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Thokchom Joydeep Singh
Dept. of Genetics and Plant Breeding, Navsari Agricultural University, Navsari, Gujarat, India

RK Patel
Dept. of Genetics and Plant Breeding, Navsari Agricultural University, Navsari, Gujarat, India

KG Modha
Dept. of Genetics and Plant Breeding, Navsari Agricultural University, Navsari, Gujarat, India

Priya Patel
Dept. of Genetics and Plant Breeding, Navsari Agricultural University, Navsari, Gujarat, India

Correspondence
Thokchom Joydeep Singh
Dept. of Genetics and Plant Breeding, Navsari Agricultural University, Navsari, Gujarat, India

Correlation and path coefficient analysis in turmeric (*Curcuma longa* L.)

Thokchom Joydeep Singh, RK Patel, KG Modha and Priya Patel

Abstract
The present research work was carried out at Research Farm, Department of Genetics and Plant Breeding, N. M. College of Agriculture, Navsari Agricultural University, Navsari during *Kharif* 2016-17. The experimental materials comprised of thirty diverse genotypes of turmeric and were evaluated in randomized block design with two replications. The magnitudes of genotypic correlations were higher as compared to the corresponding phenotypic correlations indicating that there was an inherent association between the characters at genotypic level. Among the studied fourteen traits of turmeric, plant height, rhizome length, rhizome width, rhizome weight, secondary fingers per rhizome and mother rhizomes per plant exhibited positive significant correlation with green rhizome yield and they have also exhibited positive direct effects on green rhizome yield, hence priority should be given to these traits in turmeric crop improvement programme.

Keywords: turmeric, correlation and path analysis

Introduction
Turmeric (*Curcuma longa* L.) is one of the important perennial spice crop popularly known as “Indian saffron” belongs to family Zingiberaceae. It has chromosome number of 2n = 3x = 63. It is originated in South East Asia and among which, India has achieved a predominant position as a largest producer of turmeric in the world. Besides India, it is cultivated in China, Taiwan, Indonesia, Sri Lanka, Thiland and other tropical countries but the highest diversity is concentrated in India and Thiland (Hikmat *et al.*, 2011) [4]. Over eighty species are reported in the genus *Curcuma* from the Indo-Malayan region, from which fourty are the indigenous ones.
India is the largest producer, consumer and exporter of turmeric in the world, which accounts for more than 50 percent of the world trade (Chaudhary *et al.*, 2006) [2]. The area under turmeric cultivation in India is 1,85,000 hectares with an annual production of 9,57,000 metric tons and productivity is 5.17 metric tons per hectare. Out of the total turmeric produced in India, 90 percent is consumed locally, while remaining ten percent is exported to various countries like United states of America, United Kingdom, Japan, Singapore, Malaysia, South Africa, Australia and other middle east countries. In India, Andhra Pradesh followed by Odisha, Tamil Nadu and Maharashtra are the states, which contribute the major share in total turmeric production (Maurya, 1990) [12].
The oleoresin component of turmeric is used in brine pickles and to some extent in non-alcoholic beverages, gelatins, butter and cheese etc. The curcumin extracted from turmeric is used as a colorant, hence used in preparation of dyes in textile industry. It is also having vast medicinal values like it is used in the preparation of medicinal oils, ointments and poultice and also having stomachic, carminative, tonic and blood purification properties. Apart from these, it has been also used as traditional medicines as a household remedy for various diseases including biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism and sinusitis. In old hindu medicines, it was extensively used for the treatment of sprains and swelling caused by injury.
In North East India (NEI) especially Mizoram, Meghalaya and Assam are endowed with a wide range of genetic variability in *Curcuma longa* and other related *Curcuma* species due to geo-climatic conditions of the region favouring higher accumulation of curcumin in rhizomes. The curcumin content is one of the major criteria for its export to the global markets. Alleppey turmeric is the world’s most outstanding and demanded grade, which is the richest source of curcumin. Due to vegetative propagation and flowering complexities, the genetic improvement programmes in turmeric are largely restricted to clonal selection and induced mutation

breeding. Moreover, limited viable seed settings in open-pollination and controlled crosses explore the possibility of recombination breeding through hybridization and hence few varieties such as IISR-Prabha and IISR-Pratibha have been released through progeny selection of open-pollinated seedlings. Even though, germplasm collection represents the main source of variability for turmeric genetic improvement. The turmeric studies aimed on characterizing the germplasm are limited and mostly restricted to a phenotypic evaluation of different accessions. Characterization of promising turmeric cultivars/accessions by morphological data and qualitative traits like curcumin, oleoresin and essential oil contents are not sufficient as these characters often change under varying environmental conditions, thus raising problem in proper identification and elimination of synonyms. Predominance of synonyms possess problem in identification and characterization of germplasm. Lack of clear-cut morphological traits among turmeric cultivars coupled with local identity of the germplasm collection results in accumulation of duplicates in the germplasm, which largely raising the conservation cost and delaying the crop improvement work (Sasikumar, 2005) [23].

Correlation

In the present investigation, in majority of the cases the genotypic correlation was recorded higher than phenotypic correlations for all the characters, indicating little influence of environment and the presence of inherent association between various characters. (Table 1). Similar results are reported by Rajyalakshmi (2013) in turmeric.

In all the instances however, more reliance may be placed on the genotypic correlations. Green rhizome yield showed positive and significant correlation with plant height, rhizome length, rhizome width, rhizome weight, secondary fingers per rhizome and mother rhizomes per plant at both phenotypic and genotypic level. Since, these association characters are in the desirable direction, selection for these traits may improve the green rhizome yield. Similar results are reported by Pathania *et al.* (1981) [17], Jalgaonkar *et al.* (1990) [6], Nandi *et al.* (1994) [15], Shashidhar and Sulikeri (1997) [25], Shashidhar *et al.* (1997) [25], Lynrah *et al.* (1998) [11], Venkatesha *et al.* (1998) [32], Chandra *et al.* (1999) [1], Jana *et al.* (2001) [7], Raveendra *et al.* (2001), Panja *et al.* (2002) [16], Prasad *et al.* (2004) [18], Rao *et al.* (2004) [20], Tomar *et al.* (2005) [30], Kumar *et al.*(2006) [8], Yadav *et al.* (2006) [34], Kumar *et al.* (2007) [9], Velmurugan *et al.* (2008) [31], Sharon *et al.* (2011) [24] and Singh *et al.* (2012) [26, 27] in turmeric.

Rhizome yield showed negative and significant correlation with powder recovery at genotypic level, which indicated that the character had minimum contribution for increase in green rhizome yield, so direct selection for this character should not be practiced. A positive correlation between desired characters is favorable to the breeder as it helps in selection. However, a negative correlation hinders the recovery of recombination in both characters, when the characters are generally correlated among themselves. In such a situation, any strong selection applied to parameters also brings about change in other parameters.

Among major rhizome yield contributing traits, rhizome length exhibited positive and significant correlation with rhizome width and dry rhizome weight recovery at both genotypic as well as phenotypic levels; similarly rhizome width displayed positive and significant association with rhizome weight and mother rhizomes per plant at both genotypic as well as phenotypic levels. Rhizome weight reported positive significant correlation with mother rhizomes per plant at genotypic as well as phenotypic levels, respectively.

Primary fingers per rhizome depicted positive and significant correlation with secondary fingers per rhizomes and mother rhizomes per plant at both genotypic as well as phenotypic levels. Secondary fingers per plant recorded negative and significant correlation with powder recovery at genotypic level. Similarly, mother rhizomes per plant exhibited significant and negative correlation with dry rhizome weight recovery at genotypic level. Similar finding with Datta *et al*. (2006) [3].

Dry rhizome weight recovery recorded positive and significant correlation with powder recovery at genotypic level.

A positive correlation between desirable characters is favorable to the plant breeder because it helps in simultaneous improvement of both the characters. In the present study, for most of the characters, indicating a strong inherent association between various genotypic correlation coefficients were found to be higher than phenotypic correlation coefficients characters and were masked by environmental component with regard to phenotypic expression.

In the present study, rhizome width, rhizome weight, rhizome length, secondary fingers per rhizome and mother rhizomes per plant seems to have predominant effect on green rhizome yield. Hence, there is ample scope for improvement of green rhizome yield by selecting a genotype having higher rhizome width, rhizome length, plant height as well as rhizome weight, more numbers of secondary fingers per rhizome and mother rhizomes per plant since they are highly correlated. The results on character association indicate significant positive association of green rhizome yield with leaf width, plant height, rhizome length, rhizome width, rhizome weight, secondary fingers per rhizome and mother rhizomes per plant, which indicated that the adequate knowledge of interrelationship between green rhizome yield and its components themselves is useful for selection and simultaneous improvement in these characters.

Path coefficient analysis

Path coefficient analysis indicated primary fingers per rhizome, rhizome width, rhizome weight, plant height, tillers per plant and secondary fingers per rhizome exhibited high and positive direct effects on green yield per plant. Thus, these characters turned-out to be the major components of green rhizome yield. Rhizome length exhibited moderate and positive direct effects on green rhizome yield. This result is in accordance with Pathania *et al*. (1981) [17], Lal *et al*. (1986) [10], Mukhopadhyay and Roy (1986) [13], Jalgaonkar and Jamdagni (1989), Jalgaonkar *et al*. (1990) [6], Nandi *et al*. (1994) [15], Singh and Tiwari (1995) [28], Shashidhar and Sulikeri (1997) [25] and Chandra *et al*. (1999) [1] in turmeric. These are identified as superior rhizome yield components. Hence, the genotypes which exhibited better performance for these characters can be used in further improvement of turmeric. Rhizome length has depicted highly significant and positive correlation along with positive direct effect on green rhizome yield. It has exhibited positive indirect effect on green rhizome yield for all traits except leaf length, tillers per plant, primary fingers per rhizome, mother rhizomes per plant and dry rhizome weight recovery. Similar finding with Jana *et al*. (2001) [7] and Lal *et al*. (1986) [10].

Highly significant and positive correlation along with positive direct effect was reported between rhizome width and green rhizome yield. It has exerted positive indirect effect on green rhizome yield via all characters under study except tillers per plant, primary fingers per rhizome and mother rhizome per plant.

Rhizome weight has recorded highly significant and positive correlation with green rhizome yield along with positive direct effect. It has exerted positive indirect effect on green rhizome yield *via* plant height, rhizome length, rhizome width, dry rhizome weight recovery and powder recovery. Similar findings were also reported by Yadav *et al*. (2006), [34] Sharon *et al*. (2011) [24], Verma (2014) [33] and Sumit *et al*. (2015) [29]. For the improvement of green rhizome yield, emphasis should be made on all yield contributing characters which are influencing it directly or indirectly. Direct and indirect effects of thirteen casual variables on green rhizome yield are presented in Table 2.

Based on the above observations it can be concluded that green rhizome yield per plant was found to be significantly and positively correlated with plant height, rhizome length, rhizome width, rhizome weight, secondary fingers per rhizome and mother rhizomes per plant at both phenotypic and genotypic levels.

Path coefficient analysis showed primary fingers per rhizome, rhizome width, rhizome weight, plant height, tillers per plant and secondary fingers per rhizome exhibited high and positive direct effects on green rhizome yield per plant. Hence, these traits were considered as the most important green rhizome yield contributors and due emphasis should be given while attempting green rhizome yield improvement in turmeric.

Table 1: Genotypic and phenotypic correlations of green rhizome yield with other characters of turmerics

Traits	R	LL	LW	PH	TPP	DTM	RL	RWID	RW	PFPR	SFPR	MRPP	DRWR	PR	GRY
LL	R_g	1.000	0.206^{NS}	0.150^{NS}	-0.054^{NS}	-0.074^{NS}	-0.302*	-0.058^{NS}	0.117^{NS}	0.192^{NS}	0.788**	0.110^{NS}	-0.140^{NS}	-0.277*	0.149^{NS}
	R_p	1.000	0.144^{NS}	-0.056^{NS}	-0.034^{NS}	-0.113^{NS}	-0.080^{NS}	0.024^{NS}	0.048^{NS}	0.077^{NS}	0.304*	-0.005^{NS}	-0.009^{NS}	-0.150^{NS}	0.062^{NS}
LW	R_g		1.000	0.678**	-0.233*	0.004^{NS}	0.004^{NS}	-0.012^{NS}	0.070^{NS}	0.194^{NS}	0.196^{NS}	-0.188^{NS}	0.209^{NS}	-0.124^{NS}	0.287*
	R_p		1.000	0.403**	0.175^{NS}	0.003^{NS}	0.031^{NS}	-0.004^{NS}	0.101^{NS}	0.208^{NS}	0.115^{NS}	-0.066^{NS}	0.152^{NS}	-0.192^{NS}	0.190^{NS}
PH	R_g			1.000	-0.590**	0.344**	0.593**	0.616**	0.747**	0.052^{NS}	0.383**	0.439**	0.069^{NS}	0.484**	0.659**
	R_p			1.000	-0.373**	0.218^{NS}	0.319*	0.348**	0.483**	0.133^{NS}	0.035^{NS}	0.301*	0.083^{NS}	0.129^{NS}	0.382**
TPP	R_g				1.000	0.147^{NS}	-0.466**	-0.058^{NS}	-0.222^{NS}	0.367**	-0.125^{NS}	0.191^{NS}	-0.106^{NS}	-0.138^{NS}	0.043^{NS}
	R_p				1.000	0.076^{NS}	-0.340**	0.117^{NS}	-0.196^{NS}	0.240^{NS}	-0.107^{NS}	0.101^{NS}	-0.052^{NS}	-0.039^{NS}	-0.017^{NS}
DTM	R_g					1.000	-0.560**	-0.042^{NS}	0.221^{NS}	0.287*	-0.569**	0.431**	-0.542**	0.703**	-0.137^{NS}
	R_p					1.000	-0.326*	-0.025^{NS}	0.129^{NS}	0.191^{NS}	-0.216^{NS}	0.343**	-0.321*	0.339**	-0.020^{NS}
RL	R_g						1.000	0.510**	0.154^{NS}	-0.433**	0.191^{NS}	0.117^{NS}	0.534**	0.046^{NS}	0.466**
	R_p						1.000	0.396**	0.110^{NS}	-0.187^{NS}	0.121^{NS}	0.113^{NS}	0.376**	0.024^{NS}	0.364**
RWID	R_g							1.000	0.703**	-0.531**	0.045^{NS}	0.292*	-0.182^{NS}	0.075^{NS}	0.775**
	R_p							1.000	0.620**	-0.197^{NS}	0.128^{NS}	0.280*	-0.088^{NS}	0.019^{NS}	0.600**
RW	R_g								1.000	-0.358**	-0.130^{NS}	0.482**	-0.422**	0.241^{NS}	0.630**
	R_p								1.000	-0.097^{NS}	0.098^{NS}	0.399**	-0.280*	0.179^{NS}	0.539**
PFPR	R_g									1.000	0.423**	0.465**	0.077^{NS}	- 0.398**	-0.156^{NS}
	R_p									1.000	0.384**	0.403**	0.093^{NS}	-0.161^{NS}	-0.089^{NS}
SFPR	R_g										1.000	-0.006^{NS}	-0.125^{NS}	-0.897**	0.442**
	R_p										1.000	0.203^{NS}	0.029^{NS}	-0.118^{NS}	0.290*
MRPP	R_g											1.000	-0.384**	0.102^{NS}	0.391**
	R_p											1.000	-0.116^{NS}	0.066^{NS}	0.327*
DRWR	R_g												1.000	0.405**	-0.022^{NS}
	R_p												1.000	-0.063^{NS}	- 0.027^{NS}
PR	R_g													1.000	- 0.187^{NS}
	R_p													1.000	-0.109^{NS}
GRY	R_g														1.000
	R_p														1.000

*, ** Significant at 5% and 1% level of significance, respectively

LL = Leaf length (cm)	DTM = Days to maturity	PFPR = Primary fingers per rhizome	PR = Powder recovery (%)
LW = Leaf width (cm)	RL = Rhizome length (cm)	SFPR = Secondary fingers per rhizome	GRY = Green rhizome yield (t/ha)
PH = Plant height (cm)	RWID = Rhizome width (cm)	MRPP = Mother rhizome per plant	
TPP = Tillers per plant	RW = Rhizome weight (kg)	DRWR = Dry rhizome weight recovery (%)	

Table 2: Direct and indirect effects of thirteen causal variables on green rhizome yield of turmeric

Traits	LL	LW	PH	TPP	DTM	RL	RWID	RW	PFPR	SFPR	MRPP	DRWR	PR
LL	-0.0816	-0.0169	-0.0123	0.0044	0.0061	0.0247	0.0048	-0.0096	-0.0157	-0.0644	-0.0090	0.0115	0.0227
LW	-0.0274	-0.1326	-0.0900	0.0310	-0.0006	-0.0006	0.0017	-0.0094	-0.0257	0.0260	0.0250	-0.0278	0.0165
PH	0.0722	0.3256	0.4797	-0.2831	0.1653	0.2849	0.2956	0.3587	0.0250	0.1841	0.2106	0.0333	0.2322
TPP	-0.0249	-0.1069	-0.2698	0.4572	0.0675	-0.2131	-0.0266	-0.1016	0.1680	-0.0575	0.0874	-0.0487	-0.0635
DTM	0.0431	-0.0025	-0.1990	-0.0852	-0.5776	0.3237	0.0244	-0.1277	-0.1658	0.3290	-0.2492	0.3132	-0.4065
RL	-0.0001	0.0000	0.0002	-0.0002	-0.0002	0.0003	0.0002	0.0001	-0.0001	0.0001	0.0000	0.0002	0.0000
RWID	-0.0307	-0.0067	0.3213	-0.0303	-0.0220	0.2664	0.5215	0.3670	-0.2771	0.0235	0.1525	-0.0953	0.0393
RW	0.0611	0.0366	0.3882	-0.1154	0.1148	0.0800	0.3654	0.5193	-0.1868	-0.0679	0.2507	-0.2193	0.1253
PFPR	0.1145	0.1151	0.0309	0.2181	0.1703	-0.2574	-0.3152	-0.2129	0.5933	0.2512	0.2764	0.0460	-0.2362
SFPR	0.1540	0.0383	0.0750	-0.0246	-0.1112	0.0373	0.0088	-0.0256	0.0827	0.1953	-0.0013	-0.0245	-0.2096
MRPP	-0.0534	0.0910	-0.2120	-0.0923	-0.2084	-0.0566	-0.1412	-0.2332	-0.2250	0.0031	-0.4830	0.1855	-0.0495
DRWR	0.0098	-0.0147	-0.0049	0.0075	0.0380	-0.0374	0.0128	0.0296	-0.0054	0.0088	0.0269	-0.0700	0.0284

PR	-0.0871	-0.0390	0.1517	-0.0435	0.2206	0.0146	0.0236	0.0756	-0.1247	-0.3363	0.0321	-0.1270	0.3134
Correlation coefficient	0.1494	0.2873*	0.6591**	0.0436	-0.1375	0.4668**	0.7757**	0.6303**	-0.1568	0.4429**	0.3191*	-0.0229	-0.1876

*, ** Significant at 5% and 1% percent level, respectively. Residual = 0.3474, Bold diagonal figures are the direct effect of the causal factor

LL = Leaf length (cm)	DTM = Days to maturity	PFPR = Primary fingers per rhizome	PR = Powder recovery (%)
LW = Leaf width (cm)	RL = Rhizome length (cm)	SFPR = Secondary fingers per rhizome	GRY = Green rhizome yield (t/ha)
PH = Plant height (cm)	RWID = Rhizome width (cm)	MRPP = Mother rhizome per plant	
TPP = Tillers per plant	RW = Rhizome weight (Kg)	DRWR = Dry rhizome weight recovery (%)	

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