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Research Article

Studies on growth analysis and framing selection criteria for high yield and quality traits in turmeric (*Curcuma longa* L.)

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Abstract
Fifty-five turmeric (*Curcuma longa* L.) genotypes comprising short, medium and long duration types were evaluated in augmented block design with two checks for growth, yield, and its component characters and quality to ascertain the presence of variability in the population and character association of growth, yield and quality parameters. The study revealed highly significant differences among the genotypes for all traits except total chlorophyll content. The fresh rhizome yield was maximum in the genotype CL 195 (long-duration type) and followed by CL 74 (medium duration type). For curcumin content, short-duration types and medium duration types showed better values, than long-duration types. Among the short duration type, the curcumin content was maximum in the genotype CL 78 (2.79 %) whereas, among the medium duration type, CL 22 recorded a curcumin content of 2.55 per cent. The factors, fresh rhizome yield and quality were optimum in the genotype CL 49 (short duration type), CL 22 (medium duration type), and CL 74 (long-duration type) owing to good values for overall growth parameters. The polygenic trait, yield showed a highly significant positive correlation with the characters *viz.,* the weight of primary rhizomes per plant, the weight of mother rhizomes per plant and leaf area. All the biometric and qualitative traits observed had a positive association with fresh rhizome yield except essential oil and curing per cent ensuring simultaneous improvement of these characteristics. The path coefficient study suggested that the characters *viz*., the weight of primary rhizomes per plant, the weight of mother rhizomes per plant, the weight of secondary rhizomes per plant, leaf area, plant height, pseudostem girth and curcumin content had a significant positive direct effect on rhizome yield levering more weightage for these characters in the further breeding program. The other quality traits had a relatively poor influence on yield. As short and medium duration genotypes of turmeric are advantageous over long duration types, the best performing short and medium duration types can be used for further crop improvement programme in turmeric.

Keywords: Turmeric, Duration, Yield, Curcumin, Correlation and Path Co-efficient Analysis

INTRODUCTION

Turmeric is also known as 'Indian saffron' is a rhizomatous perennial crop much valued for its coloring principle 'the curcumin'. Turmeric is believed to have originated from tropical South East Asia particularly, India which has a wide scope for natural variations (Anandaraj *et al*., 2014). Besides its use as a colorant in cooking and as a preservative, it has a wide range of usage in food industries, confectionery, pharmaceuticals and the cosmetic industries. Recently the wonder plant was reported to possess anti-cancerous properties besides anti-inflammatory properties for which it has been used since ancient times (Gupta *et al*., 2012; 2013). Awareness

of the use of natural dyes for culinary, medicinal, and cosmetic use has been increasing alarmingly and thus increasing the demand for turmeric. To expand the area under turmeric productivity and to increase production, it is essential to identify/develop genotypes with high yield and curcumin content.

The turmeric genotypes are clatssified into short, medium and long duration types based on their duration to set the harvest stage. Growth and yield analysis would help in understanding the physiology and agronomy of the crop and pave a new insight into the variability in a population. Owing to its sterility, rare seed set and incompatibility to a certain extent, it has been difficult for hybridization in turmeric. But positively the variations or goodness once achieved by selection pressure or rare natural hybridization can be passed on over generations. Hence, the crop improvement program in turmeric has been confined mainly to selection and to some extent, mutation breeding. (Ravindran *et al.*, 2007). The correlation and path study throws information on the association and influence of component characters over yield and quality. The knowledge of the yield and quality influencing traits helps in accomplishing a better breeding plan. With this background, the present investigation was undertaken to study the growth analysis and frame a selection criterion for high yield and quality in the short, medium and long duration of turmeric genotypes.

MATERIALS AND METHODS

A set of 55 turmeric genotypes comprising 20 short duration, 22 medium-duration and 13 long duration types were chosen as experimental material and planted with a spacing of 45 x 15 cm. The 55 genotypes were evaluated for variation in growth, yield, and quality. The experiment was laid at Horticultural College and Research Institute, Tamil Nadu Agricultural University (TNAU), Coimbatore during 2017-18, in augmented design with BSR 2 and CO 2 as local checks. Morphological observations were recorded in five randomly-chosen plants in each genotype at 180 DAP. Upon senescence of the above-ground parts that mark the maturity of the crop, the leaf sheaths were cut to ground level one week prior to harvest. A single randomly selected clump was taken in each genotype to study the rhizome characters. The harvested rhizomes were cured and powdered and the curcumin content was analyzed as per the procedure of ASTA, 1968. The estimates on correlation and path analysis were computed using the breeding tool TNAU STAT.

RESULTS AND DISCUSSION

Highly significant variations for growth characters was observed among and within the short, medium and long duration genotypes evaluated (**Table 1**). The maximum plant height was recorded in the genotypes CL 49 (133.02 cm), CL 22 (136.77 cm), and CL 88 (119.16 cm) among short, medium and long duration genotypes, respectively. The variation for plant height varied in the range of 67.36 to 133.02 cm, 46 to 136.76 cm and 74.5 to 119.6 cm, respectively among short, medium and long duration genotypes. The short duration types showed the highest growth, as they may follow a quick growth phase and attains maximum height earlier than the medium and long duration types. The increased interpretation of light would also favour higher photosynthetic rate and yield (Duncan, 1971). Hence, plant height is an influential trait that determines the final yield (Narayanpur *et al.*, 2003; Ravindran *et al.*, 2007). The variations observed in this prime morphological trait are of great importance in crop improvement.

The average number of tillers was high in short duration type 8.6 (CL 133), followed by long-duration type 7.4 (CL 260) and medium duration type 6.4 (CL 199). A high number of tillers may contribute to high yield if the soil and environment provide adequate nutrition to the developing tillers. In case of fragile soil or the presence of any factors that hinder nutrient acquisition, the assimilated metabolites in the main shoot get translocated to tillers and support its growth.

The number of leaves per tiller was maximum (**Table 1**) in short duration types (10.8) followed by long-duration types (10.4) and medium duration types (9.8) and depicted no significant difference between short, medium and long duration types. But significant variation existed for the number of leaves per plant within the types in the range of 4 to 10.8 in short duration types, 3.2 to 9.8 in medium duration types and 5.47 to 10.4 in long-duration types. Similarly, the leaf area among the genotypes varied in the range of 163.3 to 528.33 cm^2, 186.29 to 666.5 cm^2 and 191 to 547.88 cm^2, respectively in short, medium and long duration types. In general, the genotypes which had the highest leaf area produced significantly better fresh rhizome yield, than most of the genotypes in all the three duration types. The genotypes CL 49, CL 22, and CL 74 recorded the highest leaf area in short, medium and long duration types and produced significantly high fresh rhizome yield (453 g/plant), (692 g/plant) and (793 g/ plant), respectively. It has been reported that curcumin, the principal compound in turmeric is actively synthesized in earlier 3 to 4 leaves. The total $^{14}CO_2$ assimilated by the plant's first, second, third, and fourth leaves fixed 31, 23, 21 and 9 per cent of carbon in roots (4%), rhizome 6 (%), oil (0.01%) and curcumin (4.6%) of the fresh weight of rhizome (Dixit and Srivastava, 2000). The youngest developing leaf assimilated a maximum of $^{14}CO_2$ into metabolites and essential oil. In the rhizome, curcumin constituted the major metabolite. The incorporation of $^{14}CO_2$ into metabolites and oil declined as the leaves matured. Thus, curcumin content in any turmeric genotype depends on its leaf area and the life span of the leaf. Hence, variation in leaf number and leaf area is of great scope in breeding for the quality traits (Duncan, 1971).

Table 1. Performance of short, medium and long duration genotypes for yield and quality traits

S. No.	Genotypes	Plant height (cm)	Number of tillers per plant	Number of leaves per plant	Leaf area (cm^2)	Soluble protein (mg/g)	Yield/plant (g)	Curcumin content (%)
Short duration type								
1	CL 15	111.46	5.80	7.80	403.81	23.68	252.00	2.06
2	CL 49	133.02	4.20	10.20	528.33	23.74	453.00	2.55
3	CL 78	123.92	4.00	10.80	486.86	23.35	401.00	2.79
4	CL 100	88.80	4.80	8.20	348.63	19.39	127.00	1.58
5	CL 121	69.68	4.40	7.40	303.03	30.45	230.00	1.63
6	CL 131	91.36	3.80	8.80	384.69	11.03	117.00	2.01
7	CL 132	88.72	8.40	4.00	391.86	16.61	312.00	2.01
8	CL 133	80.80	8.60	5.20	370.75	14.81	323.00	1.75
9	CL 134	102.82	7.60	4.40	357.01	16.00	350.00	1.74
10	CL 146	103.64	5.20	9.00	412.98	17.52	371.00	1.98
11	CL 148	67.36	3.20	7.20	241.48	15.45	208.00	1.85
12	CL 169	91.16	4.40	8.60	316.56	18.58	180.00	1.59
13	CL 174	77.36	3.80	7.80	283.44	21.71	132.00	2.11
14	CL 175	73.16	5.00	8.00	321.74	16.45	196.00	2.27
15	CL 184	109.66	4.80	9.60	439.85	15.39	288.00	2.27
16	CL 189	119.07	4.60	9.60	492.30	13.10	470.00	1.83
17	CL 192	111.54	5.00	9.40	404.14	15.90	375.00	2.26
18	CL 213	92.56	3.20	8.40	359.01	21.42	289.00	1.61
19	CL 255	90.18	5.20	8.60	408.04	41.81	338.00	2.26
20	CL 269	71.10	4.60	7.20	163.30	19.23	214.00	2.30
Medium duration type								
1	CL 2	112.44	4.80	7.20	503.19	12.35	410.00	2.54
2	CL 22	136.76	3.20	3.20	666.51	18.26	692.00	2.55
3	CL 35	104.56	4.80	4.80	462.69	19.68	214.00	2.13
4	CL 41	101.94	4.60	8.20	432.16	41.74	366.00	2.52
5	CL 42	112.22	3.40	8.80	528.74	41.10	269.00	2.33
6	CL 52	101.10	3.80	8.00	492.99	35.74	347.00	2.24
7	CL 122	74.48	3.40	7.80	270.52	26.48	311.00	1.38
8	CL 130	75.88	3.60	8.20	306.26	30.23	162.00	2.02
9	CL 135	99.68	5.00	9.60	375.63	17.90	366.00	1.97
10	CL 144	101.76	4.20	9.20	398.72	15.90	215.00	2.01
11	CL 147	130.64	3.80	9.80	400.57	14.52	411.00	1.70
12	CL 149	72.76	3.00	7.80	258.17	10.90	90.00	1.77
13	CL 151	71.98	3.60	7.80	296.40	14.13	249.00	1.59
14	CL 152	105.72	4.80	9.20	422.32	14.13	353.00	2.45
15	CL 194	118.90	5.00	9.00	459.03	18.97	620.00	1.98
16	CL 195	103.30	6.20	8.60	431.92	22.39	798.00	1.93
17	CL 198	99.62	4.60	8.80	406.99	18.48	395.00	1.77
18	CL 199	111.54	6.40	9.40	435.59	21.06	266.00	2.30
19	CL 200	106.34	5.00	9.40	397.97	16.74	495.00	2.13
20	CL 201	46.00	1.40	6.20	186.29	18.42	370.00	2.09
21	CL 209	108.40	3.40	8.60	516.71	21.87	413.00	1.89
22	CL 262	104.94	8.00	9.40	443.48	20.45	516.00	1.91
Long duration type								
1	CL 43	107.40	5.00	8.80	469.30	23.74	401.00	2.09
2	CL 74	111.78	3.80	9.80	547.38	35.97	793.00	2.21
3	CL 75	74.50	2.00	7.00	386.16	24.65	207.00	2.59
4	CL 88	119.16	4.20	10.40	526.68	29.10	624.00	1.79
5	CL 89	106.90	5.80	9.40	426.22	23.16	372.00	1.75
6	CL 114	86.72	4.80	8.40	354.77	28.26	258.00	1.77
7	CL 120	81.38	3.80	7.20	373.49	32.94	117.00	1.52
8	CL 156	105.92	4.00	9.20	332.74	17.03	202.00	1.57
9	CL 158	82.90	4.50	8.00	276.24	14.94	236.00	1.51
10	CL 172	88.96	4.20	8.40	391.12	21.65	293.00	1.69
11	CL 173	82.98	4.20	7.80	338.95	20.84	280.00	1.99
12	CL 260	108.38	7.80	9.40	400.70	18.77	383.00	2.33
13	CL 263	89.88	7.20	8.60	338.61	19.16	312.00	2.16
Check								
BSR 2		91.87	2.34	5.47	387.14	22.94	317.10	2.12
CO 2		99.51	5.32	9.12	191.54	16.10	338.82	2.35
Mean		96.79	4.46	7.97	366.13	20.90	334.59	2.07
SE d		2.86	0.23	0.50	17.39	5.00	48.55	0.04
CD @ 0.05 %		6.01	0.48	1.05	36.51	10.50	101.95	0.09

The SPAD values for total chlorophyll content did not vary significantly (**Table 1**) among the genotypes at 180 DAP. There existed significant variation in leaf soluble protein content among the genotypes. The maximum values for leaf soluble protein content among the short, medium and long duration types varied in the range of 41.81 (CL 255), 41.74 (CL 41), 35.97 (CL 74) mg/g. Around 40 % of total soluble protein constitutes RuBisCo, the key enzyme in carbon fixation. Higher values for soluble protein indicate high RuBisCo activity, ultimately, high carbon fixation and productivity (Parry *et al.*, 2013).

Among the genotypes evaluated, the maximum fresh rhizome yield of 798 g per plant was registered in CL195 (medium duration type), 793 g per plant in CL74 (long-duration type) and 470 g per plant was obtained in CL189 (short duration type). Fresh rhizome yield being a complex polygenic trait, evaluating the genotypes considering yield attributing traits will be promising, rather than evaluating the yield directly. The curcumin content was maximum (2.79 %) in the short duration genotype CL78 (**Table 1**), followed by the medium duration types CL 22 (2. 55 %) and CL2 (2.54 %). Among the long duration types, the highest curcumin value was observed in the genotype CL75 (2.59 %), which is a poor yielder. The curcumin content has been reported to vary depending upon soil organic carbon, available nitrogen and manganese and agro climate condition (Geethanjali and Jayashankar, 2016; Kurian and Nair, 1996).

Hence, from the study, it is inferred that significant variation was observed among the genotypes for all the traits except total chlorophyll content at 180 DAP. The genotypes which showed high fresh rhizome yield had low curcumin content and *vice versa*. But both the yield and quality (curcumin) were optimum in the genotypes CL 74 (short duration) and CL 22 (medium duration).

Simple correlation and path co-efficient analysis studies were carried out on 15 important characters. Character association of a particular trait in relation to other traits contributing toward yield is of great importance in planning a successful breeding programme. Yield is a polygenic trait as the result of a contribution by many component traits. The effective improvement in this complex trait is only achieved by improving all components traits that are closely associated rather than considering yield directly. Hence, it is remarkable to rank all the associated traits in the hierarchy, to prioritise the most influencing characters. The current investigation revealed that the fresh rhizome yield was highly significant and positively correlated with the characters *viz.,* the weight of primary rhizomes (0.9447), the weight of mother rhizomes (0.7368), the weight of secondary rhizomes (0.7056), leaf area (0.6274), plant height (0.5844), core diameter (0.5431) and pseudo stem diameter (0.5240). Similar reports were registered for the weight of mother, primary and secondary rhizomes to yield (Hazra *et al*., 2000; Prajapati *et al.,* 2014) **(Table 2)**. Plant height has a strong inherent association with yield as supported by the findings (Bahadur *et al*., 2016, Roy *et al*., 2011) Hence, more weightage is to be given to these characters in any breeding programme. All the biometric characteristics except essential oil and curing percentage accounted positive association with yield, indicating the possibility of simultaneous improvement of component characters and yield. It has been generally accepted that correlation between different characters, results from a coordination of physiological processes, which is often achieved through linkage or pleiotropy, sometimes both (Phundan and Narayanan, 1993).

In terms of quality traits, the curcumin content (0.2393) and oleoresin content (0.0261) had a positive association while essential oil content (-0.0579) and curing percentage (-0.4226) had a negative correlation with yield. It is also known that correlation coefficients for a given pair of traits vary with the genotypes studied and the environment where, the study is carried out.

Plant height showed a highly significant correlation with leaf area (0.8507) and pseudo stem girth (0.5410). The characters *viz*., plant height and leaf area were significantly correlated with both the weight of mother rhizomes per plant and primary rhizomes per plant and the weight of primary rhizomes per plant has a significant positive association with pseudostem girth, the weight of mother rhizomes per plant and weight of secondary rhizomes per plant. The characters *viz*., plant height, leaf area, pseudo stem girth, the weight of primary rhizome per plant and weight of mother rhizomes per plant were highly inter correlated. The weight of secondary rhizomes per plant showed a significant positive association with the weight of primary rhizomes per plant. The weight of mother, primary and secondary rhizomes per plant are high intercorrelated and together it gets reflects in yield (Suresh *et al.,* 2019).

Studies on path coefficient analysis enable a breeder to concentrate on the variable which showed a direct effect on yield ultimately reducing the time in looking for more component traits by restricting selection to important traits.

In the present study, for evaluation of turmeric genotypes for special traits, the highest positive direct effect on fresh rhizome yield per plant was observed for the weight of primary rhizomes per plant (0.9447), the weight of mother rhizomes per plant (0.7368), the weight of secondary rhizomes per plant (0.7056), leaf area (0.6274), plant height (0.5844), pseudostem girth (0.524) and core diameter (0.5341). Similar results were obtained by Bahadur *et al*. (2016); Prajapati *et al.* (2014); Yadav *et al*. (2006) for plant height, the number of leaves and the weight of secondary rhizomes per plant. The influence of plant height on yield was confirmed

Table 2. Simple correlation among yield and its components in turmeric genotypes

Traits	PH	PSG	NT	NL	LA	SP	WMR	WPR	WSR	CD	E. oil	Oleo	Cur	CP	Y/p
PH	1														
PSG	0.5410*	1													
NT	0.2077	0.1131	1												
NL	0.3473	0.2881*	-0.0993	1											
LA	0.8507**	0.5786*	0.1025	0.1554	1										
SP	0.02	0.1893	-0.1598	0.1214	0.2448	1									
WMR	0.4553*	0.3774	-0.0197	0.1326	0.5700*	0.3831	1								
WPR	0.5493*	0.5149*	0.187	0.1258	0.5825*	0.0145	0.5456*	1							
WSR	0.4218	0.313	0.2452	0.2104	0.3935	-0.0942	0.2506	0.6612**	1						
CD	0.4352	0.4024	0.0099	0.2327	0.3672	0.1012	0.4804*	0.4951*	0.2534	1					
E. oil	0.0672	-0.1271	0.0799	-0.2447	-0.0676	-0.1734	-0.0657	-0.1052	-0.0931	0.1862	1				
Oleoresin	-0.226	-0.0368	-0.0396	-0.2109	-0.1796	-0.2493	-0.0702	0.1122	-0.0605	-0.1706	-0.0821	1			
Curcumin	0.3492	0.367	-0.0122	0.0534	0.4371	0.1638	0.1966	0.1843	0.2139	-0.033	0.0573	-0.3006	1		
CP	-0.3171	-0.4319	0.0473	-0.3457	-0.1943	0.0103	-0.268	-0.418	-0.3053	-0.2788	0.1665	0.1663	-0.3633	1	
Y/p	0.5844*	0.5240*	0.1654	0.1652	0.6274*	0.1233	0.7368**	0.9447**	0.7056**	0.5431*	-0.0579	0.0261	0.2393	-0.4226	1

* and ** significant at P < 5% and P < 1% level of significance, respectively

Note: PH - Plant height , PSG - Pseudo stem girth , NT – Number of tillers per plant, NL – Number of leaves per plant, LA - Leaf area , SP – Soluble protein , WMR - Weight of mother rhizome, WPR - Weight of primary rhizome , CD - Core diameter , E.oil – Essential oil, WSR - Weight of secondary rhizome, CP – Curing percentage and Y/p - Yield / plant

by earlier reports (Bahadur *et al*., 2016; Prajapati *et al.,* (2014); Yadav *et al*., 2006; Mishra *et al*., 2015; Rajyalakshmi *et al*., 2013). Hence, more weightage can be given to these characters to breed for high yield. The curcumin content (0.2393) has a moderate direct effect and the characters the number of tillers per plant, the number of leaves per plant, and soluble protein had a low direct influence on yield (**Table 3**). The curing per cent has a high direct and moderate indirect negative effect on yield by undesirable influence on the weight of primary rhizomes. Similar findings were reported by Prajapati *et al.* (2014) for curing per cent. The other qualities of oleoresins and essential oil have negligible influence on yield.

The weight of primary rhizome per plant has a high direct and indirect influence on fresh rhizome yield *via* plant height, pseudo stem girth, leaf area, the weight of mother rhizome per plant, and weight of primary rhizomes per plant. Leaf area has a moderate indirect effect on fresh rhizome yield *via* mother rhizomes per plant, while the plant height, pseudo stem girth, soluble protein, weight of primary rhizome per plant and core diameter has a low indirect effect on yield *via* weight of mother rhizomes per plant. The quality traits of oleoresin and essential oil showed a negligible impact on yield and all other characteristics. The apparent conflict between the correlation and path coefficient analysis is due to the fact that correlation simply measures the mutual association without regard to causation, while path specifies the relative importance of each causal factor. The very low residual value of 0.0981 indicates that the studied characters contribute 90 per cent, ensuring the adequacy of the characters to study fresh rhizome yield.

The present study depicts a highly significant positive correlation between the weight of primary rhizomes, the weight of mother rhizomes, leaf area, core diameter, plant height and pseudo stem diameter with fresh rhizome yield per plant presenting simultaneous improvement of these characteristics in the breeding plan for all duration germplasm.

The selection should be done, based on the expectation of the resultant breeding material, in the crop improvement programme. To identify genotypes with high curcumin and oleoresin content or with high essential oil content the selection should be done accordingly. With the objective of selection for higher yield, it's noteworthy to account for more weightage for the characters *viz.,* the weight of primary rhizomes per plant, the weight of mother rhizomes per plant, the weight of secondary rhizomes per plant, leaf area, plant height and pseudo stem girth which showed the high direct influence on yield. It can be an effective selection index to breed for higher yields in turmeric. These parameters and investigation are much useful for the identification of greater yielding genotypes and in the turmeric improvement programme.

Table 3. Path co-efficient analysis among yield and its components in turmeric genotypes

Traits	PH	PSG	NT	NL	LA	SP	WMR	WPR	WSR	CD	E.oil	Oleoresin	Curcumin	CP
PH	**0.5844**	0.0120	0.0005	0.0003	-0.0438	0.0003	0.1599	0.3399	0.0912	0.0032	0.0033	-0.0007	0.0053	0.0004
PSG	0.0067	**0.5240**	0.0003	0.0002	-0.0298	0.0028	0.1325	0.3187	0.0677	0.0030	-0.0063	-0.0001	0.0056	0.0006
NT	0.0026	0.0025	**0.1654**	-0.0001	-0.0053	-0.0024	-0.0069	0.1157	0.0530	0.0001	0.0040	-0.0001	-0.0002	-0.0001
NL	0.0043	0.0064	-0.0003	**0.1652**	-0.0080	0.0018	0.0466	0.0779	0.0455	0.0017	-0.0121	-0.0006	0.0008	0.0005
LA	0.0106	0.0128	0.0003	0.0001	**0.6274**	0.0036	0.2001	0.3605	0.0851	0.0027	-0.0034	-0.0005	0.0067	0.0003
SP	0.0002	0.0042	-0.0004	0.0001	-0.0126	**0.1233**	0.1345	0.0090	-0.0204	0.0008	-0.0086	-0.0007	0.0025	0.0000
WMR	0.0057	0.0083	0.0000	0.0001	-0.0294	0.0057	**0.7368**	0.3377	0.0542	0.0036	-0.0033	-0.0002	0.0030	0.0004
WPR	0.0068	0.0114	0.0005	0.0001	-0.0300	0.0002	0.1916	**0.9447**	0.1430	0.0037	-0.0052	0.0003	0.0028	0.0006
WSR	0.0052	0.0069	0.0006	0.0002	-0.0203	-0.0014	0.0880	0.4092	**0.7056**	0.0019	-0.0046	-0.0002	0.0033	0.0004
CD	0.0054	0.0089	0.0000	0.0002	-0.0189	0.0015	0.1687	0.3064	0.0548	**0.5431**	0.0092	-0.0005	-0.0005	0.0004
E. oil	0.0008	-0.0028	0.0002	-0.0002	0.0035	-0.0026	-0.0231	-0.0651	-0.0201	0.0014	**-0.0579**	-0.0002	0.0009	-0.0002
Oleoresin	-0.0028	-0.0008	-0.0001	-0.0002	0.0092	-0.0037	-0.0246	0.0694	-0.0131	-0.0013	-0.0041	**0.0261**	-0.0046	-0.0002
Curcumin	0.0043	0.0081	0.0000	0.0000	-0.0225	0.0024	0.0690	0.1141	0.0463	-0.0002	0.0028	-0.0009	**0.2393**	0.0005
CP	-0.0039	-0.0095	0.0001	-0.0003	0.0100	0.0002	-0.0941	-0.2587	-0.0660	-0.0021	0.0083	0.0005	-0.0056	**-0.4226**

Residual Effect = 0.0981

Note: PH - Plant height , PSG - Pseudo stem girth, NT – Number of tillers per plant, NL – Number of leaves per plant, LA - Leaf area , SP – Soluble protein , WMR - Weight of mother rhizome , WPR - Weight of primary rhizome , CD - Core diameter , E.oil – Essential oil, WSR - Weight of secondary rhizome , CP – Curing percentage

REFERENCES

American Spice Trade Association, 1968. Official analytical methods of the American Spice Trade Association-2.

Anandaraj, M., Prasath, D., Kandiannan, K., Zachariah, T.J., Srinivasan, V., Jha, A.K., Singh, B.K., Singh, A.K., Pandey, V.P., Singh, S.P. and Shoba, N., 2014. Genotype by environment interaction effects on yield and curcumin in turmeric (*Curcuma longa* L.). *Industrial Crops and Products*, **53**:.358-364. [Cross Ref]

Bahadur, V., Yeshudas, V. and Meena, O.P. 2016. Nature and magnitude of genetic variability and diversity analysis of Indian turmeric accessions using agro-morphological descriptors. *Canadian Journal of Plant Science*, **96**(3):371-381. [Cross Ref]

Dixit, D. and Srivastava, N.K. 2000. Distribution of photosynthetically fixed 14CO2 into curcumin and essential oil in relation to primary metabolites in developing turmeric (*Curcuma longa*) leaves. *Plant science*, **152**(2):165-171. [Cross Ref]

Duncan, W.G. 1971. Leaf angles, leaf area, and canopy photosynthesis 1. *Crop Science*, **11**(4):482-485. [Cross Ref]

Geethanjali, P. and Jayashankar, M. 2016. A review on litter decomposition by soil fungal community. *IOSR Journal of Pharmacy and Biological Sciences*, **11**(4):1-3. [Cross Ref]

Gupta, S.C., Patchva, S., Koh, W. and Aggarwal, B.B. 2012. Discovery of curcumin, a component of golden spice, and its miraculous biological activities. *Clinical and experimental pharmacology and physiology*, **39**(3):283-299. [Cross Ref]

Gupta, S.C., Sung, B., Kim, J.H., Prasad, S., Li, S. and Aggarwal, B.B. 2013. Multitargeting by turmeric, the golden spice: From kitchen to clinic. *Molecular nutrition & food research*, **57**(9):1510-1528. [Cross Ref]

Hazra, P., Roy, A. and Bandopadhyay, A. 2000. Growth characters as rhizome yield components of turmeric (*Curcuma longa* L.). *Crop Research (Hisar)*, **19**(2):235-240.

Kurian, A. and Nair, C.S. 1996. Evaluation of turmeric germplasm for yield and quality. *Indian Journal of Plant Genetic Resources*, **9**(2):327-329.

Mishra, R., Gupta, A.K., Lal, R.K., Jhang, T. and Banerjee, N., 2015. Genetic variability, analysis of genetic parameters, character associations and contribution for agronomical traits in turmeric (*Curcuma longa* L.). *Industrial Crops and Products*, **76**:.204-208. [Cross Ref]

Narayanpur, V.B. and Hanamashetti, S.I. 2003. Genetic variability and correlation studies in turmeric (*Curcuma longa* L.). *Journal of Plantation Crops*, **31**(2):48-51.

Parry, M.A., Andralojc, P.J., Scales, J.C., Salvucci, M.E., Carmo-Silva, A.E., Alonso, H. and Whitney, S.M. 2013. Rubisco activity and regulation as targets for crop improvement. *Journal of experimental botany*, **64**(3):717-730. [Cross Ref]

Phundan, S. and Narayanan, S.S. 1993. *Biometrical techniques in plant breeding*. Kalyani Publishers. 5th edition, New Delhi. pp.36

Prajapati, K.N., Patel, M.A., Patel, J.R., Joshi, N.R., Patel, A.D. and Patel, J.R., 2014. Genetic variability, character association and path coefficient analysis in turmeric (*Curcuma longa* L.). *Electronic Journal of Plant Breeding*, ***5***(1):131-137.

Rajyalakshmi, R., Naidu, L.N., Rajasekhar, M. and Sudhavani, V., 2013. Genetic variability, correlation and path coefficient analysis in turmeric (*Curcuma longa* L.). *Journal of Spices and Aromatic Crops*, **22**(1):104-107.

Ravindran, P.N., Babu, K.N. and Sivaraman, K., 2007. *Turmeric: the genus Curcuma*. CRC press. (No. 584.391634 T8). [Cross Ref]

Roy, S., Verma, S.K., Hore, D.K., Misra, A.K., Rathi, R.S. and Singh, S.K. 2011. Agro-morphological diversity in turmeric (*Curcuma longa*) accessions collected from north-eastern India. *Indian Journal of Agricultural Sciences*, **81**(10):898.

Suresh, R., Ramar, A., Balakrishnan, S. and Selvi, B.S., 2019. Character association in turmeric (*Curcuma longa* L.) genotypes. *The Pharma Innovation Journal*, **8**(8): 76-79.

Yadav, R.K., Yadav, D.S., Rai, N., Asati, B.S. and Singh, A.K., 2006. Correlation and path coefficient analysis in turmeric (*Curcuma longa* L.). *Indian Journal of Horticulture*, **63**(1):103-106.