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Studies on path coefficient for growth and yield attributing traits in turmeric. (*Curcuma longa* L.)

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Abstract
The present investigation was carried out in Randomized Block Design with three replications during 2016-17 and 2017-18 on two locations to study the variability, character association, and stability and adaptability for twenty two characters among thirty two genotypes across four environments. The study revealed that wide range of variation observed for all the traits among thirty two genotypes. Based on per se performance, the genotype NDH-98 produced maximum rhizome yield followed by NDH-1, NDH-74, NDH-16, NDH-11, NDH-15, NDH-79, NDH-68 and NDH-114 produced highest rhizome yield per hectare. At phenotypic level essential oil exerted highest positive direct effect on rhizome yield followed by weight of fresh rhizome per plant, width of mother rhizome, weight of secondary rhizome per plant. However, weight of mother rhizome per plant exerted highest negative direct effect on rhizome yield followed by dry matter per cent and curcumin.

Keywords: Turmeric (*Curcuma longa* L.), direct and indirect effect, path coefficient

Introduction
Historically, India has always been recognized as a "Land of Spices" since very early period of recorded history. The history of Indian spices dates back to the beginning of the human civilization. There are several references coasted about Indian spices and their uses in the Vedas (6000 BC), by 'Manu' (4000 BC). According to the Bureau of Indian standards, 63 kinds of spices are grown in our country among them turmeric (Curcuma longa L.) is one of the most important spices crop.

Turmeric, the golden spice of life, is one of the most essential spices used as important gradient in culinary all over the world. It is a multipurpose crop valued for its medicinal properties, coloring pigment and spicy flavour. According to Spices Board, Calicut, Kerala, mainly 52 spices are grown in India. Curcuma longa L. Syn. C. domestica, commonly known as turmeric, in Sanskrit 'Haridra' in Hindi 'Haldi' is one of the most important spices crop. It is a multipurpose crop valued for its medicinal properties, coloring pigment and spicy flavor. The genus Curcuma is considered to be a triploid with a somatic chromosome number of 63 (3n=3x=63) belonging to the family Zingiberaceae considered to have originated in the Indo-Malyan region (Purseglove, 1968) which comprises 40 genera and 400 tropical spices in the old world. Out of these three genera *viz*. Curcuma (Turmeric), Elletaria (Cardamom) and Zingiber (Ginger) have commercial importance as spices. Genus Curcuma has 40-50 species, which are found in tropical Asia. Turmeric leaves are large, lanceolate or oblong with short or no petioles. Flowers are dense spike ending with a tuff of large colored tracts with two or more flowers arising from each tract. Calyx is a short cylindrical toothed tube and corolla comprising of board segment. Among the 40 species of Curcuma only two species *viz*. *Curcuma longa* L. and *C. aromatic* Salisb. Are commercially cultivated for the production of turmeric. The turmeric is cultivated in India, Ceylon, many east Indian Island, Fiji, Queensland, China, Formosa and Indo China region. The crop occupies an area of 233 lakh ha with an annual production of 1190 lakh tones and productivity of 5.1 MT per ha. It occupies 6 per cent of total area under spices in India (Anonymous, 2015). The crop occupies major share of the area in the state of Tamil Nadu followed by Telangana, Andhra Pradesh, West Bengal and Karnataka.

The presence of wide range of variability in any crop provides a better chance of selecting the desirable types. The genotypic variation in the population is due to genotypic differences among individuals for particular character. On the other hand, phenotypic character is the observable difference present in individual due to the effect of both genotype and environment. A variety having wide or good adaptability is one which consistently gives superior production over a wide range of environment.

This combination of stability and performance is a very important. Stability is a common practice in trials involving varieties and breeding lines to grow a series of genotypes in a range of different environments.

Material and methods

The experimental material comprised of thirty two genotypes of turmeric maintained in All India Co-ordinated Research Project on Spices was taken for this investigation. These Narendra Haldi (NDH-8, NDH-10, NDH-11, NDH-16, NDH-161, NDH-162, NDH-68, NDH-74, NDH-79, NDH-98, NDH-114, NDH-115, NDH-116, NDH-128) genotypes were collected from Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad, Uttar Pradesh. The genotypes ACC-79, SLP-389/1 and ACC-48, IISR, Kozhikode, Calicut (Kerala), CSTH-9 from CCSHAU, Hisser (Haryana), PTS-12 and PTS-55 from Pottanigi, (Orissa), PIS- 8, RAU, Dholi, (Bihar), TCP-64 and TCP-14 UKKV, Koch Bihar, (W. B.), CL-54 TNAU, Coimbtoor, (T. N.) The check varieties were Pratibha [IISR, Kozhikode, Calicut (Kerala)] and NDH-1 (N. D. Univ. of Agri. & Tech. Faizabad, (U. P.). The experiment was conducted in Randomized Block Design. The material used in the experiment comprised of twenty five selected germplasm lines of turmeric. A random selection of five plants was made in each plot for recording the observations on different characters under study. The following observations were recorded during the course of experimentation. Observations on the following were recorded using the standard procedure: plant height (cm), number of tillers per clump, number of leaves per plant, plant girth (cm), weight of fresh rhizome per plant (g), length of mother rhizome (cm), width of mother rhizome (cm), weight of mother rhizome (g), number of primary rhizomes per plant, weight of primary rhizomes per plant (g), number of secondary rhizomes per plant, weight of secondary rhizomes per plant (g), number of tertiary rhizomes per plant, weight of tertiary rhizomes per plant, rhizome yield (q/ha), dry matter, curcumin, oleoresin and T.S.S. per cent.

Result and Discussion

Correlation studies reveal only the general relationship between any two variables without tracing any possible causes of such association. In such situation, the path coefficient analysis was used to partition the correlation coefficient into direct and indirect effects. The present study of genotypic and phenotypic path coefficient analysis for four environments pooled (Table-1) Showing the direct and indirect effects on yield are computed. Rhizome yield was taken as dependent variable. four environments pooled data (2016-17 to 2017-18), at phenotypic (Table-2) essential oil (0.88) exerted highest positive direct effect on rhizome yield followed by weight of fresh rhizome per plant (0.68), width of mother rhizome (0.58), weight of secondary rhizome per plant (0.58). However, weight of mother rhizome per plant (-0.36) exerted highest negative direct effect on rhizome yield followed by dry matter per cent (-0.36) and curcumin (-0.35). The plant height via essential oil (0.47), width of mother rhizome (0.23) and weight of fresh rhizome per plant (0.18). Number of tiller per plant via essential oil (0.50), width of mother rhizome (0.33) and weight of fresh rhizome per plant (0.27).Number of leaves per plant via essential oil (0.54), width of mother rhizome (0.39) and weight of fresh rhizome per plant (0.29). Plant girth per plant via essential oil (0.55), width of mother rhizome (0.26) and weight of fresh rhizome per plant (0.24).Weight of fresh rhizome per plant via essential oil (0.43), weight of secondary rhizome per plant (0.29) and width of mother rhizome (0.21).Length of mother rhizome via weight of fresh rhizome per plant (0.39), width of mother rhizome (0.37) and essential oil (0.18).Width of mother rhizome via essential oil (0.26) and weight of fresh rhizome per plant (0.25).Weight of mother rhizome per plant via width of mother rhizome (0.45), weight of fresh rhizome per plant (0.42), essential oil (0.23) and length of mother rhizome (0.13).Weight of primary rhizome per plant via essential oil (0.38), weight of fresh rhizome per plant (0.34) and width of mother rhizome (0.16).Number of secondary rhizome per plant via weight of fresh rhizome per plant (0.45), weight of secondary rhizome per plant (0.37) and essential oil (0.29).Weight of secondary rhizome per plant via weight of fresh rhizome per plant (0.34).

Number of tertiary rhizome per plant via weight of secondary rhizome per plant (0.21) and oleoresin (0.10).Weight of tertiary rhizome per plant via weight of secondary rhizome per plant (0.30) and weight of fresh rhizome per plant (0.12).Dry matter via essential oil (0.62), weight of fresh rhizome per plant (0.30) and width of mother rhizome (0.24).Curcumin via essential oil (0.31).Oleoresin via essential oil (0.37) and weight of fresh rhizome per plant (0.14).Essential oil via weight of fresh rhizome per plant (0.34) and width of mother rhizome (0.17) and TSS via width of mother rhizome (0.31) and weight of fresh rhizome per plant (0.11) had exerted maximum positive indirect effects on rhizome yield.

However, plant height via dry matter per cent (-0.20), weight of secondary rhizome per plant (-0.12) and number of tillers per plant (-0.11).Number of tillers per plant via Dry matter per cent (-0.24), weight of mother rhizome per plant (-0.17), plant height (-0.16) and number of leaves per plant (-0.13).Number of leaves per plant via dry matter per cent (-0.24), weight of mother rhizome per plant (-0.21), plant height (-0.12) and number of tillers per plant (-0.12).Plant girth per plant via dry matter per cent (-0.22), plant height (-0.16), number of tillers per plant (-0.13), weight of mother rhizome per plant (-0.12) and number of leaves per plant (-0.11).

Weight of fresh rhizome per plant via weight of mother rhizome per plant (-0.22) and dry matter per cent (-0.16). Length of mother rhizome via weight of mother rhizome per plant (-0.32) and dry matter (-0.14).Width of mother rhizome via weight of mother rhizome per plant (-0.28), weight of secondary rhizome per plant (-0.15), dry matter per cent (-0.15) and number of leaves per plant (-0.11).Weight of mother rhizome per plant via dry matter per cent (-0.12).Number of primary rhizome per plant via weight of secondary rhizome per plant (-0.15), essential oil (-0.11) and weight of fresh rhizome per plant (-0.10).Weight of primary rhizome per plant via dry matter per cent (-0.13) and plant height (-0.11).Number of secondary rhizome per plant via weight of mother rhizome per plant (-0.12).Weight of secondary rhizome per plant via width of mother rhizome (-0.15).Number of tertiary rhizome per plant via width of mother rhizome (-0.20) and essential oil (-0.12).Weight of tertiary rhizome per plant via width of mother rhizome (-0.21).Dry matter via weight of mother rhizome per plant (-0.13), plant height (-0.12), number of tillers per plant (-0.10) and number of leaves per plant (-0.10).Curcumin via weight of secondary rhizome per plant (-0.12), dry matter per cent (-0.12) and plant height (-0.10).

Essential oil via dry matter per cent (-0.25), oleoresin (-0.15), plant height (-0.12), number of leaves per plant (-0.10) and weight of mother rhizome per plant (-0.10).TSS via weight of secondary rhizome per plant (-0.19) and weight of mother rhizome per plant (-0.13) had exerted negative indirect effects on rhizome yield in four environment pooled data.

Table 1: Direct and Indirect effects (Phenotypic level) for different characters of turmeric in four environments (E_1, E_2, E_3, E_4) (MES, NDUAT and K.V.K, Gonda) over the year 2016-17 and 2017-18

Traits	No. of Tiller Per Plant	No. of Leaves Per Plant	Plant Girth Per Plant	Weight of Fresh Rhizome Per Plant (g)	Length of Mother Rhizome (cm)	Width of Mother Rhizome (cm)	Weight of Mother Rhizome Per Plant (g)	No. of Primary Rhizome Per Plant	Weight of Primary Rhizome Per Plant (g)	No. of Secondary Rhizome Per Plant	weight of Secondary Rhizome Per Plant (g)	No. of Tertiary Rhizome Per Plant	Weight Of Tertiary Rhizome Per Plant (gm)	Dry Matter%	Curcumin	Oleoresin	Essential Oil	T.S.S.	Rhizome Yield (q/Ha)	Traits
Plant Height (cm)	-0.22	-0.11	-0.08	-0.01	0.18	0.03	0.23	-0.05	0.00	-0.09	0.00	-0.12	0.00	-0.01	-0.20	0.03	-0.03	0.47**	0.07	0.11
No. of Tiller Per Plant	-0.16	-0.15	-0.13	-0.01	0.27	0.07	0.33*	-0.17	0.02	-0.06	-0.01	0.01	0.00	-0.01	-0.24	0.02	0.00	0.50**	0.07	0.35*
No. of Leaves Per Plant	-0.12	-0.12	-0.15	-0.01	0.29	0.07	0.39*	-0.21	0.03	-0.07	-0.02	0.03	0.00	-0.01	-0.24	0.00	0.00	0.54**	0.04	0.45**
Plant Girth Per Plant	-0.16	-0.13	-0.11	-0.01	0.24	0.04	0.26	-0.12	0.01	-0.07	-0.02	0.05	0.00	0.00	-0.22	0.02	-0.02	0.55**	0.05	0.37*
Weight of Fresh Rhizome Per Plant (g)	-0.06	-0.06	-0.07	0.00	0.68**	0.08	0.21	-0.22	0.02	-0.09	-0.04	0.29	0.00	0.01	-0.16	0.01	-0.07	0.43**	0.03	1.00
Length of Mother Rhizome (cm)	-0.04	-0.08	-0.08	0.00	0.39*	0.14	0.37*	-0.32*	0.03	-0.02	-0.01	0.03	0.00	-0.01	-0.14	0.01	-0.03	0.18	0.07	0.49**
Width of Mother Rhizome (cm)	-0.09	-0.08	-0.11	0.00	0.25	0.09	0.58**	-0.28	-0.01	-0.05	0.00	-0.15	0.00	-0.01	-0.15	0.00	-0.02	0.26	0.10	0.31*
Weight of Mother Rhizome Per Plant (g)	-0.03	-0.07	-0.09	0.00	0.42**	0.13	0.45**	-0.36*	0.01	-0.02	-0.02	0.07	0.00	-0.01	-0.12	-0.01	-0.04	0.23	0.07	0.59**
No.of Primary Rhizome Per Plant	0.00	0.02	0.03	0.00	-0.10	-0.02	0.04	0.02	-0.17	0.02	0.00	-0.15	0.00	0.01	0.08	0.01	-0.01	-0.11	0.05	-0.28
Weight of Primary Rhizome Per Plant (g)	-0.11	-0.05	-0.06	0.00	0.34	0.01	0.16	-0.04	0.02	-0.18	-0.02	0.03	0.00	0.00	-0.13	0.02	-0.07	0.38*	0.02	0.32*
No. of Secondary Rhizome Per Plant	0.00	-0.03	-0.04	0.00	0.45**	0.03	0.04	-0.12	0.00	-0.05	-0.06	0.37	0.00	0.01	-0.08	0.00	-0.06	0.29	-0.02	0.72**
weight of Secondary Rhizome Per Plant (g)	0.05	0.00	-0.01	0.00	0.34*	0.01	-0.15	-0.04	0.04	-0.01	-0.04	0.58**	0.00	0.02	0.00	-0.02	-0.04	0.02	-0.06	0.68**
No. of Tertiary Rhizome Per Plant	0.00	0.03	0.04	0.00	-0.01	-0.04	-0.20	0.08	0.01	0.02	0.00	0.21	0.00	0.02	0.07	-0.02	0.10	-0.12	-0.02	0.17
Weight of Tertiary Rhizome Per Plant (gm)	0.03	0.04	0.04	0.00	0.12	-0.03	-0.21	0.07	-0.03	0.00	-0.02	0.30	0.00	0.03	0.09	-0.01	0.04	-0.09	-0.03	0.36*
Dry Matter%	-0.12	-0.10	-0.10	-0.01	0.30*	0.06	0.24	-0.13	0.04	-0.07	-0.01	0.01	0.00	-0.01	-0.36*	0.02	-0.05	0.62**	0.04	0.37*
Curcumin	-0.10	-0.03	-0.01	0.00	0.06	0.02	0.02	0.04	-0.03	-0.05	0.00	-0.12	0.00	-0.01	-0.12	0.07	-0.08	0.31*	0.01	-0.02
Oleoresin	-0.02	0.00	0.00	0.00	0.14	0.01	0.04	-0.04	0.00	-0.03	-0.01	0.07	0.00	0.00	-0.06	0.02	-0.35*	0.37*	0.02	0.15
Essential Oil	-0.12	-0.08	-0.10	-0.01	0.34*	0.03	0.17	-0.10	0.02	-0.08	-0.02	0.01	0.00	0.00	-0.25	0.03	-0.15	0.88**	0.01	0.59**
T.S.S.	-0.09	-0.06	-0.03	0.00	0.11	0.06	0.31	-0.13	-0.04	-0.02	0.01	-0.19	0.00	-0.01	-0.07	0.00	-0.03	0.06	0.18	0.07

Table 2: Direct and Indirect effects (Genotypic level) for different characters of turmeric in four environments (E_1, E_2, E_3, E_4) (MES, NDUAT and K.V.K, Gonda) over the year 2016-17 and 2017-18

Traits	No. of Tiller Per Plant	No. of Leaves Per Plant	Plant Girth Per Plant	Weight of Fresh Rhizome Per Plant (g)	Length of Mother Rhizome (cm)	Width of Mother Rhizome (cm)	Weight of Mother Rhizome Per Plant (g)	No.of Primary Rhizome Per Plant	Weight of Primary Rhizome Per Plant (g)	No. of Secondary Rhizome Per Plant	weight of Secondary Rhizome Per Plant (g)	No. of Tertiary Rhizome Per Plant	Weight Of Tertiary Rhizome Per Plant (gm)	Dry Matter%	Curcumin	Oleoresin	Essential Oil	T.S.S.	Rhizome Yield (q/Ha)	Traits
Plant Height (cm)	-0.22	-0.11	-0.08	-0.01	0.18	0.03	0.23	-0.05	0.00	-0.09	0.00	-0.12	0.00	-0.01	-0.20	0.03	-0.03	0.47	0.07	0.11
No. of Tiller Per Plant	-0.16	-0.15	-0.13	-0.01	0.27	0.07	0.33	-0.17	0.02	-0.06	-0.01	0.01	0.00	-0.01	-0.24	0.02	0.00	0.50	0.07	0.35
No. of Leaves Per Plant	-0.12	-0.12	-0.15	-0.01	0.29	0.07	0.39	-0.21	0.03	-0.07	-0.02	0.03	0.00	-0.01	-0.24	0.00	0.00	0.54	0.04	0.45
Plant Girth Per Plant	-0.16	-0.13	-0.11	-0.01	0.24	0.04	0.26	-0.12	0.01	-0.07	-0.02	0.05	0.00	0.00	-0.22	0.02	-0.02	0.55	0.05	0.37
Weight of Fresh Rhizome Per Plant (g)	-0.06	-0.06	-0.07	0.00	0.68	0.08	0.21	-0.22	0.02	-0.09	-0.04	0.29	0.00	0.01	-0.16	0.01	-0.07	0.43	0.03	1.00
Length of Mother Rhizome (cm)	-0.04	-0.08	-0.08	0.00	0.39	0.14	0.37	-0.32	0.03	-0.02	-0.01	0.03	0.00	-0.01	-0.14	0.01	-0.03	0.18	0.07	0.49
Width of Mother Rhizome (cm)	-0.09	-0.08	-0.11	0.00	0.25	0.09	0.58	-0.28	-0.01	-0.05	0.00	-0.15	0.00	-0.01	-0.15	0.00	-0.02	0.26	0.10	0.31
Weight of Mother Rhizome Per Plant (g)	-0.03	-0.07	-0.09	0.00	0.42	0.13	0.45	-0.36	0.01	-0.02	-0.02	0.07	0.00	-0.01	-0.12	-0.01	-0.04	0.23	0.07	0.59
No.of Primary Rhizome Per Plant	0.00	0.02	0.03	0.00	-0.10	-0.02	0.04	0.02	-0.17	0.02	0.00	-0.15	0.00	0.01	0.08	0.01	-0.01	-0.11	0.05	-0.28
Weight of Primary Rhizome Per Plant (g)	-0.11	-0.05	-0.06	0.00	0.34	0.01	0.16	-0.04	0.02	-0.18	-0.02	0.03	0.00	0.00	-0.13	0.02	-0.07	0.38	0.02	0.32
No. of Secondary Rhizome Per Plant	0.00	-0.03	-0.04	0.00	0.45	0.03	0.04	-0.12	0.00	-0.05	-0.06	0.37	0.00	0.01	-0.08	0.00	-0.06	0.29	-0.02	0.72
weight of Secondary Rhizome Per Plant (g)	0.05	0.00	-0.01	0.00	0.34	0.01	-0.15	-0.04	0.04	-0.01	-0.04	0.58	0.00	0.02	0.00	-0.02	-0.04	0.02	-0.06	0.68
No. of Tertiary Rhizome Per Plant	0.00	0.03	0.04	0.00	-0.01	-0.04	-0.20	0.08	0.01	0.02	0.00	0.21	0.00	0.02	0.07	-0.02	0.10	-0.12	-0.02	0.17
Weight of Tertiary Rhizome Per Plant (gm)	0.03	0.04	0.04	0.00	0.12	-0.03	-0.21	0.07	-0.03	0.00	-0.02	0.30	0.00	0.03	0.09	-0.01	0.04	-0.09	-0.03	0.36
Dry Matter%	-0.12	-0.10	-0.10	-0.01	0.30	0.06	0.24	-0.13	0.04	-0.07	-0.01	0.01	0.00	-0.01	-0.36	0.02	-0.05	0.62	0.04	0.37
Curcumin	-0.10	-0.03	-0.01	0.00	0.06	0.02	0.02	0.04	-0.03	-0.05	0.00	-0.12	0.00	-0.01	-0.12	0.07	-0.08	0.31	0.01	-0.02
Oleoresin	-0.02	0.00	0.00	0.00	0.14	0.01	0.04	-0.04	0.00	-0.03	-0.01	0.07	0.00	0.00	-0.06	0.02	-0.35	0.37	0.02	0.15
Essential Oil	-0.12	-0.08	-0.10	-0.01	0.34	0.03	0.17	-0.10	0.02	-0.08	-0.02	0.01	0.00	0.00	-0.25	0.03	-0.15	0.88	0.01	0.59
T.S.S.	-0.09	-0.06	-0.03	0.00	0.11	0.06	0.31	-0.13	-0.04	-0.02	0.01	-0.19	0.00	-0.01	-0.07	0.00	-0.03	0.06	0.18	0.07

Path coefficient is simply a standardized partial regression coefficient and as such measures the direct influence of one variable upon another, which permits the separation of correlation coefficient into components of direct and indirect effects.

In present study at phenotypic level essential oil exerted highest positive direct effect on rhizome yield followed by weight of fresh rhizome per plant, width of mother rhizome, weight of secondary rhizome per plant. However, weight of mother rhizome per plant exerted highest negative direct effect on rhizome yield followed by dry matter per cent and curcumin.

The plant height via essential oil, width of mother rhizome and weight of fresh rhizome per plant. Number of tiller per plant via essential oil, width of mother rhizome and weight of fresh rhizome per plant. Number of leaves per plant via essential oil, width of mother rhizome and weight of fresh rhizome per plant. Plant girth per plant via essential oil, width of mother rhizome and weight of fresh rhizome per plant. Weight of fresh rhizome per plant via essential oil, weight of secondary rhizome per plant and width of mother rhizome. Length of mother rhizome via weight of fresh rhizome per plant, width of mother rhizome and essential oil. Width of mother rhizome via essential oil and weight of fresh rhizome per plant. Weight of mother rhizome per plant via width of mother rhizome, weight of fresh rhizome per plant, essential oil and length of mother rhizome. Weight of primary rhizome per plant via essential oil, weight of fresh rhizome per plant and width of mother rhizome. Number of secondary rhizome per plant via weight of fresh rhizome per plant, weight of secondary rhizome per plant and essential oil. Weight of secondary rhizome per plant via weight of fresh rhizome per plant. Number of tertiary rhizome per plant via weight of secondary rhizome per plant and oleoresin. Weight of tertiary rhizome per plant via weight of secondary rhizome per plant and weight of fresh rhizome per plant. Dry matter via essential oil, weight of fresh rhizome per plant and width of mother rhizome. Curcumin via essential oil. Oleoresin via essential oil and weight of fresh rhizome per plant. Essential oil via weight of fresh rhizome per plant and width of mother rhizome and TSS via width of mother rhizome and weight of fresh rhizome per plant had exerted maximum positive indirect effects on rhizome yield.

However, plant height via dry matter per cent, weight of secondary rhizome per plant and number of tillers per plant. Number of tillers per plant via Dry matter per cent, weight of mother rhizome per plant, plant height and number of leaves per plant. Number of leaves per plant via dry matter per cent, weight of mother rhizome per plant, plant height and number of tillers per plant. Plant girth per plant via dry matter per cent, plant height, number of tillers per plant, weight of mother rhizome per plant and number of leaves per plant. Weight of fresh rhizome per plant via weight of mother rhizome per plant and dry matter per cent. Length of mother rhizome via weight of mother rhizome per plant and dry matter. Width of mother rhizome via weight of mother rhizome per plant, weight of secondary rhizome per plant, dry matter per cent and number of leaves per plant. Weight of mother rhizome per plant via dry matter per cent. Number of primary rhizome per plant via weight of secondary rhizome per plant, essential oil and weight of fresh rhizome per plant. Weight of primary rhizome per plant via dry matter per cent and plant height. Number of secondary rhizome per plant via weight of mother rhizome per plant. Weight of secondary rhizome per plant via width of mother rhizome. Number of tertiary rhizome per plant via width of mother rhizome and essential oil. Weight of tertiary rhizome per plant via width of mother rhizome. Dry matter via weight of mother rhizome per plant, plant height, number of tillers per plant and number of leaves per plant. Curcumin via weight of secondary rhizome per plant, dry matter per cent and plant height. Essential oil via dry matter per cent, oleoresin, plant height, number of leaves per plant and weight of mother rhizome per plant. TSS via weight of secondary rhizome per plant and weight of mother rhizome per plant had exerted negative indirect effects on rhizome yield in four environment pooled data. The present findings are supported by Panja *et al.* (2002) [9], Pandey *et al.* (2003) [8], Tomar *et al.* (2005). Verma *et al*. (2014) [10], Mishra *et al.* (2015) [10] and Gupta *et al.* (2016) [5].

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