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Improvement of ginger for yield and quality traits under the hill ecosystem of Mizoram

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ABSTRACT

The field study on ginger was carried out at ICAR Research Farm, Mizoram Centre, for three consecutive years (2019-2021). The best selection criteria for crop improvement were determined based on genetic component analyses and Principal Component Analysis (PCA). There exists highly significant variation for all traits due to genotypes based on analysis of variance. The highest extent of variability was recorded in oleoresin content. The magnitude of heritability and genetic gain was moderate to high for LAI, leaves per hill, tillers per plant, fresh weight of clump, rhizomes per plant, dry recovery, total chlorophyll, total phenol content, 6-gingerol and oleoresin content, indicating the additive gene control for which choosing of these traits will be beneficial. The rhizome yield exhibited the highest positive correlation with leaves per hill, followed by LAI and tillers per plant. Direct selection of characters like LAI, fresh weight of clump, rhizomes per plant and 6-gingerol content could be most reliable for yield improvement. Based on PCA and bi-plot figures, LAI, tillers per plant, leaves per hill, rhizomes per plant, fresh weight of clump, and yield of rhizomes contributed mostly to genetic diversity among the ginger genotypes and 'Bold Nadia', 'Bhaise' and 'PGS 102' were identified as the best genotypes possessing optimum combinations of yield and quality traits for exploitation in future crop improvement programmes under Mizoram condition.

Key words: Quality, genetic variability, PCA, oleoresin, 6-gingerol.

INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is the main spice crop of Mizoram. It is the principal ingredient in many spice-based food products, spice mixes, beverage and pharmaceutical industries. Although ginger is grown worldwide, Indian ginger is considered the best in the world. Ginger occupies an area of 0.176 million hectares in India with a productivity of 10.722 t/ha (Anonymous, 1). Mizoram offers an excellent climate for quality ginger production with a productivity of 7.03 t/ha, which is still below the national average. Many ginger cultivars planted in Mizoram are indigenous cultivars with low yields that have not undergone any crop improvement. High-yielding ginger varieties of one region may not exhibit the same pattern of productivity under different agro-climatic regions. So, it is important to identify high-yielding ginger varieties suitable for Mizoram conditions that can be used for further crop improvement. Genotype selection cannot be solely based on yield as the yield is dependent on several other attributes. The best selection criteria must be determined to improve any trait and identify desirable genotypes for crop improvement. Thus, understanding the degree of variability present in a crop is crucial to making a better selection for crop improvement.

To maximize the impact of selection, it is necessary to consider variability factors and heritability. Studies on the degree of character association between traits generate information desired to be considered in a selection programme. Determining the direct effects between rhizome yield and other traits would help identify reliable yield and quality improvement traits. The principal component analysis (PCA), as a statistical tool, is used in various fields to minimize the large set of correlated variables into uncorrelated independent variables. It helps to identify the patterns of morphological variation. It is used to sum up genotype information into a smaller number of variables to choose the genotype(s) with the best performances, which could be utilized in future crop improvement programmes to develop ginger with high yield and excellent quality, which can become a driving factor for the increased overall production of ginger in the state.

MATERIALS AND METHODS

Seven ginger genotypes were acquired from various regions of India and studied in the ICAR Regional Centre for NEH Region, Mizoram Centre,

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Kolasib, for three years (2019-2021). The study area has temperatures ranging from 19.5 to 26.5°C. The clayey loam soil with pH 5.0 - 5.5 contains 1.21-1.42% organic carbon. The ginger genotypes were grown as a sole crop on a raised bed 3 × 1 × 0.15 m, at 30 × 25 cm spacing with three replications in randomized block design. Among the seven genotypes of ginger, PGS 95, PGS 102 and PGS 121 were collected from Pottangi, Odisha. In contrast, Gorubathani, Bold Nadia, Bhaise and John's ginger were obtained from West Bengal, Nagaland, Sikkim and Kerala. Observations were taken 180 days after sowing (DAS) for plant height, tillers per plant, and leaves per hill. The fresh weight of clump, rhizomes per plant and dry recovery were recorded at 210 DAS (maturity). At the same time, LAI was calculated in 30-day intervals from 30 to 210 DAS. Five random plants per plot were selected for recording the observations. Other quality parameters, such as total chlorophyll and total carotenoid, were recorded at 180 DAS; total phenol content (mg GAE/100g), 6-gingerol (%) and oleoresin (%) at maturity.

The leaf pigment estimation was done per the procedure given by Hiscox and Israelstam (2). The oleoresin (%) was calculated as per AOAC (3). The determination of total phenol content from the ginger extract was determined by the Folin-Ciocalteau colorimetric method (Singleton *et al*., 4) and calculated in mg GAE/g as per Oluyemi *et al.* (5). The per cent 6-gingerol was determined from the ginger extract obtained from solvent extraction using Soxhlet apparatus and calculated from reference UV Spectra of Standard Gingerol (Shukla *et al*., 6). All the data were recorded in triplicates and mean values were subject to statistical analyses performed using OPSTAT. Tukey's *HSD* test was performed using SPSS Version 20. The recorded data for all the traits were subject to PCA using XLSTAT 2022 software.

RESULTS AND DISCUSSION

Based on the analysis of variance, all the traits showed highly significant mean squares due to genotypes (Table 1). Characters like plant height (PH), leaves per hill (NOL), tillers per plant (NOT), total chlorophyll content (TC), total phenol content (TPC), 6-gingerol content (6-GIN), oleoresin content (OLR) and yield of rhizome (YLD) showed less than 10% coefficient of variation confirming the reliability of the experiment and less genotype by environment interactions. In comparison, the coefficient of variation was slightly higher (>10%) for traits like LAI, fresh weight of clump (FWC), rhizomes per plant (NRH), dry recovery (DR) and total carotenoid content (TCA) confirming little influence of environment on the phenotypic expression of traits. There exists a substantial amount of variability in the studied genotypes, with an ample amount of all traits exhibiting phenotypic variability and significant genotypic variation indicating great scopes of developing high-yielding ginger through judicious clonal selection pressure. For all the corresponding traits, the estimates of the phenotypic coefficient of variation (PCV) were marginally more than the genotypic coefficient of variation (GCV) indicating lower environmental influence on the expression of various traits (Table 2). The GCV to PCV ratio was high for most traits, which is more preferred for selection since the traits are largely influenced by genes as opposed to environmental factors (Kaushik *et al*., 7). Higher values of GCV and PCV estimates were observed for LAI, FWC, NRH, TPC and OLR suggesting high genetic variation among the genotypes for these traits, suggesting employing of simple selection for improving these traits. These results have been previously reported for OLR and TPC (Anargha *et al*., 8). The GCV and PCV estimates alone cannot reveal the magnitude of genes and environmental effects on total phenotypic variability. So, heritability and genetic variability should be taken into account when determining the most effective and precise effect of selection (Burton, 9).

Broad sense heritability values were recorded high for LAI, NOL, NOT, DR, TC, TPC, 6-GIN, OLR and YLD (Table 2). This indicated minimal effect of environment on the expression of these traits

Table 1. Analysis of variance for thirteen yield and quality traits of ginger.

Sources of variation	PH (cm)	LAI at 180 DAS	NOL	NOT	FWC	NRH	DR (%)	TC (mg/g F.W)	TCA (mg/g F.W)	TPC (mg GAE/ 100g)	6-GIN (%)	OLR (%)	YLD (t/ ha)
Replication	20.977	2.813	760.156	0.076	438.842	0.778	0.335	0.000	0.001	24.368	0.005	0.000	1.435
Genotype	38.963*	2.108**	196.556**	2.355**	2510.064*	2.246*	25.184**	0.082**	0.002*	45908.747**	0.036**	15.848**	6.085**
Error	10.804	0.159	30.941	0.202	735.157	0.547	4.435	0.001	0.000	262.404	0.002	0.027	0.709
CV (%)	6.322	12.087	9.868	8.558	18.601	17.739	10.439	3.481	11.612	2.695	2.448	3.382	9.722

*Significant at 5% level of significance or **Significant at 1% level of significance

Table 2. Estimates of genetic parameters for thirteen yield and quality traits of ginger.

Characters	Means	Range	PCV	GCV	GCV : PCV	Heritability (%) in broad sense	Genetic advance as % of mean
Plant height (cm)	51.995	48.23-57.30	8.642	5.892	68.179	46.488	8.276
LAI at 180 DAS	3.295	2.21-4.51	27.288	24.465	89.655	80.380	45.185
No. of leaves per hill	56.367	44.96-64.11	16.466	13.182	80.056	64.083	21.737
No. of tillers per plant	5.256	4.08-6.33	18.248	16.117	88.322	78.007	29.324
Fresh weight of clump (g)	145.766	96.90-177.59	24.989	16.687	66.777	44.591	22.954
No. of rhizomes per plant	4.171	2.29-4.75	25.301	18.041	71.305	50.843	26.499
Dry recovery (%)	20.173	16.50-24.29	16.701	13.037	78.061	60.931	20.963
Total chlorophyll (mg/g F.W)	0.852	0.66-1.07	19.645	19.334	98.417	96.858	39.197
Total carotenoid (mg/g F.W)	0.155	0.13-0.19	17.290	12.811	74.095	54.898	19.553
Total phenol content (mg GAE/100g)	600.978	430.12-743.73	20.701	20.525	99.150	98.305	41.922
6-gingerol (%)	1.941	1.75-2.08	5.968	5.443	91.203	83.174	10.225
Oleoresin (%)	4.888	2.60-9.06	47.099	46.977	99.741	99.484	96.523
Yield of rhizomes (t/ha)	8.66	6.70-10.20	18.261	15.458	84.650	71.658	26.957

and higher efficiency of selection for these traits is possible. Moderate heritability was reported in PH, FWC, NRH and TCA. In this study, the genetic advance (GA) was high for most of the traits (Table 2) like LAI, NOL, NOT, FWC, NRH, DR, TC, TPC, OLR and YLD, indicating that these characters have additive gene control and hence the selection of these yield and quality traits would be beneficial. However, it is not always true that higher GA would result from greater heritability. High heritability, coupled with high GA, will be more effective, reliable and rewarding for determining the effect of selection (Johnson *et al*., 10). Moderate to high values of heritability and high GA were recorded in LAI, NOL, NOT, DR, TC, TPC, 6-GIN and OLR content, indicating lesser environmental influence and effectiveness of the selection due to additive gene action. As a result, the genotypes expressing these traits in their phenotypes can be subject to clonal selection for their improvement. High estimates of GCV coupled with high heritability and genetic gain were recorded for LAI, TPC and OLR, indicating that these traits are influenced by additive gene action and hence could be improved through mass selection in ginger.

The magnitude and direction of the relationship between the yield of rhizome with other component traits were determined through correlation analysis. The genotypic correlation values were higher than values of phenotypic correlation (Table 3), which showed that genotypic impacts exhibited more significantly than effects of environment. Only a few characters such as NOL (r_g = 0.999**, r_p = 0.618**), LAI (r_g = 0.824**, r_p = 0.583**), NOT (r_g = 0.739**, r_p = 0.547*), 6-GIN (r_g = 0.783**, r_p = 0.591**), FWC (r_g = 0.895**, r_p = 0.742*) and NRH (only r_g = 434*) exhibited significant positive genotypic and phenotypic association with YLD. These results indicated that an increase in ginger rhizome yield could be achieved by improving these traits. A positive significant correlation of NOT on YLD was also reported (Anargha *et al*., 8).

Path coefficient analysis measures the direct and indirect contribution of each independent character on the yield of rhizome and measures the degree of dependence of one character on the other. Four characters, *viz*., LAI (0.502), NRH (0.437), 6-GIN (0.241) and FWC (0.239), showed high and positive direct effects on YLD (Table 3). These results corroborated the findings of different researchers (Anargha *et al.,* 8). Direct selection of characters like LAI, FWC, NRH and 6-GIN could be beneficial for improving the yield of rhizomes as they also exhibited true association with it. The residual effect was low (0.08) indicating that most traits which have contributed to yield were included in the investigation.

The PCA was used to determine the magnitude of genetic diversity for yield and quality attributes among different ginger genotypes. The first four principal components *viz.* PC1, PC2, PC3, and PC4, which have eigen values greater than 1.0, accounted

Table 3. Phenotypic and genotypic correlation coefficient and direct effects of characters on yield of rhizome.

Characters		LAI	NOL	NOT	FWC	NRH	DR	TCHL	TCA	TPC	6-GIN	OLR	YLD	Direct effects on yield of rhizome
PH	r_p	0.063	0.173	0.038	0.023	0.439*	-0.212	-0.296	-0.359	-0.153	-0.038	-0.384	-0.162	-0.505
	r_g	-0.066	0.077	0.163	0.492*	0.852**	-0.214	-0.493*	-0.639**	-0.219	-0.005	-0.570**	0.108	
LAI	r_p		0.908**	0.752**	0.598**	0.294	0.311	0.218	0.111	0.355	0.127	0.537*	0.583**	0.502
	r_g		0.900**	1.050**	0.971**	0.613**	0.491*	0.237	0.035	0.416	0.251	0.605**	0.824**	
NOL	r_p			0.543*	0.631**	0.275	0.364	0.105	0.034	0.136	0.307	0.232	0.618**	0.042
	r_g			0.897**	1.185**	0.716**	0.687**	0.124	-0.205	0.196	0.575**	0.295	0.999**	
NOT	r_p				0.445*	0.494*	0.156	0.069	0.031	0.365	0.154	0.524*	0.547*	-0.087
	r_g				0.839**	0.528*	0.042	0.080	0.002	0.398	0.105	0.606**	0.739**	
FWC	r_p					0.513*	0.452*	-0.018	-0.054	0.181	0.342	0.238	0.742**	0.239
	r_g					0.867**	0.623**	-0.086	-0.280	0.274	0.471*	0.387	0.895**	
NRH	r_p						0.070	-0.422	-0.466*	0.404	-0.027	0.158	0.428	0.437
	r_g						-0.075	-0.653**	-0.873**	0.571**	-0.175	0.229	0.434*	
DR	r_p							0.562**	0.162	0.070	0.141	0.174	0.162	-0.109
	r_g							0.691**	0.547*	0.104	0.121	0.267	0.237	
TC	r_p								0.682**	-0.146	-0.042	0.214	-0.210	-0.288
	r_g								0.982**	-0.137	-0.082	0.226	-0.221	
TCA	r_p									-0.226	0.009	0.237	-0.082	-0.022
	r_g									-0.366	0.153	0.295	-0.231	
TPC	r_p										-0.608**	0.765**	0.045	-0.418
	r_g										-0.670**	0.769**	0.050	
6-GIN	r_p											-0.329	0.591**	0.241
	r_g											-0.352	0.783**	
OLR	r_p												0.228	0.16
	r_g												0.263	

*Significant at 5% level of significance or **significant at 1% level of significance; rg = Genotypic correlation coefficient; rp = Phenotypic correlation coefficient. Residual effect = 0.08

for 91.92% variability among the studied ginger genotypes (Table 4). The PC1 explained 40.23% of the variance and has a high positive association with LAI, NOL, FWC, and YLD, contributing mostly to genetic diversity among ginger genotypes. PC2 explained 24.36% of the variance while PC3 and PC4 explained 18.65 and 8.69%, respectively. Momina *et al*. (11) reported 33.60 and 67.70% of the total variance in PC1 at two different places. It was observed that OLR, TC and TCA had maximum positive association and negative association with plant height in PC2. PC3 has a positive association with 6-GIN whereas PH and DR were explained by PC4. From the PCA, it was observed that LAI, NOL, NOT, FWC, NRH, and YLD contributed mostly to genetic diversity among the ginger genotypes.

The PCA reviewing the relationship between variables was drawn based on biplots of the first and second components explaining 64.58% of the variability (Fig. 1), where the horizontal axis indicated the PC1 and PC2 values in the vertical axis. There exists substantial variation among the genotypes and genotypes (Bhaise, PGS 102, PGS 121, Gorubathani) that are closer to each other are similar on PCA biplot, while genotypes which are further apart are more diverse from other genotypes. Among those genotypes, Bold Nadia, Bhaise and PGS 102 are identified as superior genotypes in the PC1. This is evident from the fact that they are at the extremity of the axes, and the genotypes are distinguished by high rhizome yield and quality attributes. The genotypes, close to the origin of

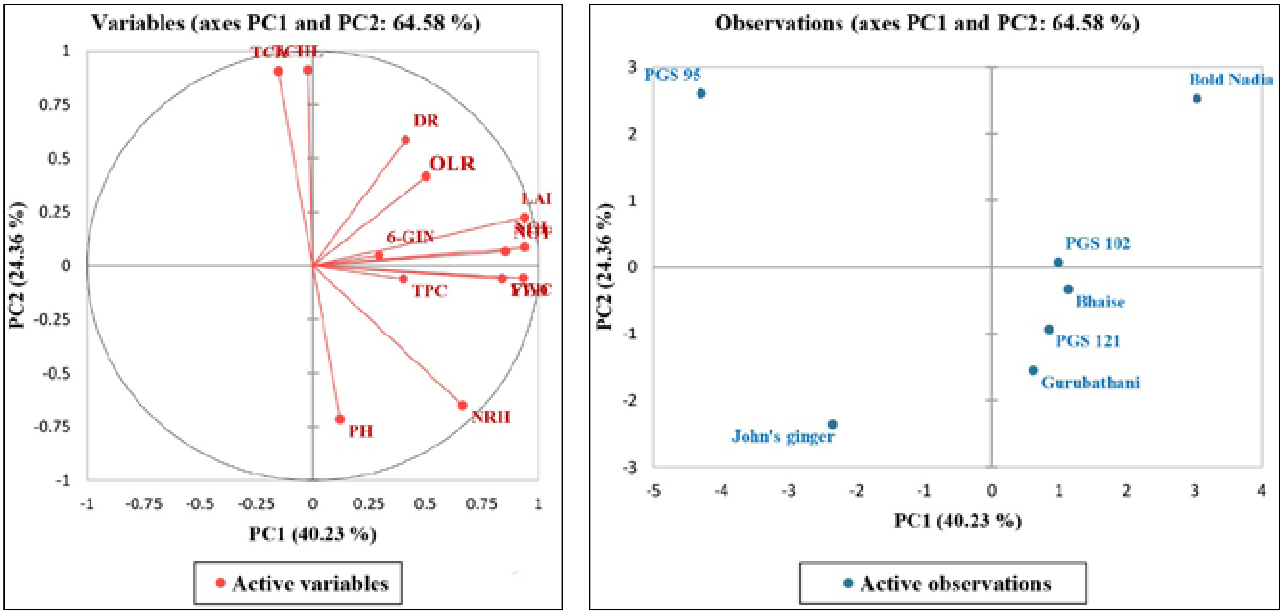

Fig. 1. Principal component bi-plot between thirteen yield and quality characters in seven genotypes of ginger.

Table 4. Results of PCA for 13 quantitative traits of ginger.

Traits	PC1	PC2	PC3	PC4
Plant height (cm)	0.053	-0.402	0.127	0.513
LAI at 180 DAS	0.411	0.126	-0.044	-0.008
Leaves per hill	0.411	0.048	0.161	0.098
Tillers per plant	0.374	0.036	-0.095	-0.135
Fresh weight of clump (g)	0.409	-0.033	0.119	0.160
Rhizomes per plant	0.291	-0.366	-0.150	0.222
Dry recovery (%)	0.180	0.329	0.080	0.495
Total chlorophyll (mg/g F.W)	-0.009	0.511	0.022	0.336
Total carotenoids (mg/g F.W)	-0.066	0.508	0.075	0.020
TPC (mg GAE/100g)	0.176	-0.035	-0.568	-0.041
6-gingerol (%)	0.128	0.026	0.574	-0.301
Oleoresin (%)	0.220	0.232	-0.435	-0.243
Yield of rhizome (t/ha)	0.367	-0.034	0.239	-0.353
Eigen value	5.229	3.166	2.424	1.129
Percentage of variance	40.225	24.356	18.649	8.685
Cumulative percentage of variance	40.225	64.581	83.23	91.915

the quadrant, could explain the low magnitude of variance for yield and quality traits.

One of the traits that is very important in ginger yield is LAI. Changes in LAI with different crop stages are presented in Table 5. The highest significant LAI was recorded for most genotypes at six months after sowing. All genotypes showed significant LAI variation during 30 to 120 DAS, which eventually showed non-significant values from 150 DAS and peaked at 180 DAS followed by its gradual decline till maturity. The use of LAI for selection criteria should be considered carefully depending on crop growth stages.

Careful selection of high-yielding genotypes with superior cultivation quality is paramount. A proper understanding of the extent and degree of

Table 5. Changes in LAI at different crop maturity among different genotypes of ginger.

Genotypes	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	210 DAS
Gurubathani	0.18^{f}	0.48^{e}	0.53^{e}	1.56^{d}	2.50^{b}	3.19^{a}	1.90^{c}
Bold Nadia	0.40^{d}	0.84^{c}	0.85^{c}	2.82^{b}	4.92^{a}	4.51^{a}	2.81^{b}
Bhaise	0.14^{f}	0.33^{e}	0.34^{e}	1.25^{d}	2.16^{c}	3.74^{a}	2.62^{b}
John's ginger	0.15^{d}	0.37^{c}	0.42^{c}	1.40^{b}	2.19^{a}	2.27^{a}	1.45^{b}
PGS 121	0.41^{e}	0.92^{d}	0.93^{d}	2.15^{c}	3.69^{a}	3.85^{a}	2.71^{b}
PGS 95	0.12^{e}	0.30^{de}	0.31^{d}	1.24^{c}	2.35^{a}	2.21^{a}	1.82^{b}
PGS 102	0.25^{f}	0.65^{e}	0.67^{e}	1.17^{d}	3.62^{a}	3.30^{b}	2.35^{c}

The mean values with same alphabets in a row are statistically non-significant at 5% level of significance, Tukey's *HSD* test.

variability and association between economic traits helps to obtain the maximum effect of selection in crop improvement programmes. Direct selection of LAI, FWC, NRH and 6-GIN content would be rewarding for improvement in the yield of rhizome. LAI appeared to be one of the most important traits as it had maximum weightage, contributing significantly to principal component one variation. However, the use of LAI as a selection determinant should be carefully considered depending on crop growth stages. Based on average performances and PCA, the three genotypes, *viz*., Bold Nadia, Bhaise, and PGS 102 can be selected as the best genotypes in terms of yield and quality traits for exploitation in future crop improvement programmes under Mizoram conditions.

AUTHORS' CONTRIBUTION

Conceptualization of research (JKS, VD, SKS); Designing of the experiments (JKS, VD, SKS); Execution of field/lab experiments and data collection (JKS, VD, SKS, BL); Analysis of data and interpretation (JKS, BL, AK); Preparation of the manuscript (JKS, BL, AK, IS, SD).

DECLARATION

The authors declare that they have no conflict of interest.

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REFERENCES

1. Anonymous 2021. Area, production and productivity of ginger in India. Indiastat. https://www.indiastat.com/table/ginger/area%C2%A0production%C2%A0and%C2%A0productivity%C2%A0of%C2%A0ginger%C2%A0in%C2%A0ind/29193#. Accessed on 1st April, 2022.
2. Hiscox, J. D. and Israelstam, G. F. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *Can. J. Bot.* **57**: 1332-40.
3. AOAC 1975. *Official Methods of Analysis.* Association of Official Analytical Chemists, Washington, D.C.
4. Singleton, V. L., Orthofer, R. and Lamuela-Raventos, R. M. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteau reagent. *Methods Enzymol*., **299**: 152-78.
5. Oluyemi, K. A, Okwuonu, U. C, Baxter, D. G. and Oyesola, T. O. 2007. Toxic effects of methanolic extract of *Aspilia africana* leaf on the estrous cycle and uterine tissues of Wistar rats. *Int. J. Morphol.* **25**: 609–14.
6. Shukla, S. S., Saraf, S. and Saraf, S. 2012. Development and validation of spectrophotometric fingerprint method of 6-gingerol in herbal formulation: *Talisadi Churna*. *Res. J. Pharm. Tech.* **5**: 138-40.
7. Kaushik, N., Kumar, K., Kumar, S., Kaushik, N. and Roy, S. 2007. Genetic variability and divergence studies in seed traits and oil content of Jatropha (*Jatropha curcas* L.) accessions. *Biomass Bioenergy* **31**(7): 497-02.
8. Anargha, T., Sreekala, G. S., Nair, D. S. and Abraham, M. 2021. Genetic variability, correlation and path analysis in ginger (*Zingiber officinale* Rosc.) genotypes. *J. Trop. Agric.* **58**: 168-78.

9. Burton, G. W. 1952. Quantitative inheritance in grasses. *Proc. 6th Int. Grassl. Cong.* **1**: 277-83.

10. Johnson, H. W., Rabinson, H. F. and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soybean. *Agron. J.* **47**: 314-18.

11. Momina, A., Sentayehu, A., Girma, H. and Abush, T. 2011. Variability of ginger (*Zingiber officinale* Rosc.) accessions for morphological and some quality traits in Ethiopia. *Int. J. Agric. Res.* **6**: 444-57.

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