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GENETIC VARIABILITY AND CHARACTER ASSOCIATION STUDIES IN TURMERIC (*CURCUMA LONGA* L.) GENOTYPES FOR GROWTH AND YIELD PARAMETERS

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ABSTRACT

An experiment aimed at assessing genetic variability and character association between growth, yield and its related traits in twenty-two turmeric genotypes along with four checks was conducted at instructional farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *Kharif* 2020 and *Kharif* 2021. The experiment was designed as per Randomized Complete Block Design (RCBD) with three replications and the data was collected for 21 parameters. The analysis of variance revealed that significant difference was observed for all the traits at 5% level of significance among the genotypes studied. In general, the magnitude of PCV (Phenotypic Coefficient of Variability) was higher than GCV (Genotypic Coefficient of Variability) for all the characters. High PCV and GCV were observed for the traits like leaf petiole length (23.44, 22.15), primary rhizomes per plant (22.08, 20.88), secondary rhizomes per plant (30.04, 27.56), weight of secondary rhizomes (41.78, 41.05), number of tertiary rhizomes (62.59, 61.87), number of mother rhizome (22.44, 20.41), weight of mother rhizome (28.72, 27.07), leaf blotch (45.92, 45.22) and total curcuminoids (37.54, 36.89) respectively. High heritability coupled with high Genetic Advance as per cent Mean (GAM) was observed for the traits such as, number of shoots, leaf petiole length, primary rhizomes per plant, weight of primary rhizomes, number of secondary rhizomes per plant, weight of secondary rhizomes, number of tertiary rhizomes, weight of tertiary rhizomes, leaf blotch and total curcuminoids indicating that these traits are governed by additive genes so, direct selection will give desirable outcomes. Weight of secondary rhizome showed highest positive correlation with weight of rhizome per plant followed by weight and number of primary rhizomes per plant.

***Key words*:** Turmeric, Variability, Heritability, Genetic advance, Correlation

Introduction

Turmeric (*Curcuma longa* L.) is an esteemed ancient spice native to India, holds significant cultural and culinary importance. As a primary rhizomatous spice, it is predominantly cultivated and exported from India. Belonging to the Zingiberaceae family, turmeric encompasses approximately 70 species and is predominantly found across South and Southeast Asia. This herbaceous perennial plant is highly valued for its underground rhizomes, which serve as a versatile spice, condiment, dye, and crucial ingredient in the cosmetic and pharmaceutical industries, notably in the formulation of anti-cancer medications (Srimal, 1997). Turmeric propagation primarily occurs through vegetative method utilizing its rhizomes. India serving as the world's largest producer of turmeric, its cultivation and utilization continue to play a pivotal role in global markets. Approximately 11 lakh metric tons of turmeric are produced worldwide per annum. India taking lead in production, consumption, and export and contributes 80% to the global turmeric production followed by China (8%), Myanmar (4%), Nigeria (3%) and Bangladesh (3%) (Anon., 2022-23).

Thus, it is crucial to develop high yielding varieties with best quality parameters. Studying genetic variability is pivotal for enhancing the genetic improvement of turmeric. The interplay between genetic makeup and environmental factors shapes observable diversity patterns crucial for developing high-yielding varieties with desired quality traits. Breeders rely on comprehensive assessments of genetic variability within germplasm collections as a fundamental resource for breeding programs (Ghosh *et al.*, 2013). Understanding the potential for advancements through selections and unraveling phylogenetic relationships is contingent upon this variability. Given that yield is a complex trait influenced by numerous genes, a thorough understanding of its inheritance patterns and contributing factors is paramount for its breeding success. In addition to evaluating genetic variability, character association studies are invaluable for providing breeders with insights to make informed decisions in the crop improvement process, guiding them towards desired outcomes. Hence, the present investigation aimed to explore genetic variability and correlations between growth, yield and its related traits in turmeric.

Material and Methods

The present experiment includes 22 turmeric genotypes along with four checks collected from different sources were listed in the Table 1. The collected materials were sown as per Randomized Complete Block Design (RCBD) design with three replications during *kharif* 2020 and 2021 at the Instructional Farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Plot size of 3 m × 2.4 m with spacing of 30 × 30 × 60 cm accommodating 40 plants per plot were maintained. The data for 21 growth, yield and its related traits were recorded for each genotype. The recorded data was subjected to statistical analysis using the programme windostat 9.30 ver. The analysis of variance conducted according to the method suggested by Panse and Sukhatme (1989). The GCV and PCV were calculated according to Burton and Devane (1953). Subsequently, heritability has been estimated as per the formula given by Lush (1940) and genetic advance as per cent of mean at 5 % selection intensity were worked out for each character adopting the formula given by Johnson *et al.*, (1955).

Methodology for extraction of curcuminoids from turmeric

The curcuminoids were extracted from turmeric powder from all the genotypes separately by dissolving 50g of turmeric powder in 125ml of dichloromethane followed by constant stirring using magnetic stirrer. This mixture was refluxed for 1hr at 50^{o}C and then filtered using Buchner funnel to separate the mother liquor. Then the mother liquor was concentrated on rotary evaporator

Table 1: List of turmeric genotypes used under study along with its derived sources.

S.	Genotype	Source
1	PWTM-1	Department of Horticulture, Dr. PDKV, Akola
2	PWTM-3	Department of Horticulture, Dr. PDKV, Akola
3	PWTM-4	Department of Horticulture, Dr. PDKV, Akola
4	PWTM-5	Department of Horticulture, Dr. PDKV, Akola
5	PWTM-6	Department of Horticulture, Dr. PDKV, Akola
6	PWTM-8	Department of Horticulture, Dr. PDKV, Akola
7	PWTM-9	Department of Horticulture, Dr. PDKV, Akola
8	PWTM-10	Department of Horticulture, Dr. PDKV, Akola
9	PWTM-11	Department of Horticulture, Dr. PDKV, Akola
10	PWTM-14	Department of Horticulture, Dr. PDKV, Akola
11	PWTM-19	Department of Horticulture, Dr. PDKV, Akola
12	AKTL-3	Department of Horticulture, Dr. PDKV, Akola
13	AKTL-8	Department of Horticulture, Dr. PDKV, Akola
14	AKTL-10	Department of Horticulture, Dr. PDKV, Akola
15	AKTL-11	Department of Horticulture, Dr. PDKV, Akola
16	AKTL-12	Department of Horticulture, Dr. PDKV, Akola
17	AKTL-13	Department of Horticulture, Dr. PDKV, Akola
18	AKTL-16	Department of Horticulture, Dr. PDKV, Akola
19	AKTL-18	Department of Horticulture, Dr. PDKV, Akola
20	AKTL-19	Department of Horticulture, Dr. PDKV, Akola
21	PDKV Waigaon (Check-1)	Department of Horticulture, Dr. PDKV, Akola
22	Roma (PTS 10) (Check-2)	Local from Telangana
23	Salem (Check-3)	Local predominant type of MH
24	IISR Pragati (Check-4)	IISR Calicut
25	AKTS 20	Department of Horticulture, Dr. PDKV, Akola
26	AKTS 21	Department of Horticulture, Dr. PDKV, Akola

resulting in dark orange oily liquid. This liquid was further precipitated by adding 50ml of heaxane. The curcuminoids obtained after precipitation was checked for its purity by UV-vis. spectrophotometer.

Results and Discussion

Table 2 represents the analysis of variance which reveals that, significant differences were observed for all traits studied among the genotypes indicating that there is a sufficient amount of variability present in the genotypes.

The genetic variability parameters of turmeric genotypes for 21 different characters were detailed in Table 3 and Fig. 1. In general, the Phenotypic Coefficient of Variation (PCV) values surpassed their corresponding Genotypic Coefficient of Variation (GCV) values, suggesting the considerable influence of the environment on the expression of these traits. A smaller disparity between GCV and PCV values indicates minimal environmental influence, whereas a larger difference signifies that higher environmental impact on these trait expressions. High magnitude of PCV and GCV were observed for number of tertiary rhizomes (62.59, 61.87) followed by leaf blotch (45.92, 45.22), weight of secondary rhizomes (41.78, 41.05), total curcuminoids (37.54, 36.89), number of secondary rhizomes per plant (30.04, 27.56), weight of mother rhizome (28.72, 27.07), leaf petiole length (23.44, 22.15), number of mother rhizome (22.44, 20.41) and number of primary rhizomes per plant (22.08, 20.88) respectively. This suggests that, the variability of these traits is majorly contributed from genetics of the genotypes rather than environment. Thus, breeder should rely on these traits for crop improvement. These findings were in consistent with the results of earlier researchers like Jan *et al.*, (2012), Singh and Ramakrishna (2014), Verma *et al.*, (2014), Luiram *et al.*, (2018) and Mamatha *et al.*, (2020).

Moderate GCV values were observed in the traits like number of shoots (14.63), weight of rhizome per plant (19.07) and weight of primary rhizome per plant (16.37)

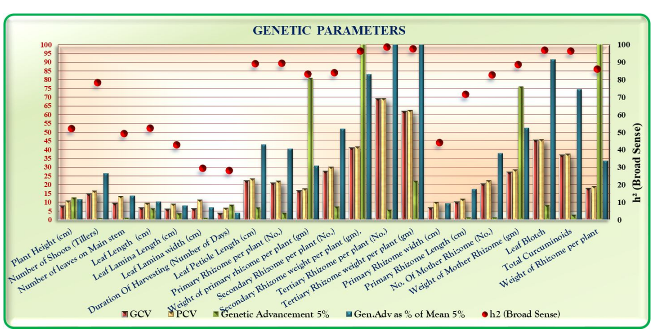

Fig. 1: Graphical representation of various genetic parameters in turmeric.

Table 2: The Analysis of variance for various yield and yield related traits in turmeric.

ANOVA Summary				
S. no.	**Source**	**Mean Sum of Squares (MSS)**		
	Degrees of freedom	**Replication**	**Treatment**	**Error**
		2	**25**	**50**
1	Plant Height (cm)	132.868	283.942**	66.705
2	Number of Shoots (Tillers)	0.108	0.636**	0.054
3	Number of leaves on Main stem	0.305	2.613**	0.665
4	Leaf Length (cm)	39.494	71.344**	16.525
5	Leaf Lamina Length (cm)	20.095	32.845**	10.079
6	Leaf Lamina width (cm)	2.019	4.635**	2.048
7	Duration of Harvesting (No. of Days)	42.923	335.381**	154.39
8	Leaf Petiole Length (cm)	0.336	40.991**	1.581
9	Primary Rhizome per plant (No.)	0.362	13.041**	0.496
10	Weight of primary rhizome per plant (gm)	578.413	5937.22**	368.516
11	Secondary Rhizome per plant (No.)	2.258	49.566**	2.921
12	Secondary Rhizome weight per plant (gm)	450.695	20651.617**	245.274
13	Tertiary Rhizome per plant (No.)	0.068	22.323**	0.086
14	Tertiary Rhizome weight per plant (gm)	5.561	358.49**	2.76
15	Primary Rhizome width (cm)	0.084	0.159**	0.047
16	Primary Rhizome Length (cm)	0.026	2.067**	0.239
17	No. Of Mother Rhizome (No.)	0.194	1.492**	0.097
18	Weight of Mother Rhizome (gm)	16.991	4824.083**	194.171
19	Leaf Blotch	1.04	50.702**	0.52
20	Total Curcuminoids	0.001	5.553**	0.065
21	Weight of Rhizome per plant	3165.541	38555.631**	1977.735

Table 3: Estimation of various genetic parameters in 21 traits of turmeric.

S. No.	Genetic Parameters	Mean	Range	GCV	PCV	h^2 (Broad Sense)	GA	GAM
1	Plant Height (cm)	109.08	95.11-137.47	7.8	10.81	52.051	12.65	11.59
2	Number of Shoots	3.01	2.28-3.92	14.63	16.53	78.339	0.8	26.67
3	Number of leaves on Main stem	8.56	7.01-10.23	9.41	13.39	49.397	1.17	13.62
4	Leaf Length (cm)	62.58	54.49-75.65	6.83	9.43	52.511	6.38	10.2
5	Leaf Lamina Length (cm)	46.22	40.19-55.80	5.96	9.1	42.951	3.72	8.05
6	Leaf Lamina width (cm)	14.91	13.44-18.18	6.23	11.44	29.623	1.04	6.98
7	Duration Of Harvesting	217.77	189.00-236.33	3.57	6.73	28.097	8.48	3.9
8	Leaf Petiole Length (cm)	16.37	7.63-23.95	22.15	23.44	89.26	7.05	43.1
9	Primary Rhizome per plant	9.79	5.02-13.17	20.88	22.08	89.4	3.98	40.67
10	Weight of primary rhizome per plant (gm)	263.23	175.51-336.33	16.37	17.92	83.436	81.07	30.8
11	Secondary Rhizome per plant	14.31	6.73-24.33	27.56	30.04	84.183	7.45	52.09
12	Secondary Rhizome weight per plant	200.92	113.33-534.07	41.05	41.78	96.52	166.92	83.08
13	Tertiary Rhizome per plant	3.95	1.43-12.57	68.99	69.39	98.849	5.58	141.3
14	Tertiary Rhizome weight per plant (gm)	17.60	8.65-48.27	61.87	62.59	97.725	22.18	126
15	Primary Rhizome width (cm)	2.85	2.28-3.48	6.77	10.19	44.162	0.26	9.27
16	Primary Rhizome Length (cm)	7.81	6.45-11.14	9.99	11.79	71.842	1.36	17.45
17	No. Of Mother Rhizome	3.34	2.00-4.65	20.41	22.44	82.736	1.28	38.24
18	Weight of Mother Rhizome (gm)	145.15	70.07-241.82	27.07	28.72	88.825	76.27	52.55
19	Leaf Blotch	9.04	1.11-16.05	45.22	45.92	96.984	8.3	91.74
20	Total Curcuminoids	3.67	1.69-6.50	36.89	37.54	96.543	2.74	74.66
21	Weight of Rhizome per plant	624.18	414.00-1011.98	17.69	19.07	86.043	211	33.8

indicating slight effect of environment on expression of these traits and caution should be taken while selecting these traits. While moderate PCV values were observed in the traits like number of shoots (16.53), number of leaves on main stem (13.39), leaf lamina width (11.44), weight of primary rhizome per plant (17.92), weight of rhizome per plant (17.69), primary rhizome width (10.19), plant height (10.81) and primary rhizome length (11.79) indicating influence of environment on expression of these traits. Similar findings were also observed by Jan *et al.*, (2011), Rajyalakshmi *et al.*, (2013), Prajapati *et al.*, (2014), Maurya *et al.*, (2018) and Pathak *et al.*, (2021).

The traits such as, plant height (7.8), number of leaves on main stem (9.41), leaf length (6.83), leaf lamina length (5.96), leaf lamina width (6.23), duration of harvesting (3.57), primary rhizome width (6.77) and primary rhizome length (9.99) were recorded low estimates of GCV. While the traits such as, leaf length (9.43), leaf lamina length (9.10) and duration of harvesting (6.73) exhibited low PCV values indicating these traits are highly influenced by environment. These results were in adjacent with the findings of Singh *et al.*, (2012), Jayasree *et al.*, (2014) and Venugopal *et al.*, (2017).

Heritability ranged from 28.10% (duration of harvesting) to 98.85% (number of tertiary rhizomes per plant) showing wide range of heritability. Higher estimates of heritability in broad sense were observed in all the traits studied except few growth parameters. However, maximum heritability was observed in number of tertiary rhizomes per plant (98.85%) followed by weight of tertiary rhizomes per plant (97.73%), leaf blotch (96.98%), total curcuminoids (96.54%) and weight of secondary rhizomes per plant (96.52%). These results were in agreement with the results of Jalata *et al.*, (2011), Verma *et al.*, (2014) and Pathak *et al.*, (2021).

Traits such as, number of shoots, leaf petiole length, number of primary rhizomes per plant, weight of primary rhizomes per plant, number of secondary rhizomes per plant, weight of secondary rhizomes per plant, number of tertiary rhizomes per plant, weight of tertiary rhizomes per plant, weight of rhizome per plant, leaf blotch, and total curcuminoids exhibited high heritability coupled with substantial genetic advance. This suggests that, these traits are primarily governed by additive genes, making direct selection of these traits likely to yield expected outcomes. Similar findings were reported by Singh *et al.*, (2018) for traits such as plant height, plant girth, weight of fresh rhizome per plant, weight of mother rhizome, weight of primary rhizomes per plant, weight of secondary rhizomes per plant, and weight of tertiary rhizomes per plant. Consistent results were also documented by other researchers such as Singh *et al.*, (2020) and Mamatha *et al.*, (2020).

Understanding the interplay between different traits

Table 4: Estimation of phenotypic and genotypic correlation among various yield and yield related traits in turmeric.

Phenotypic and Genotypic Correlation Matrix		Plant Height (cm)	No. of shoots	No. of leaves on main stem	Leaf length (cm)	Duration of Harvesting	Primary rhizome per plant	Primary rhizome weight per plant	Secondry rhizome weight per plant	Tertiary rhizome weight per plant	No. of mother rhizome	Weight of mother rhizome (g)	Total Curcuminoids	Weight of rhizome
Plant Height (cm)	P	1	-0.0872	-0.0142	0.416**	-0.0537	0.1359	0.0875	0.1608	-0.1762	-0.0774	0.224*	0.276*	0.239*
	G	1	-0.1734	0.1784	0.399**	0.0964	0.229*	0.1694	0.242*	-0.248*	-0.1051	0.376**	0.397**	0.331*
Number of Shoots	P		1	0.0558	0.0752	0.0735	0.286*	0.1385	0.1642	0.0667	0.1724	-0.0309	-0.249*	0.168
	G		1	0.285*	0.0492	0.202	0.408**	0.1998	0.1815	0.076	0.278*	0.0012	-0.255*	0.2213
Number of leaves on Main stem	P			1	-0.1882	-0.0097	0.0008	0.0562	0.0012	-0.1734	0.0398	0.088	0.261*	0.0733
	G			1	-0.1426	-0.1419	-0.0044	0.1611	0.037	-0.241*	0.135	0.1883	0.338*	0.1033
Leaf Length (cm)	P				1	0.0269	0.257*	0.0761	0.0858	-0.0064	0.1201	0.095	0.1038	0.1415
	G				1	0.228*	0.437**	0.1539	0.1536	0.0036	0.1543	0.1266	0.1506	0.2067
Duration of Harvesting	P					1	0.0467	-0.0136	-0.1912	-0.1809	0.334*	0.302*	0.1242	-0.1104
	G					1	0.0148	-0.1561	-0.380**	-0.317*	0.594**	0.588**	0.228*	-0.111
Primary Rhizome per plant	P						1	0.701**	0.2005	0.1698	0.299*	0.1897	-0.319*	0.491**
	G						1	0.720**	0.2147	0.1799	0.324*	0.2121	-0.340*	0.543**
Primary rhizome weight per plant	P							1	0.334*	0.244*	0.104	0.1981	-0.228*	0.675**
	G							1	0.342*	0.271*	0.0995	0.226*	-0.252*	0.785**
Secondary rhizome weight per plant	P								1	0.638**	-0.1903	-0.311*	-0.324*	0.759**
	G								1	0.649**	-0.1872	-0.322*	-0.342*	0.854**
Tertiary rhizome weight per plant	P									1	-0.2185	-0.472**	-0.658**	0.483**
	G									1	-0.236*	-0.501**	-0.672**	0.519**
No. of mother rhizome	P										1	0.738**	0.0556	0.1323
	G										1	0.732**	0.0487	0.1405
Weight of Mother Rhizome (g)	P											1	0.294*	0.1446
	G											1	0.312*	0.1591
Total Curcuminoids	P												1	-0.288*
	G												1	-0.312*
Weight of Rhizome	P													1
	G													1

Note: P- Phenotypic Correlation Matrix; G- Genotypic Correlation; * Significance at 5% level; ** Significance at 1% level

is crucial in breeding programs, enabling breeders to make recommended selections. Having insights into the nature of gene action and the degree of association among traits is pivotal. Indirect selection proves effective particularly, when desirable traits exhibit low heritability. The efficacy of indirect selection depends on correlated responses. Understanding correlations is vital when selecting multiple traits simultaneously. Even when focusing on a single trait, knowledge of correlations is essential to prevent unintended changes in other traits.

In the majority of traits, the genotypic correlation was observed to be slightly higher than the phenotypic correlation, indicating a stronger influence of genetic factors in determining these associations. This underscores that environmental conditions have limited impact on altering the expression of phenotypic associations (Table 4). At both phenotypic and genotypic levels, the weight of rhizome exhibited the highest significant positive correlation with secondary rhizome weight per plant (0.759, 0.854), followed by primary rhizome weight per plant (0.675, 0.785), number of primary rhizomes per plant (0.491, 0.543) and tertiary rhizome weight per plant (0.483, 0.519) respectively. Additionally, the weight of the mother rhizome showed a significant positive correlation with number of mother rhizomes (0.738, 0.732) followed by duration of harvesting (0.302, 0.588) and total curcuminoids (0.294, 0.312). Primary rhizome weight per plant positively correlated with number of primary rhizomes per plant (0.701, 0.720). Similar correlation was observed between tertiary rhizome weight per plant with number of tertiary rhizomes per plant (0.638, 0.649) and secondary rhizome weight per plant with number of secondary rhizomes per plant (0.334, 0.342). These findings suggested that, enhancing these traits will subsequently improve rhizome weight per plant, emphasizing their importance for yield enhancement in turmeric. Vithhya *et al*., (2021) reported a significantly positive association of fresh rhizome yield per plant with all biometrical traits at both phenotypic and genotypic levels, consistent with the findings of Mamatha *et al*., (2020) and Singh *et al*., (2018).

Total curcuminoids recorded highest significant negative correlation with tertiary rhizome weight per plant (-0.658, -0.672) followed by secondary rhizome weight per plant (-0.324, -0.342), number primary rhizomes per plant (-0.319, -0.340), weight of rhizome (-0.288, -0.312), number of shoots (-0.249, -0.255) and primary rhizome weight per plant (-0.228, -0.252) at both phenotypic and genotypic level respectively indicating the negative impact on yield in turmeric. Similar results were also reported by Singh *et al*., (2018), Suresh *et al*., (2019), Sivakumar *et al*., (2020), Paw *et al*., (2020) and Man *et al*., (2021) in turmeric.

Conclusion

The exploration of genetic variability parameters and character associations provides crucial insights into the diversity within genotypes and identifies key traits for crop enhancement. Our study revealed that significant variation across all examined traits among the genotypes. Notably, traits such as the number of tertiary rhizomes, leaf blotch, weight of secondary rhizomes, total curcuminoids, secondary rhizomes per plant, weight of mother rhizome, leaf petiole length, number of mother rhizome, and primary rhizomes per plant exhibited substantial variability. Traits like the number of shoots, leaf petiole length, number of primary rhizomes per plant, weight of primary rhizomes, number of secondary rhizomes per plant, weight of secondary rhizomes, number of tertiary rhizomes, weight of tertiary rhizomes, weight of rhizome per plant, leaf blotch, and total curcuminoids exhibited high heritability coupled with high genetic advance as percent mean, suggesting their regulation by additive genes and suitability for direct selection. Moreover, the weight of rhizome showed strong positive correlations with secondary rhizome weight per plant, primary rhizome weight per plant, number of primary rhizomes per plant, and tertiary rhizome weight per plant at both phenotypic and genotypic levels, indicating their importance in selection for crop improvement efforts in turmeric.

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