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Research Note

Genetic Variability, Character Association and Path Coefficient analysis in Turmeric (*Curcuma longa L.*)

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Abstract
Genetic variability, correlation and path analysis was studied for rhizome yield and its component characters in 30 diverse genotype of turmeric. The analysis of variance revealed the significant differences among the genotypes for all the traits indicating presence of sufficient variability among the genotypes for various traits. On the basis of the performance the accessions NVST 6, NVST 43, NVST 27, NVST 26 and Sugandhum found promising in rhizome yield. The high GCV and PCV were observed for weight of secondary rhizome per plant, weight of mother rhizome per plant, weight of primary rhizome per plant, dry rhizome yield per plant and initial weight of rhizome, Whereas, plant height, leaf width, leaf length and curcumin content showed low GCV and PCV. The high heritability combined with high genetic advance as per cent of mean was observed for days to maturity and wet rhizome yield per plant indicated that selection may be effective for this character. The characters like weight of mother rhizomes per plant, weight of primary rhizomes per plant and weight of secondary rhizomes per plant showed significant positive correlation with wet rhizome yield per plant at both genotypic and phenotypic levels whereas leaf width and number of primary rhizome per plant had positive and significant correlation at genotypic level indicating that these three traits were main yield attributing traits. The path analysis indicated that weight of secondary rhizomes, weight of mother rhizomes, number of leaves per plant and plant height had maximum direct effect on rhizome yield. These characters should be used as selection criterion for further improvement of rhizome yield in turmeric

Key words: Turmeric,Genetic variation, Correlation, Path analysis

Turmeric (*Curcuma longa* L. Syn *Curcuma domestica* Val.) is a herbaceous plant belonging to the family Zingiberaceae and order Sacitaminae. It's chromosome number is 2n = 32. The karyomorphological studies concluded that the species seems to be allotetraploid with basic number of X = 8 (Sato, 1960). India is known as the land of spices and they are popular for their flavour and medicinal properties both domestic and international market. Turmeric believed to be originated in South-East Asia and some species are naturalized in north eastern regions of India and Java. It is cultivated in India, Sri Lanka, Indonesia, China, Peru, Jamaica and other tropical and subtropical countries. In India, it is mainly grown in the states of Andhra Pradesh, Orissa, Tamil Nadu, Assam, Maharashtra, Karnataka and Gujarat.

It is cultivated for its underground rhizomes which are mainly used as spices, condiments, dye stuff in drug and cosmetic industry. It forms an important adjuvant in Indian culinary as it tends colour and aroma to various dishes. It is also used in pickles and curries, colouring agent in textile and confectionary industries. Further, turmeric has lots of medicinal properties. Traditionally it is used in Indian system of medicine as stomachic, carminative, blood purifier, vermicide and antiseptic. Wound healing property of turmeric is well known to Indians since long. The turmeric rhizome contains a variety of pigments among which 'curcumin' is the major pigment responsible for colour which varies from 3.5 to 9.0 per cent in different varieties. Yield of the economic component is a very complex character and it is the result of interaction of a number of factors inherent both in plant and the environment in which the plant is grown. Therefore, variability exist within each component trait must be exploited by selection to realize maximum gain in rhizome yield. Correlation and path coefficient analyses together gives a clear cut picture of interrelationships and relative contribution of independent characters on dependent variable which enables to a plant breeder to apply suitable selection procedures for crop improvement. The present investigation was, therefore, conducted to find out the major yield contributing traits in turmeric.

Thirty turmeric accessions were received from different parts of Gujarat and those were evaluated at research farm of Medicinal and Aromatic Plants Project, Anand Agricultural University, Anand. The experiment was laid out in randomized block design having three replication with the each two rows of three meter length with 45cm and 20cm inter and intra row spacing, respectively. The recommended agronomic practices and plant

protection measures were followed timely for the successful raising of the crop. Five competitive plants were randomly selected and tagged after leaving the one plant in each border row in every plot of all the replications to record the observations on rhizome yield and other morphological traits. The mean value of these plants was computed and used for statistical analysis. Analysis of variance to test the significant difference among accessions for each character was carried out as per methodology advocated by (Panse and Sukhatme 1967a). PCV and GCV were calculated by the formula given by (Panse and Sukhatme 1967b), heritability in broad sense (h^2) was worked out by using the formula suggested by (Burtan and Devane, 1953) and genetic advance *i.e*., the expected genetic advance were calculated by using the procedure given by (Johnson *et al*., 1955). The genotypic and phenotypic correlation were calculated following the method of Singh and Chaudhary (1985) whereas the path coefficient analysis as per method given by Dewey and Lu (1959).

Highly significant mean squares due to genotypes for all the characters except plant height and number of tillers per plant revealed the presence of enough genetic variability in the material under study (Table 1). The genotypic coefficient of variation provides a measure to compare of genetic variability present in twenty parameters (Table 2). In general, phenotypic coefficient of variation was higher than GCV. These findings are in agreement with the findings of (Jayasree*et al*., 2006). High genotypic coefficient of variation was recorded for weight of secondary rhizome per plant, weight of mother rhizome per plant, weight of primary rhizome per plant, dry rhizome yield per plant, initial weight of rhizome, number of mother rizhomes per plant, number of secondary rhizomes per plant and wet rhizome yield per plant. Similar finding were reported by (Hazra *et al.*, 2000).

The heritability estimates help the breeders in selection based on the phenotypic performance. In the present study the estimation of heritability ranged from plant height (11.3) to days to maturity (95.00). High heritability was observed for all traits except plant height, leaf length, leaf width, number of leaves per plant, number of tillers per plant and curcumin content. Similar findings were observed by Singh *et al. (*2003) and Nirmal *et al. (*1992). High genetic advance as percent of mean was recorded for weight of secondary rhizome per plant, weight of mother rhizome per plant, dry rhizome yield per plant, initial weight of rhizome, number of leaves per plant, number of mother rizhomes per plant, number of secondary rhozomes per plant, length of mother rhizome, core diameter of primary rhizome and wet rhizome yield per plant (Table 2). High heritability coupled with genetic advance was observed for the above traits except for number of leaves per plant. The similar results are also noticed by (Lynrah *et al.*, 1998).

Correlation: Correlation analysis suggested that the magnitude of genotypic correlation were higher as compared to their corresponding phenotypic correlations indicating the inherent relationship among the characters studied (Table 3 and 4). Wet rhizome yield per plant was significant and positively correlated with weight of mother rhizome per plant, weight of primary rhizomes per plant, and weight of secondary rhizome per plant showed significant positive correlation with wet rhizome yield per plant at both genotypic and phenotypic levels. The present findings were in close conformity with rhizome yield by Sasikumar (1992), Hazra *et al.* (2000), Ravindra (2001), Narayanpur and Hanamashetti (2003) and Yadav *et al.* (2006).

Path coefficient analysis: In turmeric wet yield of rhizome per plant is the result of direct and indirect effects of several yield contributing characters. To know the contribution of various characters towards wet rhizome yield per plant, the significant genotypic correlation of different traits with wet rhizome yield per plant have been partitioned into their direct and indirect effects. This will provide more precise information for the selection of important traits, which may contribute more towards wet yield of rhizomes per plant. Direct and indirect effects of nineteen casual variables on wet yield of rhizomes per plant are presented in Table 5.

Nineteen characters were considered as casual variables. The high positive direct effect on wet rhizome yield per plant was that of weight of secondary rhizomes, weight of mother rhizomes, number of leaves per plant, plant height and leaf width. The character having high direct effect indicates its grater important in selection on phenotypic basis. Similar findings were also reported by Sasikumar (1992), Das *et al.* (1999), Hazra *et al.* (2000), Tomar *et al*. (2005) and Yadav *et al*. (2006). The characters number of secondary rhizomes, length of mother rhizomes, length of primary rhizomes, core diameter of secondary rhizomes and weight of primary rhizomes had positive but moderate direct effect on wet rhizome yield per plant. The characters leaf length, number of primary rhizomes, number of mother rhizomes, number of tillers per plant, core diameter of primary rhizome, days to maturity, curcumin content and dry rhizome yield per plant had negative direct effect. Similar findings were also reported by Sasikumar (1992), Das *et al.* (1999), Hazra *et al.* (2000), Tomar *et al.* (2005) and Yadav *et al.* (2006). The characters dry rhizome yield per plant, weight of mother rhizome per plant and number of mother rhizome per plant had negative

and negligible direct effect though its correlation with wet rhizome yield per plant was positive and significant, this revealed that indirect effects played a major role. In such situation indirect causal factors can be used for selection.

Based on above observations, it was concluded that Turmeric accessions NVST 6 showed maximum rhizome yield per plant followed by NVST 43, NVST 27, NVST 26 and Sugandhum among the all turmeric accessions. ANDT 6 showed maximum curcumin content (3.37 %). Characters weight of mother rhizome per plant, weight of primary rhizome per plant and weight of secondary rhizome per plant are important in the genetic improvement of rhizome yield per plant in turmeric.

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Table 1. Analysis of variance (ANOVA) showing mean sum of squares of twenty characters in turmeric

Source	Replications	Genotypes	Error
d.f	**2**	**29**	**58**
Initial Weight of rhizome	394.25**	515.29**	16.54
Plant height	435.37*	125.65	90.79
Leaf length	47.93*	45.35*"*	12.08
Leaf width	3.786*	2.49**	1.06
Numbers of leaves per plant	9.79	22.60**	4.99
Number of tillers per plant	0.43	0.30	0.20
Numbers of mother rhizome per plant	0.324**	0.56**	0.07
Number of primary rhizome per plant	4.46**	2.96**	0.88
Number of secondary rhizome per plant	4.19**	14.4**	0.72
Length of mother rhizome	0.53	2.65**	0.18
Length of primary rhizome	1.72	2.53**	0.69
Core diameter of mother rhizome	0.20*	0.59**	0.05
Core diameter of primary rhizome	0.11	0.37**	0.06
Weight of mother rhizome per plant	1340.09**	3506.3**	158.40
Weight of primary rhizome per plant	2408.50**	4018.70**	374.30
Weight of secondary rhizome per plant	47.56	464.98**	22.55
Days to maturity	104.75**	959.74**	16.49
Wet rhizome yield per plant	1382.43**	461.68**	21.16
Dry rhizome yield per plant	20271.50**	13844.59**	288.79
Curcumin content	0.22*	0.17**	0.04

*** and ** significant at 5% and 1% respectively.**

Table 2. The estimates of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), Heritability (%), expected genetic advance and expected genetic advance as percentage of mean for various characters in turmeric

Characters	GCV%	PCV%	Herita-bility %	Genetic advance	Genetic advance as % of mean
Initial Weight of rhizome	29.50	30.94	90.9	25.33	57.96
Plant height	2.88	8.55	11.3	2.37	2.00
Leaf length	6.03	8.72	47.9	4.75	8.61
Leaf width	4.86	8.74	30.9	0.79	5.57
Numbers of leaves per plant	15.94	21.68	54.0	3.67	24.14
Number of tillers per plant	7.17	19.04	14.2	0.14	4.49
Numbers of mother rhizome per plant	20.31	24.27	70.0	0.70	35.18
Number of primary rhizome per plant	13.05	19.81	43.4	1.13	17.77
Number of secondary rhizome per plant	28.10	30.24	86.3	4.09	53.75
Length of mother rhizome	11.06	12.27	81.3	1.68	20.51
Length of primary rhizome	10.26	15.00	46.8	1.10	14.42
Core diameter of mother rhizome	10.24	11.75	76.0	0.76	18.45
Core diameter of primary rhizome	12.75	16.32	61.0	0.51	20.40
Weight of mother rhizome per plant	35.48	37.92	87.6	64.40	68.41
Weight of primary rhizome per plant	31.98	36.57	76.4	62.78	57.60
Weight of secondary rhizome per plant	36.32	39.00	86.7	23.30	69.70
Days to maturity	7.35	7.54	95.0	35.61	14.76
Wet rhizome yield per plant	28.41	29.31	94.0	134.25	56.75
Dry rhizome yield per plant	30.33	32.44	87.4	23.34	58.42
Curcumin content	6.84	9.92	47.5	0.29	9.73

Table 3. Genotypic correlation coefficients among twenty characters in turmeric

Characters	PH	LL	LW	NLP	NTP	NMR	NPR	NSP	LMR	LPR	CDM	CDP	WMR	WPR	WSR	DMA	YIELD-w	YIELD-dry	CURCUMIN
IWR	0.1	0.1	0.2	0.1	-0.1	0.3	0.3	0.2	0.1	-0.1	-0.1	0.1	0.3	0.1	0.2	0.0	0.3	0.2	0.2
PH	1.0	1.0	-0.1	0.6	-0.9	-0.1	-0.2	0.4	-0.2	-0.5	0.5	0.6	-0.4	0.1	0.2	-0.2	0.2	0.2	-0.2
LL		1.0	0.7	0.2	-0.8	-0.3	0.2	-0.3	-0.2	0.1	0.2	0.2	0.0	0.1	0.1	0.0	0.2	0.3	0.6
LW			1.0	-0.2	-1.5	-0.4	0.1	-0.4	0.0	-0.1	-0.2	-0.3	0.3	0.0	0.0	0.1	0.4	0.5	-0.2
NLP				1.0	0.7	0.1	0.0	-0.2	0.3	-0.6	0.3	0.3	-0.1	-0.3	0.0	0.0	-0.1	-0.1	-0.1
NTP					1.0	0.1	-0.4	0.1	0.3	-1.3	0.0	0.1	-0.5	-0.6	-0.3	-0.2	-0.3	-0.5	-0.2
NMR						1.0	-0.4	-0.1	0.3	-0.3	0.2	0.2	0.2	-0.1	0.0	0.1	0.1	0.0	0.0
NPR							1.0	0.7	-0.2	0.3	-0.2	0.3	0.2	0.3	0.3	-0.4	0.4	0.5	-0.4
NSP								1.0	-0.3	0.2	-0.3	0.1	-0.1	0.1	0.2	-0.1	0.1	0.1	-0.1
LMR									1.0	-0.4	0.0	0.1	0.3	0.1	0.1	-0.1	0.3	0.2	0.0
LPR										1.0	-0.5	0.0	0.0	0.2	0.1	-0.2	0.2	0.3	-0.1
CDM											1.0	0.2	0.1	0.1	0.1	0.3	0.2	0.2	-0.4
CDP												1.0	0.2	0.0	0.0	-0.1	0.1	0.0	-0.6
WMR													1.0	0.3	0.4	0.1	0.8	0.8	-0.2
WPR														1.0	0.8	-0.3	0.9	0.8	-0.2
WSR															1.0	-0.1	0.8	0.7	-0.1
DMA																1.0	-0.1	0.0	-0.3
YIELD (w)																	1.0	0.9	-0.1
YIELD **(d)**																		1.0	0.3

IWR- initial wt. of rhizome (kg), PH- Plant height (cm), LL- Leaf length (cm), LW- Leaf width (cm), NLP- Numbers of leaves per plant, NTP- Number per tillers per plant, NMR- Numbers of mother rhizome per plant, NPR- Number of primary rhizome per plant, NSP- Number of secondary rhizome per plant, LMR- Length of mother rhizome per plant (cm), LPR- Length of primary rhizome, CDM- Core diameter of mother rhizome (cm), CDP- Core diameter of primary rhizome (cm), WMR- Weight of mother rhizome per plant (gm), WPR- Weight of primary rhizome per plant (gm), WSR- Weight of secondary rhizome per plant (gm), DMA- Days to maturity, YIELD (W) - Wet rhizome yield per plant, YIELD (D) –Dry rhizome yield per plant, CURCUMIN- Curcumin

Table 4. Phenotypic correlation coefficients among twenty characters in turmeric

Characters	LL	LW	NLP	NTP	NMR	NPR	NSP	LMR	LPR	CDM	CDP	WMR	WPR	WSR	DMA	YIELD w	YIELD dry	CURCUMIN
IWR	0.0	0.1	0.0	0.0	0.2	0.2	0.2	0.1	-0.1	-0.1	0.1	0.3	0.1	0.2	0.0	0.2	0.1	0.1
PH	0.8	0.5	0.5	0.4	0.3	0.4	0.1	0.2	0.3	0.5	0.3	0.1	0.4	0.3	0.1	0.1	0.1	0.1
LL	1.0	0.7	0.4	0.2	0.1	0.4	0.0	0.1	0.4	0.3	0.3	0.1	0.3	0.3	0.1	0.1	0.2	0.1
LW		1.0	0.4	0.2	0.1	0.4	0.0	0.2	0.4	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.3	0.2
NLP			1.0	0.7	0.3	0.3	0.1	0.3	0.0	0.4	0.4	0.1	0.1	0.1	0.1	-0.1	-0.1	0.2
NTP				1.0	0.3	0.2	0.2	0.3	0.0	0.3	0.3	0.0	0.1	0.1	0.1	-0.1	-0.2	0.3
NMR					1.0	0.0	0.1	0.3	0.0	0.3	0.2	0.2	0.1	0.1	0.2	0.1	0.0	0.2
NPR						1.0	0.5	0.0	0.4	0.1	0.3	0.3	0.4	0.3	-0.1	0.2	0.3	0.0
NSP							1.0	-0.1	0.3	-0.2	0.2	0.0	0.2	0.3	0.0	0.1	0.1	0.1
LMR								1.0	-0.1	0.1	0.2	0.3	0.2	0.2	-0.1	0.2	0.2	0.2
LPR									1.0	-0.2	0.2	0.2	0.3	0.2	0.0	0.1	0.2	0.1
CDM										1.0	0.3	0.2	0.2	0.2	0.3	0.1	0.1	-0.1
CDP											1.0	0.2	0.1	0.1	0.0	0.1	0.0	-0.2
WMR												1.0	0.4	0.4	0.2	0.7	0.7	0.0
WPR													1.0	0.8	-0.2	0.8	0.7	0.1
WSR														1.0	0.0	0.7	0.6	0.1
DMA															1.0	-0.1	0.0	-0.1
Yield-w																1.0	0.9	-0.1
Yield-d																	1.0	0.2

IWR- initial wt. of rhizome (kg), PH- Plant height (cm), LL- Leaf length (cm), LW- Leaf width (cm), NLP- Numbers of leaves per plant, NTP- Number per tillers per plant, NMR- Numbers of mother rhizome per plant, NPR- Number of primary rhizome per plant, NSP- Number of secondary rhizome per plant, LMR- Length of mother rhizome per plant (cm), LPR- Length of primary rhizome, CDM- Core diameter of mother rhizome (cm), CDP- Core diameter of primary rhizome (cm), WMR- Weight of mother rhizome per plant (gm), WPR- Weight of primary rhizome per plant (gm), WSR- Weight of secondary rhizome per plant (gm), DMA- Days to maturity, YIELD (W) - Wet rhizome yield per plant, YIELD (D) –Dry rhizome yield per plant, CURCUMIN- Curcumin

Table 5. Path coefficient analysis showing direct and indirect effects of twenty causal on rhizome yield per plant variables in turmeric

	IWR	PH	LL	LW	NLP	NTP	NMR	NPR	NSP	LMR	LPR	CDM	CDP	WMR	WPR	WSR	DMA	YIELD (D)	CURCUMIN	Genotypic cor. with yield
IWR	**0.2**	0.1	-0.1	0.1	0.1	0.1	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.2	0.0	0.2	0.0	-0.1	-0.2	0.3
PH	0.0	**0.7**	-1.9	-0.1	0.4	0.7	0.0	0.0	0.0	-0.1	-0.1	0.1	-0.2	-0.3	0.0	0.1	0.1	-0.1	0.9	0.2
LL	0.0	0.6	**-1.9**	0.3	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.1	0.0	-0.2	0.5	0.2
LW	0.0	-0.1	-1.3	**0.5**	-0.1	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	-0.4	0.2	0.4**
NLP	0.0	0.4	-0.4	-0.1	**0.7**	-0.6	-0.1	0.0	0.0	0.1	-0.1	0.1	-0.1	-0.1	0.0	0.0	0.0	0.1	0.1	-0.1
NTP	0.0	-0.6	1.6	-0.7	0.5	**-0.8**	0.0	0.0	0.0	0.1	-0.3	0.0	0.0	-0.4	0.0	-0.2	0.0	0.4	0.2	-0.3
NMR	0.1	0.0	0.6	-0.2	0.1	0.0	**-0.4**	0.0	0.0	0.1	-0.1	0.0	-0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1
NPR	0.1	-0.1	-0.3	0.1	0.0	0.3	0.2	**-0.1**	0.0	0.0	0.1	0.0	-0.1	0.1	0.0	0.2	0.1	-0.3	0.3	0.4**
NSP	0.1	-0.2	0.6	-0.2	-0.1	-0.1	0.0	-0.1	**0.1**	-0.1	0.1	-0.1	0.0	0.0	0.0	0.1	0.0	-0.1	0.1	0.1
LMR	0.1	-0.2	0.3	0.0	0.2	-0.2	-0.1	0.0	0.0	**0.2**	-0.1	0.0	0.0	0.2	0.0	0.1	0.0	-0.1	0.0	0.3
LPR	0.0	-0.3	-0.2	-0.1	0.4	1.0	0.1	0.0	0.0	-0.1	**0.3**	-0.1	0.0	0.0	0.0	0.0	0.1	-0.2	0.1	0.2
CDM	0.0	0.4	-0.3	-0.1	0.2	0.0	-0.1	0.0	0.0	0.0	-0.1	**0.2**	-0.1	0.1	0.0	0.1	-0.1	-0.1	0.3	0.1
CDP	0.0	0.4	-0.4	-0.2	0.2	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	**-0.4**	0.1	0.0	0.0	0.0	0.0	0.5	0.1
WMR	0.1	-0.3	0.1	0.1	-0.1	0.4	-0.1	0.0	0.0	0.1	0.0	0.0	-0.1	**0.7**	0.0	0.2	0.0	-0.6	0.2	0.8**
WPR	0.0	0.1	-0.1	0.0	-0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	**0.1**	0.5	0.1	0.5	0.2	0.9**
WSR	0.1	0.1	-0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	**0.7**	0.0	-0.5	0.0	0.8**
DMA	0.0	-0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	-0.1	**-0.3**	0.0	0.2	-0.1
YIELD(D)	0.0	0.1	-0.6	0.3	-0.1	0.4	0.0	-0.1	0.0	0.0	0.1	0.0	0.0	0.5	0.1	0.5	0.0	**-0.7**	0.2	0.9**
CURCUMIN	0.1	-0.8	1.2	-0.1	-0.1	0.2	0.0	0.0	0.0	0.0	0.0	-0.1	0.2	-0.2	0.0	0.0	-0.1	0.2	**-0.2**	**0.3**

Residual: 0.0770

IWR- initial wt. of rhizome (kg), PH- Plant height (cm), LL- Leaf length (cm), LW- Leaf width (cm), NLP- Numbers of leaves per plant, NTP- Number per tillers per plant, NMR- Numbers of mother rhizome per plant, NPR- Number of primary rhizome per plant, NSP- Number of secondary rhizome per plant, LMR- Length of mother rhizome per plant (cm), LPR- Length of primary rhizome, CDM- Core diameter of mother rhizome (cm), CDP- Core diameter of primary rhizome (cm), WMR- Weight of mother rhizome per plant (gm), WPR- Weight of primary rhizome per plant (gm), WSR- Weight of secondary rhizome per plant (gm), DMA- Days to maturity, YIELD (W) - Wet rhizome yield per plant, YIELD (D) –Dry rhizome yield per plant, CURCUMIN- Curcumin