Genetic variability, correlation and path analysis in ginger (*Zingiber officinale* Rosc.) genotypes

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Abstract

A study was conducted to assess the variability of ginger genotypes in the Western Ghat regions of Kerala. Twenty ginger genotypes were collected and raised in randomized block design with four replications in the College of Agriculture, Vellayani during May 2018 to January 2019. Morphological parameters like plant height, number of tillers, leaf length, leaf breadth, leaf area, rhizome spread, rhizome thickness, yield parameters like fresh and dry rhizome yield, and quality parameters like starch, crude fibre, essential oil, oleoresin and total phenol content were evaluated. Genetic variability, heritability, genetic advance, correlation, path analysis and selection index were also assessed. All the genotypes showed significant variation for the quantitative traits. The ginger genotypes evaluated revealed higher fresh rhizome yield for T_{11} (Kazhakootam) followed by T_{15} (Nedumkandam) which produced 65.27 and 20.87 percentage increase in fresh rhizome yield over control. T_{12} (Irinjalakkuda) genotype recorded higher quality parameters such as starch (6.5% increase) and oleoresin (140 % increase) over the control suggesting the suitability of the genotype for processing. Based on selection index, ranking was done and genotypes T_{11} (Kazhakootam), T_{12} (Irinjalakkuda) and T_{15} (Nedumkandam) were found superior. High genotypic and phenotypic coefficient of variation, heritability and genetic advance were observed for fresh rhizome yield, oleoresin, crude fibre, total phenol and essential oil. High heritability coupled with moderate genetic advance was noted for plant height, rhizome spread, starch and number of tillers. Genotypic correlation coefficients revealed that fresh rhizome yield was positively and significantly correlated with rhizome thickness, number of tillers, rhizome spread, plant height, leaf area, oleoresin and leaf length, while leaf area, number of tillers, rhizome spread, rhizome thickness and oleoresin had positive direct effect on yield. Hence, characters such as rhizome spread and number of tillers with high heritability coupled with moderate genetic advance, and oleoresin with high heritability and high genetic advance were found superior and these traits could be used for effective selection.

Key words: Fresh rhizome yield, Ginger, Heritability, Path coefficient analysis, Variability.

Introduction

Ginger (*Zingiber officinale* Rosc.), one of the important herbaceous perennials of Zingiberaceae family, is of South East Asian origin. It is cultivated in India, China, Nepal, Indonesia, Thailand, Bangladesh and West Indies islands. India is the largest producer of ginger in the world with a production of 1.04 million tonnes from an area of 1.60 lakh hectares (Spices Board, 2018). At present, more than 50 ginger cultivars are grown in India (Ravindran and Nirmal, 2005). Indian ginger is well known for its quality (Ravi et al., 2017). In India production of dried ginger of commerce is mostly confined to the state of Kerala. Dried ginger from Kerala is considered to be superior because of its low fibre content, boldness and characteristic aroma and pungency (Nair, 2019). Cochin ginger and Calicut ginger are popular ginger types in international market. Odour and flavour of ginger are determined by volatile oil while the pungency is determined by the non-volatile compounds.

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Volatile oil comprises mainly of sesquiterpene hydrocarbons, monoterpene hydrocarbons and oxygenated monoterpenes (Purseglove et al., 1981). Major sesquiterpene hydrocarbon constituent of ginger oil is á-zingeberene (Zachariah, 2008). Pungency of ginger is due to gingerols, shogaols, paradols and zingerone (Baliga et al., 2013).

Ginger is vegetatively propagated and hence the genetic variability is narrow (Babu et al., 2013). An insight into the magnitude of variability present in a crop is thus of utmost importance as it provides the basis for effective selection. The available germplasm serves as the most valuable natural reservoir for providing donor parent to improve a particular trait (Hawkes, 1981). North East and Western Ghats, where ginger cultivation is carried out, form the area for diversity. The richness of diversity of ginger plants grown in the Western Ghat region of Kerala needs to be investigated and documented. Hence an attempt was made to collect ginger genotypes grown in the Western Ghats of Kerala and evaluate and compare their variability with the released variety (Aswathy) of the Kerala Agricultural University.

Material and methods

Experimental site

The investigation was undertaken in the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram during 2018- 2019. The site represented low land with sandy clay loam soil and is located at a latitude of 8^0 30'North and at a longitude of 76^0 54'East.

Experimental material

The present investigation comprised of twenty ginger genotypes (T_1 to T_{20}) collected from different regions of Kerala, planted in Instructional Farm, College of Agriculture, Vellayani and compared with control variety Aswathy, the high yielding variety released from Kerala Agricultural University for morphological traits, yield and quality parameters (Table 1). Rhizomes of ginger genotypes were cut into pieces of 10-15g weight containing at least one bud, treated with *Pseudomonas* (20g L^{-1}) for 20 minutes, shade dried and planted in protrays containing potting medium of coir pith and farm yard manure (FYM) in 3:1 ratio.

Table 1. Details of collected ginger genotypes

Genotype	Location	Village, Taluk, District	Latitude	Longitude	Altitude
T_1 (Mananthavady)	Mananthavady	Mananthavady, Wayanad	11°48'0''N	76°0'E	760m
T_2 (Kanchiar)	Kanchiar	Kanchiar, Idukki	9°41'45''N	76°59'47''E	850m
T_3(Thalayolaparambu)	Thalayolaparambu	Thalayolaparambu, Kottayam	9°78'0''N	76°44'E	24m
T_4 (Haripad)	Haripad	Haripad, Alappuzha	9°18' 0''N	76°28'0''E	10m
T_5 (Kottarakkara)	Kottarakkara	Kottarakkara, Kollam	8°59'0''N	76°46'00''E	41m
T_6 (Ambalavayal)	Ambalavayal	Ambalavayal, Wayanad	11°61'9''N	76°21'01''E	974m
T_7 (Kothamangalam)	Kothamangalam	Kothamangalam, Ernakulam	10°4'48''N	76°37'12''E	34m
T_8 (Karunagapally)	Karunagapally	Karunagapally, Kollam	9°30'16''N	76°32'70''E	14m
T_9 (Mannarkkad)	Mannarkkad	Mannarkkad, Palakkad	11°0'0''N	77°0'0''E	76m
T_{10} (Kattapana)	Kattapana	Kattapana, Idukki	9°84'30''N	77°15'1''E	900m
T_{11} (Kazhakootam)	Kazhakootam	Kazhakootam, Trivandrum	8°33'56''N	76°52'29''E	11m
T_{12} (Irinjalakkuda)	Irinjalakkuda	Irinjalakkuda, Thrissur	10°30'0''N	76°15'25''E	39m
T_{13} (Sultan Bathery)	Sultan bathery	Sultan bathery, Wayanad	11°0'0''N	76°0'0''E	901m
T_{14} (Murickassery)	Murickassery	Murickassery, Kottayam	9°57'20''N	77°10'0''E	28m
T_{15} (Nedumkandam)	Nedumkandam	Udumbanchola, Idukki	9°84'30''N	77°15'19''E	975m
T_{16} (Pozhuthana)	Pozhuthana	Pozhuthana, Wayanad	11°41'49''N	76°03'21''E	700m
T_{17} (Kalliyur)	Kalliyur	Kalliyur, Trivandrum	8°25'0''N	77°0'0''E	28m
T_{18} (Kottiyoor)	Kottiyoor	Kottiyoor, Kannur	11°52'35''N	75°51'15''E	11m
T_{19} (Thariyode)	Thariyode	Thariyode, Wayanad	11°41'49''N	76°11'09''E	52m
T_{20} (Thalavur)	Thalavur	Thalavur, Kollam	9°2'40''N	76°49'46''E	41m

Experimental design

Randomized block design with four replications was adopted. The experimental plot was prepared by ploughing followed by bed preparation with a plot size of 1.5m x 1m. The spacing followed was 20cm x 20 cm. The ginger seedlings were transplanted to the main field 40-45 days after planting. Manuring and fertilizer application was carried out as per Package of Practices Recommendations of Crops for ginger (KAU, 2016).

Morphological, yield and quality parameters of ginger genotypes

Various morphological parameters like plant height, number of tillers, leaf length, leaf breadth and leaf area were evaluated at seven months after planting. Fresh and dry rhizome yield (g per plant), rhizome spread (cm), rhizome thickness (cm), essential oil (per cent), oleoresin (per cent), starch (per cent), crude fibre (per cent) and total phenol content (mg standard per 100g) were evaluated after harvest. Height of the plant was measured from the base of the plant to the tip of the young fully opened leaf of the main shoot. Length of upper fourth leaf of the main shoot was measured from base of petiole to highest tip of leaf and width of the upper fourth leaf of the main shoot was measured at widest portion of leaf using a meter scale (PPVFRA, 2007). Leaf area was estimated using the formula,

Leaf Area (Y) = k x Leaf length x Leaf width – 0.7607, where, k= 0.6695 and was expressed in cm^2 (Joseph, 1992).

Rhizomes were harvested after yellowing and drying of the plants in the field and the fresh rhizome yield was recorded. The horizontal width of the rhizomes was measured as rhizome spread and rhizome thickness was measured using Vernier calipers. Essential oil and oleoresin were estimated as per the procedure of Pruthy (1993) and Braga et al. (1998), while starch, crude fibre and total phenol were estimated as per the procedure laid out by Sadasivam and Manickam (2008). The biometric observations recorded from the field evaluation were subjected to analysis of variance for the comparison among the genotypes (Panse and Sukhatme, 1967).

Variability among ginger genotypes

The genetic variability, heritability, genetic advance, correlation and path coefficient were estimated for yield and yield attributing traits in twenty ginger genotypes. The different characters used in the study included morphological traits such as plant height, number of tillers, leaf length, leaf breadth, leaf area, rhizome spread, rhizome thickness, and fresh rhizome yield, and quality traits such as starch, crude fibre, essential oil, oleoresin and total phenol content. The phenotypic and genotypic variances were calculated according to the method suggested by Johnson et al. (1955). These characters were categorized into high, medium and low values according to Sivasubrahmanian and Menon (1973). Broad sense heritability for each trait were estimated and expressed in percentage. Genetic advance were estimated using Burton (1952) formula. Range of broad sense heritability and genetic advance were estimated according to Johnson et al. (1955). The correlation coefficients were partitioned into direct and indirect effects using the path coefficient summarized by Dewey and Lu (1959). The statistical analysis was performed using the online agriculture data analysis tool OPSTAT (Sheoran et al., 1998). Selection index for these morphological and quality traits were estimated using R software (R Core Team 2020) and ranking of all genotypes were done based on index scores.

Results and discussion

Variation in morphological, yield and quality traits of ginger genotypes

Among the twenty ginger genotypes evaluated, Irinjalakkuda (T_{12}) genotype recorded the highest plant height (68.75 cm) and leaf length (23.75 cm) at 7 months after planting, indicating a vigorous nature of growth. At 7 months after planting, T_{11} (Kazhakootam) genotype recorded highest number of tillers per plant of 11.50. Rhizome spread and rhizome thickness among the ginger genotypes

ranged from 10.77cm to 13.91 cm and 1.08cm to 2.02cm respectively. T_{11} (Kazhakootam) genotype recorded the highest rhizome spread of 13.91 cm and the highest rhizome thickness of 2.02cm at harvest. The mean of fresh rhizome yield per plant varied from 49.32 to 150.40 g among the ginger genotypes collected (Plate 1). T_{11} (Kazhakootam) genotype recorded the highest fresh rhizome yield per plant (150.40 g), followed by T_{15} (Nedumkandam) genotype (110.17 g). Genotypes such as T_{16} (Pozhuthana) and T_{12} (Irinjalakkuda) recorded yields of 96.13 and 94.95 g per plant and these four genotypes recorded significantly higher mean fresh rhizome yield per plant than control variety T_{21} (Aswathy), which recorded fresh rhizome yield of 90.86 g per plant. T_{11} (Kazhakootam) genotype recorded the highest dry rhizome yield per plant (30.81 g), followed by T_{15} (Nedumkandam) genotype (23.48 g) (Table 2).

Significant variation in starch content was noticed among the ginger genotypes. Starch content ranged from 32.53 to 41.90 per cent in ginger genotypes collected. Significantly higher starch content was recorded from T_{12} (Irinjalakkuda) genotype (41.90%). Among the genotypes, crude fibre content ranged between 1.20 and 5.75 per cent. The highest crude fibre content (5.75 %) was observed in T_{16} (Pozhuthana) and the lowest crude fibre content (1.20 %) was observed in T_7 (Kothamangalam) genotype. Essential oil content of selected ginger genotypes varied from 0.90 to 2.42 per cent. The highest percentage of essential oil content was observed in Thalavur (T_{20}) (2.42%) followed by T_{16} (Pozhuthana) with 1.97 per cent. The essential oil is important in ginger, as the cumulative effect of the essential oil components impart the perfumery smell to ginger (Goudar et al., 2017). In this study, oleoresin content among genotypes ranged from 4.00 to 12.50 per cent. Significantly superior oleoresin content was observed in T_{12} (Irinjalakkuda) (12.50%) followed by T_{16} (Pozhuthana) (10.47%). Total phenol content varied from 20.63 to 82.44 (mg g^{-1}) in the selected

Plate 1. Fresh rhizomes of ginger genotypes

Table 2. Variability of the ginger genotypes for quantitative traits

Genotype	Plant height (cm)	Number of tillers	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)	Fresh rhizome yield(g/plant)	Dry rhizome yield (g/plant)	Rhizome spread (cm)	Rhizome thickness (cm)
T_1 (Mananthavady)	60.54	10.59	21.43	3.08	43.38	49.32	10.11	11.49	1.12
T_2 (Kanchiar)	61.80	10.05	22.15	3.09	42.89	61.21	12.01	12.79	1.14
T_3 (Thalayolaparambu)	58.80	10.10	21.51	3.07	43.39	60.20	11.05	11.98	1.28
T_4 (Haripad)	63.65	9.56	20.87	3.03	41.49	70.76	15.29	11.94	1.19
T_5 (Kottarakkara)	61.91	10.10	21.23	2.92	40.76	65.37	11.71	10.77	1.15
T_6 (Ambalavayal)	53.44	9.10	21.77	3.13	43.14	65.07	11.93	11.19	1.08
T_7 (Kothamangalam)	57.00	9.10	21.89	3.06	44.01	67.37	11.88	11.68	1.25
T_8 (Karunagapally)	63.43	8.65	21.52	3.03	48.20	77.60	14.94	11.80	1.24
T_9 (Mannarkkad)	60.25	10.52	21.67	3.04	43.33	84.30	16.19	11.54	1.10
T_{10} (Kattapana)	51.92	9.05	21.71	3.02	43.17	64.67	12.21	11.46	1.14
T_{11}(Kazhakootam)	63.74	11.50	21.84	3.01	45.06	150.40	30.81	13.91	2.02
T_{12}(Irinjalakkuda)	68.75	10.40	23.75	3.07	47.96	94.95	20.56	13.76	1.17
T_{13}(Sultan Bathery)	57.22	9.85	20.49	3.06	41.24	68.32	14.25	12.03	1.14
T_{14}(Murickassery)	57.57	9.55	21.28	3.03	42.41	64.82	12.21	13.13	1.19
T_{15}(Nedumkandam)	64.56	10.35	21.58	3.04	44.84	110.17	23.48	13.02	1.30
T_{16}(Pozhuthana)	60.35	10.21	21.23	3.04	43.25	96.13	16.98	13.03	1.18
T_{17}(Kalliyur)	54.56	9.45	22.01	3.00	42.37	65.05	11.93	12.09	1.09
T_{18}(Kottiyoor)	63.07	9.10	21.84	3.04	43.60	66.97	13.89	11.70	1.15
T_{19}(Thariyode)	58.00	9.15	21.11	2.99	41.58	78.07	13.86	11.47	1.17
T_{20}(Thalavur)	54.37	9.45	20.27	2.99	39.75	61.58	11.79	12.26	1.18
T_{21}(Control- Aswathy)	61.60	9.95	20.85	3.01	41.19	90.86	18.04	11.91	1.16
CD (0.05)	0.854	0.617	0.400	0.048	1.001	1.450	0.703	0.29	0.049
SE (m) +	0.301	0.218	0.141	0.017	0.353	0.558	0.248	0.10	0.017
CV	1.007	4.440	1.309	1.119	1.635	1.789	3.317	1.682	2.855

Table 3. Quality parameters of the ginger genotypes

Genotype	Starch content(%)	Crude fibre content(%)	Essential oil(%)	Oleoresin (%)	Total phenol content (mg standard/100g)
T_1 (Mananthavady)	40.82	2.30	1.21	4.45	20.63
T_2 (Kanchiar)	37.70	2.80	1.10	6.55	82.44
T_3(Thalayolaparambu)	35.91	2.40	1.00	5.97	64.80
T_4 (Haripad)	35.75	2.60	1.40	9.42	22.77
T_5 (Kottarakkara)	36.21	3.45	1.45	5.55	64.45
T_6 (Ambalavayal)	32.53	3.48	0.98	4.00	61.62
T_7 (Kothamangalam)	35.56	1.20	1.28	5.55	55.26
T_8 (Karunagapally)	37.60	2.55	1.50	6.05	22.35
T_9 (Mannarkkad)	36.93	1.57	1.28	7.05	72.99
T_{10} (Kattapana)	33.16	2.55	0.95	4.44	22.21
T_{11}(Kazhakootam)	35.85	1.32	1.02	6.53	57.80
T_{12}(Irinjalakkuda)	41.90	2.45	1.05	12.50	66.14
T_{13}(Sultan Bathery)	33.06	2.02	1.17	5.48	57.87
T_{14}(Murickassery)	38.62	4.65	0.90	6.15	47.97
T_{15}(Nedumkandam)	37.45	2.31	1.12	6.47	52.93
T_{16}(Pozhuthana)	35.24	5.75	1.97	10.47	56.42
T_{17}(Kalliyur)	36.13	3.17	1.10	9.22	51.54
T_{18}(Kottiyoor)	33.21	1.77	1.10	4.23	76.62
T_{19}(Thariyode)	35.73	1.52	1.00	4.42	33.29
T_{20}(Thalavur)	37.52	1.60	2.42	4.45	22.59
T_{21} (Control-Aswathy)	39.34	1.47	1.07	5.20	70.19
CD (0.05)	2.232	0.232	0.185	0.262	2.346
SE (m) +	0.787	0.082	0.065	0.092	0.827
CV	4.314	6.480	10.494	2.891	3.208

genotypes (Table 3). The highest total phenol content was found in T_2 (Kanchiar) (82.44 mg g^{-1}). Quantitative characters such as number of tillers, rhizome spread, rhizome thickness, fresh rhizome yield per plant and dry rhizome yield per plant were significantly superior for T_{11} (Kazhakootam) genotype, suggesting its suitability for fresh ginger production.T_{12} (Irinjalakkuda) recorded higher quality parameters like starch (41.90 %) and oleoresin content (12.50 %), suggesting the suitability of the genotype for processing.

Variability among ginger genotypes

The estimates of variance which included phenotypic and genotypic variance, phenotypic coefficient of variation (%), genotypic coefficient of variation (%), heritability in broad sense (%), genetic advance (as % of means) are presented in table 4. In this study, phenotypic variance ranged from 0.0025 for leaf breadth to 500.20 for fresh rhizome yield, which was followed by total phenol content (394.38). Genotypic variance ranged from 0.0015 for leaf breadth to 498.96 for fresh rhizome yield. Islam et al. (2008) reported high genotypic variance for rhizome yield per plant (6807.42) and lowest for leaf breadth (0.13) in 19 ginger genotypes. In the present study, GCV (genotypic coefficient of variation) ranged from 1.28 per cent for leaf breadth to 44.36 per cent for crude fibre content. High GCV was observed for crude fibre, total phenol, oleoresin, essential oil and fresh rhizome yield. Moderate GCV was observed for rhizome thickness. Low GCV were recorded for characters like plant height, rhizome spread, starch content, number of tillers, leaf area, leaf length and leaf breadth. Islam et al. (2008) also reported high GCV for rhizome yield per plant (57.18%) and low GCV for leaf breadth (13.89%). Ravishanker et al. (2013) also reported high GCV for acidity percentage (42.94 %), oleoresin content (37.50 %) and yield per plant (23.81 %). PCV (Phenotypic coefficient of variation) assessed in the present study ranged from 1.65 per cent for leaf breadth to 44.84 per cent for crude fibre content. The characters like crude fibre, total phenol, oleoresin, essential oil and fresh rhizome yield showed high value of PCV while rhizome thickness showed moderate PCV. Low PCV was recorded for characters like starch, number of tillers, plant height, rhizome spread, leaf area, leaf length and leaf breadth, which indicate low variability. Islam et al. (2008) also reported high PCV for rhizome yield per plant (58.42 %) and low PCV for leaf breadth (13.90 %). Ravishanker et al. (2013) also reported high PCV for acidity percentage (44.46 %), oleoresin content (37.93 %) and yield per plant (25.51 %).The close correspondence of the genotypic and the phenotypic variance for almost all traits indicated less influence by environmental conditions, and hence a wider scope to select genotypes for yield.

High heritability was noted for fresh rhizome yield (99.75%), followed by oleoresin (99.33%), total phenol content (99.31%), plant height (97.97%),

Table 4. Genetic parameters of the ginger genotypes

Characters	Phenotypic variance	Genotypic variance	Genotypic Coefficient of Variation(%)	Phenotypic Coefficient of Variation(%)	Heritability (%)	Genetic advance (as % of means)
Plant height	17.78	17.41	6.98	7.05	97.97	14.23
Number of tillers	0.55	0.36	6.13	7.60	65.14	10.20
Leaf length	0.56	0.48	3.21	3.47	85.77	6.13
Leaf breadth	0.0025	0.0015	1.28	1.65	57.64	2.05
Leaf area	4.74	4.24	4.77	5.04	89.49	9.30
Fresh rhizome yield	500.20	498.96	29.08	29.11	99.75	59.82
Rhizome spread	0.72	0.68	6.8	7.01	94.24	13.60
Rhizome thickness	0.04	0.04	15.84	16.05	96.86	32.13
Starch	7.83	5.35	6.34	7.67	68.34	10.79
Crude fibre	1.28	1.25	44.36	44.84	97.91	90.43
Oleoresin	5.09	5.06	35.2	35.32	99.33	72.26
Essential oil	0.15	0.13	28.86	30.71	88.32	55.87
Total phenol	394.38	391.64	38.38	38.51	99.31	78.78

crude fibre (97.91%), rhizome thickness (96.86%), rhizome spread (94.24%), leaf area (89.49%), essential oil (88.32%), leaf length (85.77%), starch (68.34%) and number of tillers (65.14%). Moderate heritability was observed for leaf breadth (57.64%). Genetic advance (GA), expressed as percentage of mean, was low to high in nature and ranged from 2.05 to 90.43 per cent. The highest estimate of genetic advance was observed for crude fibre (90.43%), followed by total phenol (78.78%), oleoresin (72.26%), fresh rhizome yield (59.82%), essential oil (55.87%) and rhizome thickness (32.13%). Moderate genetic advance was observed for plant height (14.23%), rhizome spread (13.60%), starch (10.79%) and number of tillers (10.20%). Lower value of genetic advance was obtained for leaf area (9.30%), leaf length (6.13%) and leaf breadth (2.05%). High genetic gain was observed for acidity, oleoresin and ascorbic acid content among 25 ginger genotypes evaluated (Ravishanker et al., 2013). Karthik et al. (2017) reported high heritability coupled with high genetic gain for oleoresin content and fresh rhizome yield per plant in sixteen ginger genotypes evaluated. The efûciency with which genotypic variability could be exploited by selection depended upon heritability and the genetic advance of individual traits (Bilgin et al., 2010). Nwangburuka et al. (2012) opined that characters with high heritability as well as high genotypic co efûcient of variation and genetic advance could be explained by additive gene action and hence could be improved through mass selection in ginger.

In the present experiment, high coefficient of variation, high heritability as well as high genetic advance were recorded for characters like crude fibre, total phenol, oleoresin, fresh rhizome yield, essential oil and rhizome thickness, indicating that selection for these characters in ginger could be more effective due to additive gene action.

Genotypic correlation coefficients were calculated for all characters and high positive correlation was found between fresh rhizome yield and rhizome thickness (0.770), number of tillers (0.711), rhizome spread (0.650), plant height (0.505), leaf area (0.399), oleoresin (0.323), leaf length (0.210), total phenol (0.204) and starch (0.100). All these characters showed significant positive correlation except for total phenol and starch which were positive but non-significant. Leaf breadth (-0.174), crude fibre (-0.211) and essential oil (-0.073) showed non significant negative correlation with fresh rhizome yield. Rhizome thickness presented the highest positive correlation with fresh rhizome yield among the traits evaluated (Table 5). Yield was positively associated to rhizome thickness (Nandkangre et al., 2016), plant height and number of tillers (Ravi et al., 2017).

Table 5. Character association of the ginger genotypes

	Yield (fresh rhizome yield)	Plant height	No. of tillers	Leaf length	Leaf breadth	Leaf area	Rhizome spread	Rhizome thickness	Starch	Crude fibre	Oleoresin	Essential oil	Total phenol
Yield(Fresh rhizome yield)	1.00												
Plant height	0.505**	1.00											
No. of tillers	0.711**	0.530**	1.00										
Leaf length	0.210^{NS}	0.392**	0.208^{NS}	1.00									
Leaf breadth	-0.174^{NS}	-0.047^{NS}	-0.100^{NS}	0.389**	1.00								
Leaf area	0.399**	0.539**	0.119^{NS}	0.742**	0.388**	1.00							
Rhizome spread	0.650**	0.449**	0.686**	0.380**	0.144^{NS}	0.422**	1.00						
Rhizome thickness	0.770**	0.304**	0.633**	0.085^{NS}	-0.175^{NS}	0.322**	0.540**	1.00					
Starch	0.100^{NS}	0.547**	0.353**	0.304**	-0.087^{NS}	0.303**	0.414**	-0.005^{NS}	1.00				
Crude fibre	-0.211^{NS}	-0.134^{NS}	-0.051^{NS}	0.029^{NS}	0.047^{NS}	-0.038^{NS}	0.169^{NS}	-0.261*	0.025^{NS}	1.00			
Oleoresin	0.323**	0.489**	0.395**	0.503**	0.028^{NS}	0.379**	0.580**	0.030^{NS}	0.383**	0.285**	1.00		
Essential oil	-0.073^{NS}	-0.063^{NS}	-0.077^{NS}	-0.465**	-0.354**	-0.249*	-0.013^{NS}	-0.086^{NS}	0.054^{NS}	-0.001^{NS}	0.109^{NS}	1.00	
Total phenol	0.204^{NS}	0.263*	0.395**	0.384**	0.215*	0.051^{NS}	0.186^{NS}	0.006^{NS}	-0.063^{NS}	-0.001^{NS}	0.152^{NS}	-0.323**	1.00

**Significant at 1% level,*Significant at 5% level

Table 6. Influence of independent characters on fresh rhizome yield of ginger genotypes

	Plant height	Number of tillers	Leaf area	Rhizome spread	Rhizome thickness	Oleoresin
Plant height	**-0.16**	0.39	0.52	0.23	-0.11	0.008
Number of tillers	-0.08	**0.74**	0.11	0.35	-0.24	0.007
Leaf area	-0.09	0.09	**0.96**	0.21	-0.12	0.007
Rhizome spread	-0.07	0.51	0.40	**0.50**	-0.20	0.010
Rhizome thickness	-0.05	0.47	0.31	-0.27	**0.37**	0.001
Oleoresin	-0.08	0.29	0.36	0.29	-0.01	**0.017**

Residual effect: 0.109. Dependent variable: Fresh rhizome yield. Independent variables: Plant height, Number of tillers, Leaf area, Rhizome spread, Rhizome thickness, Oleoresin

In the present study, the highly correlated yield components like plant height, number of tillers, leaf area, rhizome spread, rhizome thickness and oleoresin were taken as independent characters, and fresh rhizome yield as a dependent character for path coefficient analysis (Table 6). Leaf area (0.96), number of tillers (0.74), rhizome spread (0.50), rhizome thickness (0.37) and oleoresin (0.017) had positive direct effect on fresh rhizome yield, as shown in the path diagram (Figure 1).

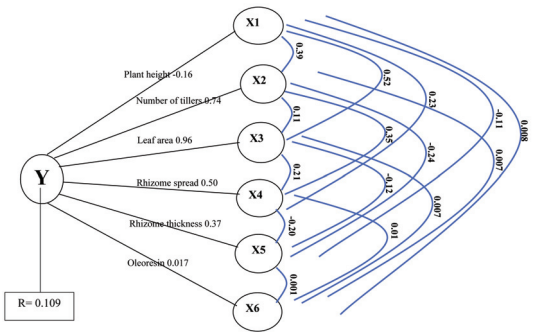

Figure 1. Path diagram for direct and indirect effects of independent characters on fresh rhizome yield
Y- Fresh rhizome yield; X1- Plant height; X2- Number of tillers; X3- Leaf area; X4- Rhizome spread; X5- Rhizome thickness; X6- Oleoresin

Plant height showed a negative direct effect on fresh rhizome yield per plant (-0.16) even though it had significant positive genotypic correlation, indicating the indirect effect through other independent characters like leaf area (0.52), number of tillers (0.39), rhizome spread (0.23), oleoresin (0.008). This result was supported by the study of Islam et al. (2008) who reported a negative direct effect of plant height (-0.315) on yield per plant in ginger.

Number of tillers had positive direct (0.74) and indirect effect through leaf area (0.11), rhizome spread (0.35) and oleoresin (0.007) on fresh rhizome yield per plant. Negative indirect effect was showed through plant height (-0.08) and rhizome thickness (-0.24). Ravi et al. (2017) also reported high positive direct effect of number of tillers (3.488) on yield per plant in 16 ginger genotypes evaluated.

Leaf area showed a positive direct effect (0.96) and indirect effect through number of tillers (0.09), rhizome spread (0.21) and oleoresin (0.007) on fresh rhizome yield per plant. Negative indirect effect was shown through plant height (-0.09) and rhizome thickness (-0.12). Ravi et al. (2017) reported positive direct effect of leaf area index on yield per plant among ginger genotypes.

Rhizome spread recorded a positive direct effect on fresh rhizome yield per plant (0.50). Positive indirect effect was shown through number of tillers (0.51), leaf area (0.40) and oleoresin (0.01). Negative indirect effect was shown through plant height (-0.07) and rhizome thickness (-0.20). Abraham and Latha (2003) also reported positive direct effect of rhizome length (0.16) on yield plant $^{-1}$ in 40 ginger genotypes.

Rhizome thickness recorded a positive direct effect on fresh rhizome yield per plant (0.37). Positive indirect effect was shown through number of tillers (0.47), leaf area (0.31) and oleoresin (0.001). Negative indirect effect was shown through plant height (-0.05) and rhizome spread (-0.27). Pandey and Dhobal (1993) also reported positive direct effect of thickness of secondary rhizome on yield

per plant (0.093) in 29 ginger genotypes evaluated.

Oleoresin recorded a positive direct effect on fresh rhizome yield per plant (0.017). Positive indirect effect was shown through number of tillers (0.29), leaf area (0.36) and rhizome spread (0.29). Negative indirect effect was shown through plant height (-0.08) and rhizome thickness (-0.01). Mehra (2012) also reported positive direct effect of oleoresin (0.238) on yield per plant in 40 ginger genotypes evaluated.

Selection index were estimated for all genotypes, based on morphological, yield and quality parameters. Ranking were done based on index score (table 7).T_{11} (Kazhakootam) genotype ranked first with index score of 352.00 followed by T_{12} (Irinjalakkuda) (321.60) and T_{15} (Nedumkandam) genotype (304.05). Genotypes were arranged In the descending order of index value. This result indicated that T_{11} (Kazhakootam), T_{12} (Irinjalakkuda) and T_{15} (Nedumkandam) genotypes were superior among the ginger genotypes evaluated.

Table 7. Selection index values of genotypes

Genotype	Selection index score
T_{11}(Kazhakootam)	352.00
T_{12}(Irinjalakkuda)	321.60
T_{15}(Nedumkandam)	304.05
T_{16}(Pozhuthana)	292.57
T_{21}(Control-Aswathy)	291.51
T_{9} (Mannarkkad)	289.34
T_{2} (Kanchiar)	281.57
T_{18}(Kottiyoor)	273.24
T_{5} (Kottarakkara)	259.78
T_{3}(Thalayolaparambu)	255.32
T_{13}(Sultan Bathery)	249.14
T_{7} (Kothamangalam)	249.13
T_{14}(Murickassery)	247.12
T_{17}(Kalliyur)	245.85
T_{6} (Ambalavayal)	244.69
T_{19}(Thariyode)	234.77
T_{8}(Karunagapally)	234.71
T_{4} (Haripad)	230.71
T_{10} (Kattapana)	205.46
T_{20}(Thalavur)	204.62
T_{1}(Mananthavady)	203.58

Table 8. Selection index coefficients

Characters	Coefficients
Plant height	1.03
Number of tillers	0.52
Leaf length	-1.03
Leaf breadth	-12.37
Leaf area	1.79
Fresh rhizome yield	0.97
Rhizome spread	1.32
Rhizome thickness	-1.55
Starch	0.70
Crude fibre	0.85
Oleoresin	1.24
Essential oil	0.02
Total phenol	0.99

In the present experiment, variability was noticed among the twenty ginger genotypes for morphological, yield and quality parameters. Higher fresh rhizome yield was recorded for T_{11} (Kazhakootam) followed by T_{15} (Nedumkandam) which produced 65.27 and 20.87 percentage increase in yield over control. The ginger genotype T_{12} (Irinjalakkuda) recorded higher quality parameters such as starch (6.5% increase) and oleoresin (140 % increase) over the control suggesting the suitability of the genotype for processing. Among genetic parameters, high genotypic and phenotypic coefficient of variation, heritability and genetic advance were observed for fresh rhizome yield, oleoresin, crude fibre, total phenol and essential oil. High heritability coupled with moderate genetic advance was noted for plant height, rhizome spread, starch and number of tillers. High heritability and low genetic advance was observed for leaf area which indicated non-additive gene action. Hence, selection based on leaf area would not be rewarding. Genotypic correlation coefficients revealed that fresh rhizome yield was positively and significantly correlated with rhizome thickness, number of tillers, rhizome spread, plant height, leaf area, oleoresin and leaf length. Leaf area, number of tillers, rhizome spread, rhizome thickness and oleoresin had positive direct effect on yield. Quality parameter oleoresin showed high heritability and genetic advance while morphological parameters such as rhizome spread

and number of tillers showed high heritability coupled with moderate genetic advance, suggesting that these traits could be used for effective selection.

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