचिकर पाया गया कि प्रकन्द द्रव्यमान एवं कुरकुमिन के बीच का सहसम्बन्ध धनात्मक एवं अत्यन्त महत्वपूर्ण रहा। कुरकुमिन का अल्फा – टरमिरॉन के साथ भी धनात्मक सहसम्बन्ध देखा गया। प्रजाति राजेन्द्र सोनिया के राइजोम में कुल टयूमेरॉन भी सबसे अधिक पाया गया। कुल तेल की मात्रा भी एआर – कुरकुमीन, लाइनालूल एवं जीन्जीबरीन के साथ धनात्मक सहसम्बन्ध प्रदर्शित करती है। उपरोक्त प्रयोग से प्राप्त परीणाम बताता है कि राजेन्द्र सोनिया अन्य प्रजातियों की तुलना में चिकित्सीय रूप से अधिक महत्वपूर्ण हैं क्योंकि इसमें कुरकुमिन की मात्रा ज्यादा पायी गयी।

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