Received: 13 Oct 2021 | Revised: 09 Dec 2021 | Accepted: 15 Dec 2021

Electronic Journal of Plant Breeding

Research Article

Per se performance and diversity analysis in turmeric (*Curcuma longa* L.) genotypes for plant and rhizome yield characters

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Abstract
Evaluation of turmeric genotypes is useful to study genetic variation among them and to identify high yielding genotypes. Analysis of genetic divergence in turmeric genotypes is much essential for grouping them based on the observed biometrical and yield traits and to choose the traits responsible for contribution to diversity. Turmeric genotypes were evaluated during 2020 -2021 and 2021 – 2022 and they exhibited wide variation among the observed quantitative traits. Among the turmeric genotypes, CL 95 recorded the highest fresh rhizome yield per plant of 381.8 g followed by CL 258 (341.2 g). CL 95, CL 258, Salem local and CL 197 exhibited better performance for yield and yield contributing traits. Totally six clusters were formed by using Mahalanobis D^2 statistics method and genotypes listed in cluster VI were more diverse. Fresh rhizome yield per plant contributed more (41. 99 %) for genetic diversity. The genotypes selected in the present study could used to improve the rhizome yield of turmeric.

Key words: *Per se* performance, diversity, cluster distance, per cent contribution and quantitative traits

INTRODUCTION

Turmeric (*Curcuma longa* L.) is one of the major spice crop and it is originated from South East Asia. It belongs to the family Zingiberaceae and it is widely grown in tropical and subtropical parts of the world. India has emerged as the leading producer, consumer and exporter of turmeric in the world. In the world market, turmeric from India is considered as the best, due to its quality and high curcumin content. In India, turmeric is cultivated in an area of 2,96,181 ha with the production and productivity of 11,78,750 t and 3.98 t/ha respectively during 2019 to 2020. Telangana recorded the highest area (55,444 ha), production (3,86,596 t) and productivity (6.97 t/ha) of turmeric in India followed by Maharashtra (Indiastat - Ministry of Agriculture and Farmers Welfare, Govt. of India and Spices board). Turmeric is mainly cultivated for its underground rhizomes. Turmeric is a triploid (2n=63) perennial spice crop and it is propagated asexually through underground rhizome parts (Ramachandran, 1961). It is a multipurpose spice, used as traditional medicine, colouring material, food preservative, pharmaceutical and cosmetic purposes (Sasikumar, 2005 and Anandaraj and Sudharshan, 2011). Due to its clonal method of propagation, crop improvement in turmeric is restricted only through selection and mutation breeding methods. Genetic variation and diversity in turmeric mainly depends on the collection and evaluation of germplasm which is from various places of origin (Chandra *et al*., 1997). The yield potential of the crop is one of the main criteria in crop improvement programme of turmeric. Hence, this study was carried out to evaluate the performance of 22 different turmeric genotypes for morphological and yield parameters and their divergence.

MATERIALS AND METHODS

The study was carried out at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 2019-2020 and 2020- 2021. A total of 22 different turmeric genotypes were collected from various places of India (Tamil Nadu, Kerala, Orissa, Bihar, Uttar Pradesh and North East India regions) and were studied for morphological and yield performance. The experiment was carried out by Randomized Block Design with three replications (plot size – 3 x 1 m^2). Each replication consisted of 15 plants and data was recorded from randomly selected five plants per genotype/replication. Biometical and yield parameters *viz.,* plant height (cm), number of tillers per plant, number of leaves per plant, leaf length (cm), leaf width (cm), number of mother rhizomes per plant, weight of mother rhizomes per plant (g), number of primary rhizomes per plant, weight of primary rhizomes per plant (g), number of secondary rhizomes per plant, weight of secondary rhizomes per plant (g) and fresh rhizome yield per plant (g) were recorded. Pooled data of two seasons were utilized for statistical analysis by using SPSS 28.0 software. Genetic diversity analysis was carried out by using Mahalanobis (1936) D^2 statistics and clustering of turmeric genotypes by Tocher's method as described by Rao (1952). Average inter and intra cluster distances were estimated as suggested by Singh and Choudhary (1977) using the statistical software GENRES.

RESULTS AND DISCUSSION

Evaluation of genotypes for their available variability and diversity is considered as the base for any crop improvement programme. All the 22 turmeric genotypes exhibited significant variation for all the observed traits. The mean performance of turmeric genotypes for morphological and yield characters (pooled data)

Table 1. *Per se* performance of turmeric genotypes for biometrical characters

Genotypes	Plant height (cm)	Number of tillers per plant	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)
CO 2	98.10	5.38	8.21	40.63	13.02
BSR 2	89.94	5.90	7.26	38.25	12.03
IISR Pragati	73.77	4.78	6.87	35.72	12.27
Salem local	101.47	7.14	7.39	43.00	13.03
IISR Prathibha	99.87	5.68	7.57	41.65	12.73
Salem Narayappanur	82.65	4.92	7.16	37.47	11.53
Lakadong	46.68	2.17	5.49	24.93	9.80
Salem Eraiyur	80.80	4.08	6.80	39.27	13.41
Erode local	69.38	4.71	6.99	31.54	10.46
Megha turmeric	74.20	5.01	7.02	36.20	11.80
Rajendra Sonia	64.65	3.48	6.79	31.28	10.32
Suroma	52.39	2.76	5.88	30.30	11.07
NDH 11	83.36	3.99	6.83	40.39	12.27
Kanti	84.05	4.08	6.83	42.44	14.00
NDH 128	73.01	4.67	6.86	34.53	11.11
CL 272	84.28	4.67	7.31	40.57	11.98
CL 258	96.28	5.96	7.16	43.36	13.01
CL 118	79.28	4.58	6.57	36.39	11.07
CL 123	89.45	5.36	7.19	40.81	12.53
CL 197	97.71	5.10	7.07	43.17	13.69
CL 225	94.12	5.09	7.11	42.24	12.94
CL 95	93.09	4.75	7.70	42.23	13.00
Mean	82.21	4.74	7.00	38.02	12.14
Minimum	46.68	2.17	5.49	24.93	9.80
Maximum	101.47	7.14	8.21	43.36	14.00
SEd	2.22	0.30	0.25	1.96	0.40
CD (P=0.05)	4.48	0.60	0.51	3.96	0.81

is furnished in **Table 1 and Table 2**. With regard to morphological traits, plant height ranged from 46.68 to 101.47 cm. Salem local recorded the highest plant height of 101.47 cm followed by IISR Prathibha (99.87 cm) and CO 2 (98.10 cm). Biomass accumulation and yield potential of any crop are decided by the plant growth characters (Gupta *et al*., 2015). The number of tillers per plant was maximum in Salem local (7.14) followed by CL 258 (5.96) and BSR 2 (5.90). The number of leaves per plant was higher in CO 2 (8.21) followed by CL 95 (7.70). Leaf length ranged from 24.93 to 43.36 cm. The highest leaf length was recorded by CL 258 (43.36 cm) followed by CL 197 (43.17 cm) and Salem local (43.00 cm). Maximum leaf width was observed in Kanti (14.00 cm) followed by CL 197 (13.69 cm) and Salem Eraiyur (13.41 cm). A total of 200 turmeric genotypes were evaluated for morphological and yield traits by Suresh *et al.* (2020).

With regard to yield characters, the number of mother rhizomes per plant ranged from 2.5 to 5.2. More number of mother rhizomes per plant was recorded by Salem local (5.2) followed by CL 95 (4.9) with a mean value of 3.9. CL 95 recorded the highest weight of mother rhizomes per plant of about (131.4 g) followed by CL 197 (120.2 g). More number of primary rhizomes per plant was observed in CL 197 (12.2) followed by NDH 11 (11.3) and Megha turmeric (11.0). The weight of primary rhizomes per plant ranged from 19.8 g and 170.6 g. The weight of primary rhizomes per plant was high in Salem local (170.6 g) followed by CL 95 (158.5 g) and CL 258 (156.5 g) with the mean of 106.0 g. The number of secondary rhizomes per plant was high in CL 258 (16.4) followed by CL 272 (14.7) and BSR 2 (14.2) as compared to the mean number of secondary rhizomes per plant (9.8). The weight of secondary rhizomes per plant was maximum in CL 272 followed by

Table 2. ***Per se*** **performance of turmeric genotypes for yield characters**

Genotypes	Number of mother rhizomes per plant	Weight of mother rhizomes per plant (g)	Number of primary rhizomes per plant	Weight of primary rhizomes per plant (g)	Number of secondary rhizomes per plant	Weight of secondary rhizomes per plant (g)	Fresh rhizome yield per plant (g)
CO 2	4.0	86.2	8.7	140.2	13.4	88.3	314.7
BSR 2	4.5	90.7	8.2	126.6	14.2	61.3	278.6
IISR Pragati	3.8	51.8	7.2	125.4	8.5	44.1	221.2
Salem local	5.2	115.9	10.5	170.6	9.7	49.5	336.0
IISR Prathibha	4.1	86.5	10.2	121.5	10.4	85.8	293.8
Salem Narayappanur	3.7	56.1	8.0	94.1	8.7	27.1	177.3
Lakadong	2.5	21.5	2.7	19.8	2.6	3.8	45.1
Salem Eraiyur	3.5	72.1	8.2	106.1	8.4	28.8	207.0
Erode local	3.5	69.1	7.7	88.8	8.0	33.5	191.4
Megha Turmeric	4.2	66.8	11.0	99.6	10.7	38.7	205.1
Rajendra Sonia	2.7	32.9	6.4	49.0	4.4	19.2	101.1
Suroma	2.6	39.4	5.6	38.6	3.5	9.3	87.3
NDH 11	4.0	99.2	11.3	122.4	12.3	71.0	292.6
Kanti	4.2	70.3	9.3	127.2	8.5	22.7	220.2
NDH 128	4.4	70.7	8.3	94.3	7.4	25.5	190.5
CL 272	3.4	49.4	7.5	133.8	14.7	99.4	282.5
CL 258	4.7	88.4	9.2	156.5	16.4	96.3	341.2
CL 118	3.4	44.9	7.1	82.5	11.7	37.1	164.5
CL 123	4.5	66.7	7.8	70.2	9.2	40.6	177.5
CL 197	4.4	120.2	12.2	139.2	13.9	58.8	318.2
CL 225	3.5	53.0	6.3	67.8	8.2	40.9	161.7
CL 95	4.9	131.4	9.5	158.5	10.5	91.8	381.8
Mean	3.9	72.0	8.3	106.0	9.8	48.8	226.8
Minimum	2.5	21.5	2.7	19.8	2.6	3.8	45.1
Maximum	5.2	131.4	12.2	170.6	16.4	99.4	381.8
SEd	0.26	4.29	0.50	2.47	0.51	2.06	6.08
CD (P=0.05)	0.52	8.66	1.01	4.98	1.02	4.16	12.26

https://doi.org/10.37992/2021.1204.180

CL 258 and CL 95 with average of 48.8 g. Among the 22 genotypes, CL 95 recorded the highest fresh rhizome yield per plant of 381.8 g followed by CL 258 (341.2 g) and Salem local (336.0 g) **(Fig. 1)**. Better photosynthetic activity and biomass accumulation resulted in high fresh rhizome yield per plant in turmeric genotypes. CL 95, CL 258, Salem local, CL 197, CO 2, IISR Prathibha, NDH 11, CL 272 and BSR 2 recorded high fresh rhizome yield per plant, compared to mean value (226.8 g). Assessment of genetic variation and divergence is a prerequisite in breeding programme for the selection of turmeric genotypes with useful traits (Vinodhini *et al.,* 2018). In line with this, 55 turmeric genotypes were evaluated by Vinodhini *et al*. (2019) and 22 turmeric genotypes were studied by Man *et al*. (2021).

In clonally propagated crops, the genetic makeup of any population is decided by the diversity analysis and it is essential for a breeding programme to classify the whole population into homogenous clusters (Sharma and Devi, 2013). Totally six clusters were obtained from 22 turmeric genotypes and presented in **Table 3**. Among the six clusters, the highest number of turmeric genotypes were listed in cluster III (7) followed by cluster V (5). Four turmeric genotypes accommodated in cluster VI and each two genotypes in cluster I, cluster II and cluster IV. Clusters containing more number of turmeric genotypes indicates their homogeneity among them. Genetic diversity analysis in turmeric was investigated by many research workers such as Bahadur *et al*. (2016) grouped 25 turmeric accessions to six clusters using Mahalanobis distance, Mishra *et al.* (2018) classified 65 turmeric genotypes into nine clusters and Suresh *et al.* (2019) grouped 200 genotypes into three clusters based on Euclidean distance with wards method.

In this study, per cent contribution of different traits to diversity was analysed **(Fig. 2)** and the highest per cent of divergence was contributed by fresh rhizome yield per plant (41.99 %) followed by weight of primary rhizomes per plant (28.14 %) and weight of secondary rhizomes per plant (22.08 %). Plant height (0.43 %), weight of mother rhizomes per plant (0.43 %), the number of primary rhizomes per plant (1.30 %) and the number of secondary rhizomes per plant (5.63 %) contributed in minor levels. Rhizome yield is one of the important trait for crop improvement in turmeric, hence this analysis is effective to choose the trait of importance for the selection of better yielding genotypes. Verma *et al*. (2014) reported similar results with the highest contribution of diversity by rhizome yield of turmeric.

With regard to intra and inter cluster distance, range of intra cluster distance between clusters was from 6.29 to 24.37 and results are represented in **Table 4**. Maximum intra cluster distance was observed in cluster V (24.37) subsequently by cluster III (23.39), cluster VI (19.51) and least intra cluster distance was registered by cluster II (6.65) and cluster I (6.29). Cluster with high intra cluster distance have significant amount of diversity within them and less diversity exists in clusters which showed less intra cluster distance. Among the six clusters, inter cluster distance was varied from 15.25 to 57.74. The maximum

Fig. 1. High yielding turmeric genotypes

Table 3. Clustering pattern of turmeric genotypes on the basis of Mahalanobis D² values

Cluster	Number of genotypes	Name of turmeric genotypes
I	2	Erode local & NDH 128
II	2	CL 123 & CL 225
III	7	CO 2, BSR 2, IISR Pragati, Salem local, IISR Prathibha,, Salem Narayappanur & CL 118
IV	2	Lakadong, & Suroma
V	5	Salem Eraiyur, Megha Turmeric, Rajendra Sonia, NDH 11 & Kanti
VI	4	CL 272, CL 258, CL 197 & CL 95

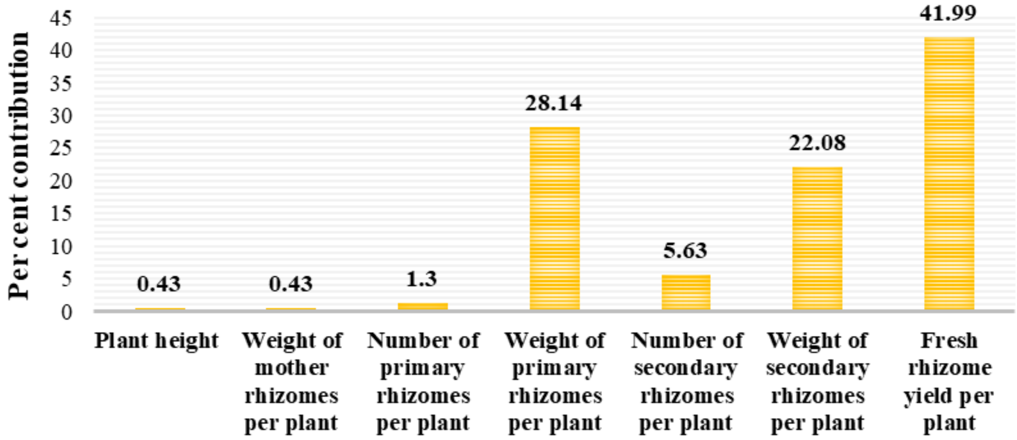

Fig.2. Per cent contribution of biometrical and yield traits to genetic diversity

Table 4. Average intra (diagonal) and inter (between) cluster distance of turmeric genotypes

Cluster	I	II	III	IV	V	VI
I	6.29	15.25	23.66	28.15	16.89	33.43
II		6.65	25.59	30.02	21.89	34.27
III			23.39	46.75	25.80	24.48
IV				8.38	35.33	57.74
V					24.37	33.29
VI						19.51

inter cluster was observed between cluster IV and cluster VI (57.74) followed by cluster III and cluster IV (46.75). The findings revealed that, wide genetic diversity was noticed among these clusters containing genotypes and useful for breeding programme of turmeric (Momina *et al*., 2011). Minimum inter cluster distance was registered between cluster I and cluster II (15.25). This result suggested that, turmeric genotypes of these clusters are closely related to each other, less diverse and are not useful for further crop improvement. Intra and inter cluster distance was observed by Bahadur *et al.* (2016) in 25 turmeric accessions with six clusters and Paw *et al.* (2020) in 78 *Curcuma caesia* germplasm with nine clusters.

Cluster wise mean performance was studied in turmeric genotypes for 12 traits and is presented in **Table 5.** The highest cluster mean values for plant height was recorded by cluster VI (92.84 cm) followed by cluster II (91.78 cm) and cluster III (89.30 cm). Cluster III (5.48) and cluster II (5.22) registered the highest cluster mean values for number of tillers per plant. Cluster mean performance for the number of leaves per plant was maximum in cluster VI (7.31) and cluster III (7.29). Maximum cluster mean values for leaf length was observed in cluster VI (42.33 cm) and cluster II (41.53 cm). Mostly similar cluster mean values were registered by all clusters (12.24 cm to 12.92 cm) except cluster I (10.79 cm) and cluster IV (10.44 cm) for leaf width. The highest mean values for number of mother rhizomes per plant and weight of mother rhizomes per plant was recorded by cluster VI (4.33 and 97.35 g) and cluster III (4.08 and 75.99 g), respectively. Cluster mean performance for number of primary rhizomes per plant was high in cluster VI (9.58) followed by cluster V (9.24). Cluster VI followed by cluster III registered maximum cluster mean values for weight of primary rhizomes per plant (147.02 g and 122.99 g), number of secondary rhizomes per plant (13.86 and 10.93), weight of secondary rhizomes per plant (86.58 g and 56.16 g) and fresh rhizome yield per plant (330.94 g and 255.14 g), respectively. Mishra *et al.* (2018) reported that cluster mean values of 65 turmeric genotypes into nine clusters. Yield potential of turmeric is decided by the plant characters such as plant height, number of leaves per plant and leaf length (Narayanpur and Hanamashetti, 2003). Cluster VI showed the highest mean values for all plant characters and also yield characters and is useful for genetic improvement programme.

Table 5. Cluster wise mean performance of various characters in turmeric genotypes

Cluster	PH	NOT	NOL	LL	LW	NMR	WMR	NPR	WPR	NSR	WSR	FRY
I	71.20	4.69	6.93	33.04	10.79	3.93	69.90	8.03	91.56	7.68	29.50	190.95
II	91.78	5.22	7.15	41.53	12.73	4.01	59.85	7.08	69.01	8.68	40.76	169.62
III	89.30	5.48	7.29	39.02	12.24	4.08	75.99	8.56	122.99	10.93	56.16	255.14
IV	49.54	2.47	5.69	27.62	10.44	2.53	30.47	4.17	29.18	3.03	6.55	66.18
V	77.41	4.13	6.86	37.92	12.36	3.72	68.26	9.24	100.87	8.87	36.08	205.20
VI	92.84	5.12	7.31	42.33	12.92	4.33	97.35	9.58	147.02	13.86	86.58	330.94

PH – Plant height (cm), NOT – Number of tillers per plant, NOL – Number of leaves per plant, LL – Leaf length (cm), LW – Leaf width (cm), NMR – Number of mother rhizomes per plant, WMR – Weight of mother rhizomes per plant (g), NPR – Number of primary rhizomes per plant, WPR – Weight of primary rhizomes per plant (g), NSR – Number of secondary rhizomes per plant, WSR – Weight of secondary rhizomes per plant (g) and FRY – Fresh rhizome yield per plant (g)

In the present study, all the observed traits registered wide variation among the turmeric genotypes. Salem local, IISR Prathibha, CO 2, CL 95, CL 197, CL 258, BSR 2 and Kanti recorded better performance for plant height, number of tillers per plant, number of leaves per plant, leaf length and leaf width. CL 95, CL 258, Salem local, CL 197, NDH 11, CL 272, CO 2 and BSR 2 were exhibited superior performance for yield and yield attributing traits. Twenty-two turmeric genotypes were grouped into six clusters. Fresh rhizome yield per plant followed by weight of primary rhizomes per plant and weight of secondary rhizomes per plant contributed majorly for genetic divergence. Among the clusters, cluster VI and cluster IV registered maximum inter cluster distance. These parameters and analysis are much useful for the identification of superior yielding genotypes in turmeric and to further crop improvement programme.

ACKNOWLEDGEMENT

The author expresses gratitude to the Department of Science and Technology (INSPIRE Fellowship) for the provision of funds to carry out this research work.

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