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Estimates of genetic variability, inter character association and path analysis in turmeric over environments

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Abstract

Pooled data of 27 traits, including quantitative and qualitative, from 15 turmeric varieties grown in three locations over two years were used to estimate the genetic parameters of variability and path analysis. High genotypic coefficient of variation (GCV) combined with high phenotypic coefficient of variation (PCV) was observed for collar girth, length of mother rhizome, number of mother rhizomes, weight of mother rhizome, weight of primary rhizome, number of secondary rhizomes, primary rhizome inter-nodal length, bisdemethoxycurcumin (BDMC), demethoxycurcumin (DMC), curcumin (CUR) and yield. High heritability coupled with high genetic advance as per cent mean (GAM) was recorded for plant height, number of shoots, leaf petiole length, leaf length, collar girth, length of mother rhizome, girth of mother rhizome, primary rhizome inter-nodal length, dry recovery, oleoresin, BDMC, DMC and curcumin. Correlation coefficients showed that yield was significantly associated with collar girth, weight of mother rhizome, number of primary rhizomes, weight of primary rhizome and number of secondary rhizomes. Path coefficient analysis at phenotypic level revealed that, positive direct effect was high for length of mother rhizome followed by number of mother rhizomes, weight of primary rhizome and curcumin content. The study confirmed that characters such as weight of mother rhizome, girth of mother rhizome, weight of primary rhizomes, number of primary rhizomes and curcumin content can be relayed upon to form selection criteria in turmeric.

Keywords: *Curcuma longa*, curcumin, dry recovery, heritability, location

Introduction

Turmeric, a native of India is a perennial rhizomatous crop grown as an annual crop. It was valued mainly as a spice for food and a natural dye for clothing until recently, when it was discovered to be a potential source of new drugs for a variety of diseases (Corcolon & Dionisio-Sese 2014). Selection breeding including open pollinated progeny selection is the most preferred method of improving the crop (Nazeem & Menon 1994; Nair & Aarthi, 2018). The present investigation was taken up to understand the pattern of genetic variability parameters over environments for yield and yield components including quality traits and intercharacter association so as to select the most suitable and reliable traits as selection criteria. Fifteen turmeric genotypes conserved at the National Active Germplasm Site, ICAR-Indian Institute of Spices Research, Kozhikode, Kerala were used in the study.

Materials and Methods

The present investigation using 15 turmeric genotypes (Suvarna, IISR Prathiba, IISR Pragati, SLP-389/1, SC-61, Acc. 849, BSR-2, CO-2, Varna, Duggirala Red, Rajendra Sonia, Punjab Haldi-1, Megha Turmeric-1, Rajapuri and Narendra Haldi-98) was carried out in three locations *viz*., ICAR-Indian Institute of Spices Research (ICAR-IISR) Kozhikode, Kerala; ICAR-IISR, Regional Station, Appangala, Karnataka and Perur, Coimbatore, Tamil Nadu (farmers field) for two years (2016-2017 and 2017-2018) in RBD design with three replications. Recommended package of practices were followed for crop cultivation (Jayashree *et al.* 2015). Agro morphological observations on 27 traits (morphological, yield and quality) were recorded from five plants per replication. Curcumin, bisdemethoxycurcumin (BDMC) and demethoxycurcumin (DMC) estimations were done using HPLC with authentic standards. Oleoresin and essential oil were estimated as per ASTA (2004) and ASTA (1975), respectively. Variability parameters like phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h2) and genetic advance as per cent mean (GAM) were calculated (Johnson *et al.* 1955). PCV and GCV were categorized as low, moderate or high following Sivasubramanian and Menon (1973). Heritability percentage was classified as suggested by Robinson *et al.* (1949). Genetic advance as per cent of mean (GAM) was categorized according to Johnson *et al.* (1955). Correlation and path analysis were carried out as per Goulden (1952) and Dewey & Lu (1959) respectively.

Analysis of variance, genetic variability, pooled correlation and path analysis were done using TNAUSTAT software (Manivannan, 2014).

Results and Discussion

The analysis of variance for the different characters based on pooled environment is presented in the Table 1. The results revealed significant variation for the characters studied over the location x year effect. The differences within the replications were non-significant for all the traits studied.

High GCV combined with high PCV was observed for collar girth, length of mother rhizome, number of mother rhizomes, weight of mother rhizome, weight of primary rhizome, number of secondary rhizomes, primary rhizome inter-nodal length, BDMC, DMC, curcumin and yield (Table 2). Similar findings were reported by Bahadur *et al*. (2016), Gupta *et al*. (2016), Aarthi *et al.* (2018), Maurya *et al.* (2018) and Sadanand *et al.* (2019) in turmeric. Estimates of PCV were greater than GCV for all the traits indicating the role of environment in the expression of these traits.

Although GCV and PCV reveal the extent of variability present, an estimate of heritability coupled with genetic advance (GAM) offer a better insight of the selection success. High heritability coupled with high GAM was recorded for pseudostem height, number of shoots, leaf petiole length, leaf length, collar girth, length of mother rhizome, girth of mother rhizome, primary rhizome inter-nodal length, dry recovery, oleoresin, BDMC, DMC and curcumin suggesting the involvement of additive gene effects in the expression of these traits and therefore effectiveness of selection. However, the low estimates of heritability combined with low GAM observed for length of primary rhizome, girth of primary rhizome and inner core primary rhizome diameter indicates poor selection success for these traits. This is in agreement with Bahadur *et al*. (2016) and Gupta *et al*. (2016) in turmeric.

Correlation estimates revealed, that rhizome yield per plant exerted positive correlation with collar girth, weight of mother rhizome, number of primary rhizome, weight of primary rhizome and number of secondary rhizome. Except for inter nodal length and dry recovery all the other traits were positively correlated with yield but not significant (Table 3). Earlier studies too reported positive correlation

Table 1. Pooled analysis of variance for different characters in turmeric

Character	Replication	Location (L)	Year (Y)	Genotype (G)	L * Y	G*E	Pooled error
Degrees of freedom	2	2	1	14	2	70	168
PH	8.89	36134.67*	967.00*	5644.11*	6240.82*	473.21*	26.66
NS	0.14	3.43*	0.15*	6.10*	4.71*	1.23*	0.07
NL	3.06	20.56*	87.04*	60.85*	1423.00*	28.15*	1.77
LPL	1.83	2217.44*	174.61*	208.41*	406.82*	30.22*	1.69
LL	9.23	5850.90*	540.26*	748.10*	1153.99*	67.54*	4.04
LW	0.26	55.63*	79.36*	44.06*	125.65*	6.54*	0.79
CG	0.42	187.54*	4.91*	109.56*	143.32*	6.86*	0.65
LPR	0.19	67.76*	19.59*	6.40*	19.82*	2.31*	57.47
LMR	0.50	94.39*	4.37*	80.55*	15.23*	2.51*	0.44
LSR	0.09	67.55*	5.69*	3.57*	10.40*	1.08*	0.25
GMR	0.001	42.09*	11.40*	68.97*	36.10*	3.49*	0.51
GPR	0.73	17.44*	12.78*	8.86*	7.67*	2.76*	0.73
GSR	0.10	22.60*	22.03*	6.78*	4.09*	0.71*	0.27
NMR	0.30	12.757*	31.49*	13.78*	5.75*	1.90*	0.10
WMR	88.45	48743.84*	4338.32*	23611.58*	1832.04*	2613.63*	127.06
NPR	0.95	236.61*	1236.92*	85.75*	20.16*	44.09*	1.55
WPR	33.41	48777.85*	12399.13*	92664.06*	14062.98*	27246.45	246.32
NSR	0.83	1215.02*	821.08*	519.89*	374.02*	96.89*	2.31
IN	0.01	0.026	0.09	1.62	0.43*	0.11*	0.03
IC	0.003	0.685*	0.13*	0.31*	0.15*	0.13*	0.01
DR	0.36	210.08*	1.51*	148.39*	0.63	4.43*	0.51
OLE	0.424	295.82*	45.72*	63.19*	20.42*	3.73*	0.18
EO	0.014	38.39*	0.91**	8.56*	0.85*	2.43*	0.08
BDMC	0.000	2.18*	0.02**	1.23*	0.24*	0.09*	0.001
DMC	0.000	1.30*	1.01*	0.560*	0.08*	0.05*	0.003
CUR	0.001	21.95*	1.77*	15.23*	3.63*	0.43*	0.0014
YLD	155.51	351311.13*	18665.762*	226691.35*	36054.55*	53915.43*	867.12

* Significant at 5% level of probability

PH-Pseudostem height (cm); NS - no. of shoots; NL- no. of leaves; LPL-leaf petiole length (cm); LL - leaf length (cm); LW- leaf width (cm); CG- collar girth (cm); LPR – length of primary rhizome (cm); LMR - length of mother rhizome (cm); LSR - length of secondary rhizome (cm); GMR - girth of mother rhizome (cm); GPR - girth of primary rhizome (cm); GSR - girth of primary rhizome (cm); NMR - no. of mother rhizomes; WMR - wt. of mother rhizome (g plant^{-1}); NPR - no. of primary rhizomes; WPR - wt. of primary rhizome (g plant^{-1}); NSR- no. of secondary rhizomes; IN - inter nodal length (cm); IC - inner core; DR - dry recovery (%); OLE - oleoresin (%); EO- essential oil (%); BDMC- bisdemethoxy curcumin (%); DMC - demethoxycurcumin (%); CUR - curcumin (%); YLD - yield (g plant^{-1}).

of yield with weight of primary, number of primary rhizome and weight of mother rhizome (Prajapati *et al.* 2014; Verma *et al.* 2014). The positively correlated traits also had high values of heritability, indicating better advantage in selection breeding.

The inter correlation among the quality traits revealed that dry recovery is negatively

Table 2. Estimates of genetic variability in turmeric

Character	Grand mean	GCV (%)	PCV (%)	h2 (%)	GAM (%)
PH	108.63 ± 2.96	16.07	19.80	65.90	26.87
NS	3.00 ± 0.15	18.73	28.42	43.50	25.44
NL	13.91 ± 0.73	12.14	25.30	23.00	12.00
LPL	17.15 ± 0.75	19.35	26.78	52.20	28.81
LL	46.84 ± 1.12	13.55	16.95	64.00	22.33
LW	14.28 ± 0.37	10.65	15.33	48.20	15.23
CG	9.62 ± 0.37	25.35	30.17	70.60	43.90
LPR	8.16 ± 0.23	6.76	13.57	24.80	6.94
LMR	6.27 ± 0.24	33.50	37.28	80.80	62.02
LSR	4.81 ± 0.17	8.60	16.92	25.80	9.00
GMR	10.51 ± 0.28	18.40	21.57	73.10	32.46
GPR	7.24 ± 0.27	8.93	18.24	23.90	9.00
GSR	5.75 ± 0.15	10.37	15.12	47.00	14.64
NMR	2.93 ± 0.19	29.17	39.81	53.70	44.04
WMR	89.23 ± 6.91	39.85	51.63	59.60	63.35
NPR	10.59 ± 0.88	18.85	40.11	22.10	18.24
WPR	204.43 ± 21.33	33.51	55.52	36.40	41.67
NSR	12.94 ± 1.29	40.32	58.52	47.50	57.21
IN	1.05 ± 0.05	27.99	35.16	63.40	45.90
IC	1.30 ± 0.05	9.38	19.27	23.70	9.40
DR	20.09 ± 0.3	14.21	15.60	83.10	26.69
OLE	9.44 ± 0.26	19.65	22.88	73.80	34.79
EO	5.88 ± 0.21	11.20	18.67	36.00	13.84
BDMC	0.34 ± 0.04	76.87	90.19	72.60	134.96
DMC	0.47 ± 0.03	36.70	44.63	67.60	62.16
CUR	1.53 ± 0.02	60.65	65.01	87.00	116.56
YLD	397.51 ± 30.25	27.19	42.21	41.50	36.08

Note: For details of abbreviations, refer Table 1.

correlated with oleoresin, BDMC and curcumin. Oleoresin is positively correlated with BDMC, DMC and Curcumin. BDMC is positively correlated with DMC and curcumin. DMC is positively correlated with curcumin. Curcumin content showed positive correlation with oleoresin, BDMC and BMC, and negative correlation with dry recovery.

Yield being a dependent character, is a resultant of the interactions of a number of component characters among themselves as well as with the environment in which the plants grow. The idea of degree of association of yield with its components is of great importance. Further each character is likely to be modified by action of genes present in the genotypes of plant and also by the environment and it becomes difficult to evaluate this complex character directly. Partitioning of the correlation into direct and indirect effect (path analysis) assumes significance in this context.

High positive direct effect was observed for the length of mother rhizome, followed by number of mother rhizomes, weight of primary rhizome and curcumin. Moderately high direct effect was recorded for collar girth, girth of secondary rhizome and number of secondary rhizomes. The effect was low and positive for

Table 3. Pooled correlation coefficients for different characters in turmeric

Character	PH	NS	NL	PL	LL	LW	CG	LPR	LMR	LSR	GMR	GPR	GSR	NMR	WMR	NPR	WPR	NSR	IN	IC	DR	OLE	EO	BMC	DMC	CUR	YLD
PH	1.00	-0.10	0.15	0.63*	0.87*	0.59*	0.52*	0.19	0.52*	0.03	0.63*	0.02	0.00	0.13	0.65*	0.43	0.22	0.41	-0.26	0.05	0.11	-0.01	-0.03	-0.13	0.22	-0.03	0.42
NS		1.00	0.44	0.15	-0.14	-0.24	-0.18	0.03	-0.32	0.16	-0.29	0.22	0.26	0.39	-0.15	0.19	0.35	0.02	0.28	0.28	-0.36	0.36	0.15	0.42	0.19	0.44	0.17
NL			1.00	0.23	0.21	0.11	0.35	0.03	0.26	-0.02	0.27	0.13	0.21	0.13	0.16	0.12	0.17	0.11	-0.12	0.18	-0.02	0.15	-0.06	0.10	0.24	0.20	0.17
PL				1.00	0.71*	0.38	0.20	0.23	0.14	0.01	0.24	0.10	0.16	0.29	0.32	0.37	0.23	0.19	0.10	0.14	-0.29	0.37	-0.06	0.32	0.36	0.42	0.28
LL					1.00	0.76*	0.57*	0.26	0.52*	-0.01	0.63*	0.07	-0.03	0.09	0.56*	0.45	0.22	0.45	-0.19	0.03	0.10	0.08	0.00	-0.03	0.27	0.02	0.40
LW						1.00	0.62*	0.37	0.47	0.06	0.62*	0.11	-0.09	0.05	0.51*	0.42	0.20	0.47	-0.25	0.04	0.32	-0.05	0.12	-0.23	0.18	-0.14	0.39
CG							1.00	0.22	0.83*	0.13	0.79*	0.28	0.18	-0.23	0.66	0.12	0.21	0.39	-0.45	0.23	0.11	-0.01	0.11	-0.09	0.32	-0.15	0.51*
LPR								1.00	0.11	0.54*	0.13	0.24	0.23	-0.04	0.14	0.32	0.23	0.48	0.32	0.13	-0.05	0.37	0.37	0.14	0.17	0.15	0.31
LMR									1.00	-0.03	0.76*	0.13	0.13	-0.33	0.69	0.01	0.05	0.17	-0.48	0.07	0.14	-0.13	-0.13	-0.17	0.31	-0.25	0.37
LSR										1.00	0.01	0.30	0.53*	-0.23	-0.06	0.09	0.21	0.55	0.15	0.18	-0.20	0.16	0.29	0.10	0.02	-0.04	0.29
GMR											1.00	0.09	0.09	-0.18	0.70*	0.20	0.14	0.32	-0.56*	0.03	0.26	-0.19	-0.17	-0.30	0.23	-0.24	0.41
GPR												1.00	0.62*	0.15	0.25	0.18	0.42	0.16	0.00	0.42	-0.42	0.40	0.24	0.46	0.46	0.25	0.41
GSR													1.00	0.02	0.11	0.13	0.48	0.15	0.11	0.47	-0.64*	0.44	0.06	0.50	0.48	0.28	0.46
NMR														1.00	0.20	0.55*	0.42	0.07	0.13	0.28	-0.23	0.25	-0.03	0.20	0.25	0.34	0.28
WMR															1.00	0.38	0.28	0.23	-0.39	0.21	0.06	-0.01	-0.10	-0.15	0.42	-0.04	0.51*
NPR																1.00	0.57	0.56*	0.11	0.21	-0.01	0.20	0.13	0.04	0.26	0.10	0.51*
WPR																	1.00	0.38	0.12	0.42	-0.31	0.28	0.18	0.30	0.25	0.25	0.85*
NSR																		1.00	0.04	0.20	0.14	-0.02	0.30	-0.16	-0.02	-0.19	0.53*
IN																			1.00	0.09	-0.29	0.26	0.20	0.33	-0.17	0.23	-0.03
IC																				1.00	-0.45	0.40	0.26	0.39	0.35	0.31	0.39
DR																					1.00	-0.66*	-0.08	-0.82*	-0.45	-0.61*	-0.21
OLE																						1.00	0.41	0.84*	0.65*	0.84*	0.23
EO																							1.00	0.25	-0.04	0.11	0.16
BMC																								1.00	0.50	0.78*	0.19
DMC																									1.00	0.63*	0.34
CUR																										1.00	0.15
YLD																											1.00

*Significant at 5% level of probability

(For details of abbreviations refer Table 1)

Table 4. Pooled path coefficient analysis showing direct and indirect effect of different characters on rhizome yield in turmeric

Character	PH	NS	NL	PL	LL	LW	CG	LPR	LMR	LSR	GMR	GPR	GSR	NMR
PH	-0.012	0.000	-0.034	0.002	-0.072	-0.009	0.140	-0.031	0.264	0.003	0.049	-0.002	0.000	0.050
NS	0.001	0.003	-0.105	0.001	0.012	0.004	-0.050	-0.005	-0.167	0.019	-0.022	-0.020	0.071	0.155
NL	-0.002	0.001	-0.237	0.001	-0.018	-0.002	0.095	-0.004	0.133	-0.004	0.021	-0.012	0.056	0.052
PL	-0.008	0.001	-0.055	0.004	-0.059	-0.006	0.053	-0.037	0.073	0.002	0.019	-0.011	0.041	0.115
LL	-0.011	-0.001	-0.050	0.003	-0.083	-0.011	0.153	-0.041	0.267	-0.002	0.049	-0.007	-0.007	0.036
LW	-0.007	-0.001	-0.027	0.001	-0.064	-0.015	0.170	-0.060	0.243	0.008	0.049	-0.012	-0.024	0.018
CG	-0.006	-0.001	-0.085	0.001	-0.047	-0.009	0.266	-0.036	0.426	0.016	0.062	-0.029	0.049	-0.093
LPR	-0.002	0.000	-0.006	0.001	-0.022	-0.006	0.062	-0.155	0.053	0.067	0.010	-0.022	0.065	-0.016
LMR	-0.007	-0.001	-0.063	0.001	-0.044	-0.007	0.226	-0.016	0.502	-0.003	0.058	-0.013	0.033	-0.133
LSR	0.000	0.001	0.008	0.000	0.001	-0.001	0.036	-0.089	-0.014	0.117	0.001	-0.030	0.147	-0.095
GMR	-0.008	-0.001	-0.066	0.001	-0.053	-0.009	0.217	-0.020	0.387	0.002	0.076	-0.009	0.021	-0.070
GPR	0.000	0.001	-0.030	0.000	-0.007	-0.002	0.083	-0.038	0.070	0.039	0.007	-0.092	0.183	0.064
GSR	0.000	0.001	-0.052	0.001	0.002	0.001	0.050	-0.039	0.063	0.066	0.006	-0.065	0.259	0.009
NMR	-0.002	0.001	-0.032	0.001	-0.008	-0.001	-0.064	0.006	-0.172	-0.029	-0.014	-0.015	0.006	0.388
WMR	-0.008	-0.001	-0.039	0.001	-0.047	-0.008	0.179	-0.024	0.352	-0.007	0.054	-0.024	0.031	0.077
NPR	-0.005	0.001	-0.030	0.001	-0.038	-0.006	0.031	-0.053	0.007	0.012	0.016	-0.018	0.038	0.219
WPR	-0.003	0.001	-0.042	0.001	-0.018	-0.003	0.055	-0.036	0.026	0.026	0.011	-0.042	0.131	0.165
NSR	-0.005	0.000	-0.027	0.001	-0.038	-0.007	0.105	-0.077	0.087	0.068	0.024	-0.016	0.040	0.027
IN	0.003	0.001	0.031	0.000	0.017	0.004	-0.128	-0.053	-0.252	0.018	-0.045	0.000	0.033	0.052
IC	-0.001	0.001	-0.045	0.001	-0.003	-0.001	0.065	-0.022	0.040	0.023	0.003	-0.044	0.138	0.112
DR	-0.001	-0.001	0.006	-0.001	-0.008	-0.005	0.028	0.008	0.071	-0.025	0.020	0.043	-0.176	-0.089
OLE	0.000	0.001	-0.037	0.001	-0.007	0.001	-0.004	-0.059	-0.064	0.020	-0.015	-0.040	0.120	0.097
EO	0.000	0.001	0.015	0.000	0.000	-0.002	0.030	-0.061	-0.068	0.036	-0.013	-0.025	0.015	-0.012
BMC	0.002	0.001	-0.025	0.001	0.003	0.004	-0.024	-0.022	-0.086	0.013	-0.023	-0.046	0.137	0.078
DMC	-0.003	0.001	-0.059	0.001	-0.023	-0.003	0.085	-0.027	0.156	0.002	0.018	-0.047	0.133	0.099
CUR	0.000	0.001	-0.049	0.002	-0.002	0.002	-0.040	-0.025	-0.125	-0.005	-0.019	-0.025	0.077	0.134

Table 4. Cont.

Character	WMR	NPR	NSR	IN	IC	DR	OLE	LPR	LMR	LSR	GMR	GPR	GSR
PH	-0.049	-0.060	0.139	0.101	-0.045	-0.008	0.017	0.000	-0.002	0.011	-0.017	-0.011	0.424
NSR	0.011	-0.026	0.225	0.006	0.048	-0.041	-0.060	-0.009	0.012	-0.038	-0.015	0.158	0.169
NL	-0.012	-0.017	0.110	0.028	-0.022	-0.026	-0.004	-0.004	-0.005	-0.009	-0.019	0.073	0.176
PL	-0.024	-0.051	0.147	0.048	0.018	-0.019	-0.047	-0.009	-0.005	-0.029	-0.028	0.152	0.283
LL	-0.042	-0.061	0.139	0.112	-0.033	-0.005	0.016	-0.002	0.000	0.003	-0.021	0.008	0.407
LW	-0.039	-0.058	0.129	0.119	-0.044	-0.006	0.052	0.001	0.010	0.021	-0.014	-0.051	0.399
CG	-0.050	-0.016	0.129	0.097	-0.079	-0.033	0.017	0.000	0.009	0.008	-0.025	-0.053	0.518*
LPR	-0.011	-0.046	0.144	0.122	0.056	-0.019	-0.008	-0.009	0.031	-0.013	-0.014	0.056	0.319
LMR	-0.052	-0.002	0.033	0.042	-0.083	-0.011	0.023	0.003	-0.011	0.015	-0.024	-0.089	0.377
LSR	0.005	-0.014	0.136	0.141	0.025	-0.027	-0.034	-0.004	0.024	-0.009	-0.001	-0.015	0.308
GMR	-0.053	-0.028	0.090	0.079	-0.097	-0.005	0.043	0.005	-0.014	0.027	-0.018	-0.088	0.409
GPR	-0.020	-0.026	0.288	0.043	-0.001	-0.066	-0.075	-0.011	0.022	-0.045	-0.040	0.097	0.447
GSR	-0.009	-0.020	0.317	0.038	0.021	-0.072	-0.109	-0.011	0.005	-0.047	-0.040	0.105	0.482
NMR	-0.015	-0.076	0.266	0.017	0.022	-0.039	-0.037	-0.006	-0.002	-0.018	-0.020	0.123	0.284
WMR	-0.074	-0.052	0.179	0.058	-0.067	-0.029	0.009	0.000	-0.008	0.013	-0.034	-0.015	0.517*
NPR	-0.029	-0.135	0.357	0.140	0.020	-0.030	-0.002	-0.005	0.011	-0.004	-0.020	0.035	0.510*
WPR	-0.021	-0.077	0.625	0.093	0.021	-0.059	-0.050	-0.007	0.014	-0.027	-0.020	0.088	0.852*
NSR	-0.018	-0.077	0.237	0.245	0.007	-0.029	0.022	0.000	0.024	0.014	0.002	-0.069	0.540*
IN	0.030	-0.016	0.079	0.010	0.164	-0.014	-0.048	-0.007	0.017	-0.030	0.014	0.085	-0.033
IC	-0.016	-0.030	0.275	0.052	0.017	-0.135	-0.076	-0.010	0.022	-0.036	-0.029	0.116	0.414
DR	-0.004	0.002	-0.196	0.034	-0.049	0.064	0.160	0.016	-0.007	0.073	0.036	-0.220	-0.220
OLE	0.001	-0.028	0.179	-0.004	0.045	-0.057	-0.108	-0.024	0.033	-0.074	-0.051	0.301	0.228
EO	0.008	-0.018	0.113	0.074	0.036	-0.037	-0.013	-0.010	0.079	-0.022	0.003	0.039	0.167
BMC	0.011	-0.006	0.191	-0.039	0.057	-0.055	-0.133	-0.020	0.020	-0.088	-0.039	0.277	0.186
DMC	-0.032	-0.035	0.156	-0.006	-0.029	-0.050	-0.073	-0.016	-0.004	-0.044	-0.078	0.223	0.346
CUR	0.003	-0.013	0.154	-0.047	0.039	-0.044	-0.099	-0.021	0.009	-0.069	-0.049	0.355	0.147

* Significant at 5% level of probability

Residual effect: 0.264

Note: For details of abbreviations, refer Table 1.

dry recovery, length of secondary rhizome and negative for length of primary rhizome, number of primary rhizomes and inner core. The effect was negligible for the other characters (Table 4). Earlier workers (Verma *et al.* 2014, Mishra *et al.* 2015, Aarthi *et al.* 2018 and Maurya *et al.* 2018) have also reported similar effects of component traits on yield. Oleoresin had positive indirect effect through curcumin on yield. BDMC and DMC had positive indirect effect through curcumin respectively on yield.

The choice of economic trait for selection criteria based on pooled data recorded over the environment showed that selection for yield improvement in turmeric should be made on the basis of path analysis on rhizome characters like weight of mother rhizome, girth of mother rhizome, weight of primary rhizome, number of primary rhizomes and curcumin content. An attempt to emphasize on phyto constituents like CUR, BDMC and DMC variability and their association with yield is discussed, which can be used to develop or select a genotype for yield coupled with enriched phyto constituents.

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