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Character association in turmeric (*Curcuma longa* L.) genotypes

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Abstract
The experimental material comprising of 200 turmeric genotypes were evaluated at Department of Spices and Plantation crops, Horticultural College & Research Institute, TNAU, Coimbatore, Tamil Nadu, India during 2017-18. Association analysis of different quantitative traits with rhizome yield plant^{-1} in turmeric genotypes were investigated through the study of phenotypic correlation coefficient and path coefficient analysis. The study revealed that, the quantitative traits *viz.*,weight of mother rhizomes plant^{-1} (0.849**), number of primary rhizomes plant^{-1} (0.693**), number of secondary rhizomes plant^{-1} (0.643**), number of mother rhizomes plant^{-1} (0.595**), length of primary rhizome plant^{-1} (0.553**), length of secondary rhizome plant^{-1} (0.518**), number of leaves plant^{-1} (0.442**), plant height (0.440**), leaf area (0.289**), leaf length (0.249**) and leaf width (0.248**) and pseudo stem girth (0.228**) were highly significant and positively correlated with rhizome yield plant^{-1}. The estimates indicated that the weight of mother rhizome (0.576) had high positive direct effect on rhizome yield plant^{-1} followed by leaf area (0.384). Number of primary rhizomes plant^{-1} (0.249) and number of secondary rhizomes plant^{-1} (0.239) had moderate positive direct effect on rhizome yield plant^{-1}. The low amount of positive direct effect on rhizome yield plant^{-1} was recorded by length of primary rhizome plant^{-1} (0.147) and number of leaves plant^{-1} (0.122). The negligible amount of direct effect was illustrated for length of secondary rhizome plant^{-1} (0.059), plant height (0.030), length of mother rhizome plant^{-1} (0.026) and petiole length (0.012). Considering the indirect effect, all the traits had high positive indirect effect on rhizome yield plant^{-1} except leaf area, leaf length, leaf width and pseudostem girth where showed moderate indirect effect on rhizome yield plant^{-1}.

Keywords: Character association, turmeric, *Curcuma longa* L., genotypes

Introduction
Turmeric, is an important spice crop in India and traditionally known as “Indian saffron” belongs to Zingiberaceae family with the chromosome number 2n = 3x = 63. Though its origin is South East Asia, India is the largest producer of turmeric in the world. Affiliation of varied independent and dependent traits and their effect of relationship can be predicted by correlation and path coefficient analysis. The natural genetic variation for the majority of the yield contributing characters is significant in this crop this is the basic requirement for the breeders to reorganize the materials for increasing the production and productivity. The objective of the present study was to correlate the yield and yield attributing traits for the assessment of superior genotypes selection during crop improvement programme. Path analysis provides an effective means of finding out direct and indirect source of relationship and authorizes the assessment of given correlation and measure the relative importance of every trait.

Materials and Methods
Two hundred turmeric genotypes were evaluated at Department of Spices and Plantation crops, Horticultural College & Research Institute, TNAU, Coimbatore, Tamil Nadu, India during 2017-18. The experiment was laid out in augmented randomized complete block design (ABD) with two checks *viz.*, BSR 2 and CO 2. Sixteen profitable quantitative traits *viz.*, the plant height (cm), pseudostem girth plant^{-1} (cm), number of tillers plant^{-1}, number of leaves plant^{-1}, petiole length (cm), leaf length (cm), leaf width (cm), leaf area (cm^2), number of mother rhizomes plant^{-1}, weight of mother rhizomes plant^{-1}(g), length of mother rhizome plant^{-1}(cm), number of primary rhizomes plant^{-1}, length of primary rhizome plant^{-1}(cm), number of secondary rhizomes plant^{-1}, length of secondary rhizome plant^{-1} (cm) and rhizome yield plant^{-1}(g) were recorded. Correlation coefficients were computed according to the method suggested by Singh and Chaudhary (1985) [5] using statistical software SPSS 20.0 version.

Path analysis was analyzed with the help of formula suggested by Dewey and Lu (1959) [1] using TNAUSTAT software.

Result and discussion

In any crop improvement programme selection is very effective only when genetic variability is present. However, selection for some traits needs to be correlated to explain the interrelationships among the traits and make it easy to identify elite genotypes. It is very helpful to know the interrelationships between variable vital characters. Association analysis of different quantitative traits with rhizome yield plant^{-1} on turmeric genotypes and their interrelationships were investigated through the study of phenotypic correlation coefficients Table 1. Among the sixteen traits, weight of mother rhizomes plant^{-1} (0.849**) was highly significant and positively correlated with rhizome yield plant^{-1} followed by number of primary rhizomes plant^{-1} (0.693**), number of secondary rhizomes plant^{-1} (0.643**), number of mother rhizomes plant^{-1} (0.595**), length of primary rhizome plant^{-1} (0.553**), length of secondary rhizome plant^{-1} (0.518**), number of leaves plant^{-1} (0.442**), plant height (0.440**), leaf area (0.289**), leaf length (0.249**), leaf width (0.248**) and pseudo stem girth (0.228**). Hence, these traits were found to be a good criterion for selection. Similar results were reported by by (Verma *et al.,* 2014) [2] for weight of fresh rhizomes plant^{-1}, weight of mother rhizomes plant^{-1} and number of primary rhizomes plant^{-1} which exhibited highly significant and positive correlation with rhizome yield plant^{-1} in turmeric. The results also indicated that, the traits have an assured intrinsic association with yield and also suggested their impact in determining rhizome yield in turmeric. While, number of tillers plant^{-1} (-0.077) had negative correlation with yield.

Plant height was highly significant and positively correlated with leaf length (0.806**), leaf area (0.783**), number of leaves plant^{-1} (0.771**), pseudostem girth (0.630**), leaf width (0.597**), petiole length (0.548**), rhizome yield plant^{-1} (0.440**), weight of mother rhizome plant^{-1} (0.397**), length of mother rhizome plant^{-1} (0.342**) and length of primary rhizome plant^{-1} (0.321**) whereas, number of tillers plant^{-1} (-0.316**) was highly significant and negatively correlated with plant height. Number of leaves plant^{-1} was highly significant and positively correlated with leaf length (0.623**), leaf area (0.618**), leaf width (0.463**), weight of mother rhizome plant^{-1} (0.455**), rhizome yield plant^{-1} (0.442**), length of mother rhizome plant^{-1} (0.334**) and petiole length (0.338**). The above results indicated that, these traits have assured intrinsic relationship with yield and suggest their importance in determining rhizome yield plant^{-1}. Similar observations were obtained by Verma *et al.,* (2014) [2] and Rajyalakshmi *et al.,* (2013) [3].

Number of mother rhizome plant^{-1} was highly significant and positively correlated with weight of mother rhizomes plant^{-1} (0.756**), number of primary rhizome plant^{-1} (0.635**), rhizome yield plant^{-1} (0.595**), length of mother rhizome plant^{-1} (0.395**), number of secondary rhizomes plant^{-1} (0.332**) and length of secondary rhizome plant^{-1} (0.151*). Weight of mother rhizome plant^{-1} highly significant and positively correlated with rhizome yield plant^{-1} (0.849**), length of mother rhizome plant^{-1} (0.616**), number of primary rhizomes plant^{-1} (0.583**), number of secondary rhizomes plant^{-1} (0.402**), length of primary rhizome plant^{-1} (0.343**) and length of secondary rhizome plant^{-1} (0.334**). Laxmi *et al.,* (2017) [4] found number of secondary rhizome plant^{-1} was highly significant and positive correlation with rhizome yield per plant.

Length of mother rhizome plant^{-1} was highly significant and positively correlated with rhizome yield plant^{-1} (0.587**), length of primary rhizome plant^{-1} (0.364**), number of primary rhizome plant^{-1} (0.342**), number of secondary rhizomes plant^{-1} (0.331**) and length of secondary rhizome plant^{-1} (0.258**) while, number of primary rhizomes plant^{-1} was highly significant and positively correlated with rhizome yield plant^{-1} (0.693**), number of secondary rhizomes plant^{-1} (0.436**), length of primary rhizome plant^{-1} (0.278**) and length of secondary rhizome plant^{-1} (0.261**). Length of primary rhizome plant^{-1} was highly significant and positively correlated with rhizome yield plant^{-1} (0.553**), number of secondary rhizomes plant^{-1} (0.448**) and length of secondary rhizome plant^{-1} (0.402**). Number of secondary rhizomes plant^{-1} showed highly significant and positively correlation with rhizome yield plant^{-1} (0.643**) and length of secondary rhizome plant^{-1} (0.541**) while, length of secondary rhizome exhibited highly significant positive correlation with rhizome yield plant^{-1} (0.518**). The present findings are in accordance with Pandey *et al.,* (2012) [8] and Singh *et al.,* (2012) [9] in turmeric.

Path coefficients were divided into direct and indirect effects and presented in Table 2. The estimates indicated that the weight of mother rhizome plant^{-1} (0.576) had the high positive direct effect on rhizome yield plant^{-1} followed by leaf area (0.384). Similar findings were reported by Bhadur *et al.,* (2016). Number of primary rhizome plant^{-1} (0.249) and number of secondary rhizomes plant^{-1} (0.239) had moderate positive direct effect on rhizome yield plant^{-1}. The low amount of positive direct effect on rhizome yield plant^{-1} was recorded length of primary rhizome plant^{-1} (0.147) and number of leaves plant^{-1} (0.122). The negligible amount of direct effect on rhizome yield plant^{-1} was illustrated for length of secondary rhizome plant^{-1} (0.059), plant height (0.030), length of mother rhizome plant^{-1} (0.026) and petiole length (0.012). Similar results were observed by (Verma *et al.,* 2014. Pandey *et al*., 2012 and Yadav *et al*., 2004) [2, 8, 6] for weight of fresh rhizomes plant^{-1} and number of leaves shoot^{-1} which showed the highest positive direct effect on rhizome yield plant^{-1}. Whereas, leaf length (-0.308), leaf width (-0.204) had high and moderate negative direct effect on rhizome yield plant^{-1}. Number of mother rhizome plant^{-1} (-0.134) showed low negative direct effect on rhizome yield plant^{-1} while pseudo stem girth (-0.015) and number of tillers plant^{-1} (-0.020) exhibited negligible negative direct effect on rhizome yield plant^{-1}.

Considering the indirect effect, all the traits had high positive indirect effect on rhizome yield plant^{-1}. Leaf area, leaf length, leaf width and pseudo stem girth showed moderate indirect effect on rhizome yield plant^{-1} while, petiole length showed low positive indirect effect on rhizome yield plant^{-1} and number of tillers plant^{-1} had the negligible negative indirect effect on rhizome yield plant^{-1} (Table 2).

Summarizing the path coefficient analysis, number of mother rhizome plant^{-1} had negative direct effect on rhizome yield plant^{-1} but high positive indirect effect on rhizome yield plant^{-1}. Leaf length had the high negative direct effect on rhizome yield plant^{-1} but moderate positive indirect effect on rhizome yield plant^{-1}. This is in accordance with the earlier findings of turmeric (Naresh *et al.,* 1981) [7].

Table 1: Estimation of correlation coefficients between sixteen quantitative characters in turmeric genotypes

Traits	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	1	0.630**	-0.316**	0.771**	0.548**	0.806**	0.597**	0.783**	0.083	0.397**	0.342**	0.209**	0.321**	0.181*	0.231**	0.440**
X2		1	-0.261**	0.607**	0.467**	0.659**	.604**	0.709**	-0.042	0.263**	0.201**	-0.039	0.195**	0.022	0.121	0.228**
X3			1	-0.317**	-0.298**	-0.372**	-0.082	-0.260**	0.121	-0.029	0.003	-0.037	-0.029	0.028	-0.023	-0.077
X4				1	0.338**	0.623**	0.463**	0.618**	0.137	0.455**	0.334**	0.147*	0.206**	0.044	0.238**	0.442**
X5					1	0.635**	0.373**	0.563**	-0.137	0.041	0.005	0.043	0.102	0.075	0.07	0.103
X6						1	0.607**	0.902**	-0.057	0.237**	0.241**	0.036	0.227**	0.109	0.180*	0.249**
X7							1	0.879**	0.101	0.307**	0.222**	0.069	0.157*	0.054	0.135	0.248**
X8								1	0.021	0.308**	0.255**	0.062	0.214**	0.094	0.194**	0.289**
X9									1	0.756**	0.395**	0.635**	0.110	0.332**	0.151*	0.595**
X10										1	0.616**	0.583**	0.343**	0.402**	0.334**	0.849**
X11											1	0.342**	0.364**	0.331**	0.258**	0.587**
X12												1	0.278**	0.436**	0.261**	0.693**
X13													1	0.448**	0.402**	0.553**
X14														1	0.541**	0.643**
X15															1	0.518**
X16																1

**Correlation is significant at the 0.01 level *Correlation is significant at the 0.05 level

X1: Plant height (cm), X2: Pseudo stem girth (cm), X3: Number of tillers, X4: Number of leaves, X5: Petiole length (cm), X6: Leaf length (cm), X7: leaf width (cm), X8: Leaf area (cm^2), X9: Number of mother rhizome, X10: Weight of mother rhizome (g), X11: Length of mother rhizome (cm), X12: Number of primary rhizome, X13: length of primary rhizome (cm), X14: Number of secondary rhizome, X15: Length of secondary rhizome (cm), X16: Rhizome yield per plant (g)

Table 2: Direct and indirect effects of sixteen quantitative characters on rhizome yield per plant in turmeric genotypes

Traits	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	0.030	-0.010	0.006	0.094	0.007	-0.248	-0.122	0.300	-0.011	0.229	0.009	0.052	0.047	0.043	0.014	0.440
X2	0.019	-0.015	0.005	0.074	0.006	-0.203	-0.123	0.272	0.006	0.151	0.005	-0.010	0.029	0.005	0.007	0.228
X3	-0.010	0.004	-0.020	-0.039	-0.004	0.115	0.017	-0.100	-0.016	-0.017	0.000	-0.009	-0.004	0.007	-0.001	-0.077
X4	0.023	-0.009	0.006	0.122	0.004	-0.192	-0.094	0.237	-0.018	0.262	0.009	0.037	0.030	0.010	0.014	0.442
X5	0.017	-0.007	0.006	0.041	0.012	-0.195	-0.076	0.216	0.018	0.024	0.000	0.011	0.015	0.018	0.004	0.103
X6	0.024	-0.010	0.007	0.076	0.008	-0.308	-0.124	0.346	0.008	0.137	0.006	0.009	0.034	0.026	0.011	0.249
X7	0.018	-0.009	0.002	0.057	0.005	-0.187	-0.204	0.337	-0.014	0.177	0.006	0.017	0.023	0.013	0.008	0.248
X8	0.024	-0.011	0.005	0.076	0.007	-0.278	-0.179	0.384	-0.003	0.177	0.007	0.015	0.032	0.023	0.012	0.289
X9	0.003	0.001	-0.002	0.017	-0.002	0.018	-0.021	0.008	-0.134	0.436	0.010	0.158	0.016	0.079	0.009	0.595
X10	0.012	-0.004	0.001	0.056	0.001	-0.073	-0.063	0.118	-0.101	0.576	0.016	0.145	0.051	0.096	0.020	0.849
X11	0.010	-0.003	0.000	0.041	0.000	-0.074	-0.045	0.098	-0.053	0.355	0.026	0.085	0.054	0.079	0.015	0.587
X12	0.006	0.001	0.001	0.018	0.001	-0.011	-0.014	0.024	-0.085	0.336	0.009	0.249	0.041	0.104	0.015	0.693
X13	0.010	-0.003	0.001	0.025	0.001	-0.070	-0.032	0.082	-0.015	0.198	0.009	0.069	0.147	0.107	0.024	0.553
X14	0.005	0.000	-0.001	0.005	0.001	-0.033	-0.011	0.036	-0.045	0.232	0.009	0.108	0.066	0.239	0.032	0.643
X15	0.007	-0.002	0.000	0.029	0.001	-0.055	-0.028	0.074	-0.020	0.192	0.007	0.065	0.059	0.129	0.059	0.518

Residue effect = 0.2960

X1: Plant height (cm), X2: Pseudo stem girth (cm), X3: Number of tillers, X4: Number of leaves, X5: Petiole length (cm), X6: Leaf length (cm), X7: leaf width (cm), X8: Leaf area (cm^2), X9: Number of mother rhizome, X10: Weight of mother rhizome (g), X11: Length of mother rhizome (cm), X12: Number of primary rhizome, X13: length of primary rhizome (cm), X14: Number of secondary rhizome, X15: Length of secondary rhizome (cm), X16: Rhizome yield per plant (g)

Conclusion

Correlation and path analysis sixteen quantitative traits *viz*., plant height, number of leaves, leaf length, leaf width, leaf area, number of mother rhizome, weight of mother rhizome, length of mother rhizome, number of primary rhizome, length of primary rhizome, number of secondary rhizome and length of secondary rhizome indicated the importance of desirable traits for intensifying the turmeric breeding program for high rhizome yield.

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