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GENOTYPE BY ENVIRONMENT INTERACTION EFFECTS ON RHIZOME YIELD AND QUALITY IN GINGER (*ZINGIBER OFFICINALE* ROSC.)

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ABSTRACT

Six cultivars of ginger were evaluated for fresh rhizome yield , dry recovery per cent , essentiall oil and oleoresin per cent in eight different environments like Barapani, Chintapalli, Kalyani, Mizoram, Passighat, Pottangi, Pundibari and Solan across India ranging from 43 to 943m above mean sea level from 2009 to 2012. Combined analyses showed significant differences among cultivars, environments and cultivar by environment interaction for fresh rhizome yield, per cent of dry recovery, essential oil and oleoresin contents. A large proportion of variation on fresh ginger rhizome yield per ha was attributed to environments, however, variation due to genotypic effect for dry recovery per cent , oleoresin and essential oil per cent accounted for 31.78%, 99.86% and 92.78%, respectively. Oleoresin and essential oil per cent in ginger were highly inherited characters and less influenced by environments. Varada ginger was the most stable genotype for fresh rhizome yield with above average yield across all the environments. Rejitha was performing well at specific locations as the fresh rhizome yield was the highest and was highly responsive to favourable environment. Passighat was most favourable environment among all for fresh rhizome yield (19.36t/ha). Himgiri showed good stability (b= 1.083), high mean and less deviation from regression that it was stable for dry recovery per cent across the locations. Mahima and Himgiri had average mean with b=1.17 and -0.94 and less non-significant deviation from regression were stable for oleoresin per cent across the locations. Suprabha and Suravi had regression coefficient near to one, high mean and less deviation , predicted that they are stable for essential oil per cent across the location. Four varieties like Himgiri, Mahima, Suprabha and Suravi could serve as a good genetic source for dry ginger, oleoresin and essential oil content in ginger.

1. INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) belongs to family Zingiberaceae which comprises 47 genera and about 1400 species. It is believed to have originated in South- East Asia probably in India or China (Bailey, 1949). India produces 7, 15,100 tonnes of ginger annually from an estimated area of 1, 37,990ha with the productivity of 5182 Kg/ha . Ginger was brought to Mediterranean region from India by traders during 1st century (Burkill, 1966) and by Arabs to East Africa during thirteenth century. It was spread to West Africa by Portuguise for commercial cultivation. It is grown in almost all the tropical countries of which China, Taiwan, India, Phillipines, Jamaica and Nigeria are important. Kerala is the leading state in area and production of ginger followed by Odisha, Meghalaya, Himachal Pradesh, Karnataka, Mizoram, Manipur, Tamil Nadu, Maharastra, Bihar, Tripura, Gujarat, Uttar Pradesh, Nagaland, Rajasthan, Haryana, Assam and to some extent in Jammu & Kashmir, Sikkim and Arunachal Pradesh.

Ginger is commonly used to treat various types of "stomach problems," including motion sickness, morning sickness, colic, upset stomach, gas, diarrhoea, irritable bowel syndrome (IBS), nausea, nausea caused by cancer treatment, nausea caused by HIV/AIDS treatment, nausea and vomiting after surgery, as well as loss of appetite. Other uses include pain relief from rheumatoid arthritis (RA), osteoarthritis, menstrual pain, upper respiratory tract infections, cough, respiratory problems, migraine headache, bronchitis, and diabetes. Ginger is also sometimes used for chest pain, low back pain, and stomach pain, discontinuing use of drugs called selective serotonin reuptake inhibitors (SSRIs), anorexia, to stimulate breast milk, as a diuretic, and to increase sweating. It is also used to treat cholera, bleeding, bacterial bloody diarrhoea, baldness, malaria, inflamed testicles, poisonous snake bites, and toothaches. Some people pour the fresh juice on their skin to treat burns. The oil made from ginger is sometimes applied to the skin to relieve pain. Ginger extract is also applied to the skin to prevent insect bites. In foods and beverages, ginger is used as a flavouring agent. In manufacturing, ginger is used as for fragrance in soaps and cosmetics. One of the chemicals in ginger is also used as an ingredient in laxative, anti-gas, and antacid medications.

Fibre and volatile oil contents and pungency levels are the most important criteria in accessing the suitability of ginger rhozomes

for processing. Oleoresin and oil contents rose sharpely rose up to 150-180DAP beyond which there was a decline and fibre development was extremely rapid between 180-210DAP.

It is important to determine and quantify the extent to which factors like the environment (E) and genotype x environment interaction (GEI) contribute to variations in quality parameters in ginger. The influence of E on certain quality parameters may vary. In order to minimize the masking effect of GEI, breeders should determine a quality parameter or parameters that perform consistently in the Environments (Lin & Binns, 1994). A genotype that has stable trait expression across environments contributes little to GEI and its performance should be more predictable from the main effects of genotypes and environments than the performance of an unstable cultivar(Sneller et al, 1997). Several statistical methods have been proposed for stability analysis, with the aim of explaining the information contained in the GEI. Regression technique was proposed by Finley and Wilkinson(1963) and was improved by Eberhart and Russel (1966). Generally, genotype stability is estimated by the scope of and deviation from regression line for each of genotypes. This is a popular method in stability analysis and has been applied in many crops. Stability of essential oil, oleoresin, crude fibre and yield in ginger is the main concern in ginger industry and export., as genotypes performs differently across the locations in the country. Keeping on the limitations on information on stability on yield and quality parameters in ginger , this trial was designed and conducted at 8 different locations by taking 6 cultivars across the country.

2. MATERIALS AND METHODS

2.1. Plant materials and field experiments

Six cultivars of ginger (Table-1) from different sources with differences in yield and quality parameters levels were evaluated tested for stability test. These cultivars were sampled among the released varieties and most promising cultivars. Field experiments were conducted across 32 testing environments for fresh rhizome yield, essential oil, oleoresin and crude fibre contents (combination of 8 locations and 4 cropping seasons2009-2013) under All India Coordinated Research Project on Spices(AICRPS). The additional information on the environments is given in Table-2.At each environment, the experimental layout was a randomized complete block design with three replications (40 plants/ replication/ genotypes). For estimation of quality parameters like dry recovery, oleoresin, essential oil and crude fibre contents the samples were collected from different locations and estimated.

2.2. Dry recovery per cent: Fresh ginger is processed to obtained the dried rhizome by soaking in water for 12 hour, peeling and chopping followed by sun drying. One kilogram of fresh rhizomes per replication per genotype is processed and dried to get 10% moisture level approximately. The dry recovery per cent was calculated based on the pre-plant-fresh yield and its dry weight for each cultivar.

2.3. Essential oil content: There are two ways of extraction, that is using steam distillation and solvent extraction. In order to get oleoresin, solvent extraction technique is used but to obtain essential oil, steam distillation technique is used. 3 Steam distillation method is used for temperature sensitive material like natural aromatic compounds. For this method, there is no solvent is used to extract the material but pure water is the main component to do it.

Steam distillation was one of the separation processes that used solid-liquid extraction theory. Liquid was used to extract the solid. It means the essential oil had been removed from its raw material. The extractor for this process would have three main parts. First, the steam was supplied into the vessel. The steam would be contacted to the raw material and force the essential oils out of its raw material. Second, a condenser was used to change the mixture of vapours to be two separated layer of water and essential oil. This two separated mixture occurred because of the different in density. Lastly, the mixture of water and essential oil was collected in a vessel. Steam distillation was most used to produce many types of essential oil such as from ginger.

2.4.Oleoresin per cent: Solvent extraction was used to extract an initial weight of 35 g of the powdered ginger dried samples in a 500 ml glass column with 100 ml acetone (solvent), which was also used for washing the samples after the first extraction (Meadows et al., 2005). The solvent was allowed to percolate the separate ginger samples for 48 h each before the first extracts were collected. The glass columns containing the samples were re-soaked with additional 100 ml of acetone for another 24 h before collecting the second set of the extracts. The process was stopped when a cotton wool soaked with the extract from the glass column was devoid of ginger aroma. The extracts from each sample were pooled together and the solvent was removed using Rotavapor RE 111 with Buchi 461 water bath (Buchi, Sweden). Portions (300 ml) of each extract was poured in rotary evaporators flask and evaporated at 65°C till all the solvents were expelled. The concentrated extracts (oleoresin) were collected and treated as crude ginger peel, unpeeled and peeled ginger oleoresin extracts, respectively (Lewis et al., 1972). The difference between the empty flask and flask with the separate concentrated extracts was used in obtaining the oleoresin content yield (Onyenekwe, 2000).

2.5. Crude fibre : Crude fibre in the ginger samples were determined by the routine semi – micro kjeldahl procedure. This was consisted of three techniques of analysis namely: Digestion, Distillation and Titration. Distillation was done using Markham Distillation Apparatus which allowed volatile substances such as ammonia to be steam distilled with complete collection of the distillate. 5ml portion of the digest above was taken into the body of the apparatus via small funnel aperture. Then 3ml of 40% (w/v) NaOH was added through the same opening with a 5ml pipette. The mixture was steam distilled for 2 minutes into a 50ml conical flask containing 10ml of 2% Boric acid mixed indicator solution placed at the receiving tips of the condenser. The Boric acid plus indicator solution changed colour from red to green showing that all the ammonia liberated had been trapped. Furthermore, digestion was done by taking 0.50g of ground dried sample carefully into the kjeldahl digestion tubes to ensure that all samples got to the bottom of the tubes and was added to 10ml of conc. H_2SO_4 which were set in the appropriate hole of the digestion block heater in a fume cupboard. The digestion was left for hours after which a clear colourless solution was left in the tube. The digestion was cooled and carefully transferred into 100ml volumetric flask and made to mark with distilled water. Consequently, the green colour obtained from distillation was then titrated against 0.01N HCl contained in a burette. At the equivalent point, the green colour turned to wine colour which indicated that all Nitrogen trapped an Ammonium Borate have been removed as Ammonium chloride. %N = Titre value x Atomic mass of Nitrogen x molarity of HCl x 4 The total crude protein content was determined by multiplying percentage nitrogen by a constant factor of 6.26. % crude protein =%N x 6.26

2.6. Data analysis : Fresh yield, dry recovery per cent, essential oil and oleoresin per cent were statistically analyzed for each environment. Error variance were tested for homogeneity with Bartlett's test as described by Gomez and Gomez(1984). Duncan multiple range test (DMRT) was used to compare mean differences for significant cultivar and environment effect. Combined analysis of variance for fresh yield, dry recovery per cent, essential oil and oleoresin per cent was done for eight environments according to a statistical model explained by Freeman and Dowker (1973). Since there was significant interactions between G x E , stability parameters were calculated as suggested by Eberhart and Russell (1966). Means across environments, linear regression coefficient (b), deviation from regression (Sd^2) of genotypic mean over environment index were calculated. Significance of regression coefficient (b), deviation from regression (Sd^2) were tested using t-test and F-test respectively.

Table1: Description of ginger varieties used in the experiment.

Cultivar	Pedigree name	Source	Characteristics
IISR Varada	Clonal selection from germplasm	Indian Institute of Spices Research, Kozhikode	High fresh and dry yield, high dry recovery %, resistant to storage pests, plumpy rhizome with flattened fingers and medium sized reddish brown scale
IISR Mahima	Clonal selection from germplasm	Indian Institute of Spices Research, Kozhikode	High yielder, plumpy extra bold rhizomes, resistant to M. icognita and M. javanica pathotype I
Himgiri	Clonal selection from germplasm	Dr Y S Parmer University of Horticulture and Forestry, Himachal Pradesh	Best for green ginger, less susceptible to rhizome rot disease, suitable for rainfed condition
IISR Rejitha	Clonal selection from germplasm	Indian Institute of Spices Research, Kozhikode	High yielder, plumpy and bold rhizomes
Suprabha	Clonal selection from Kunduli Local	HARS (Orissa University of Agril. & Technology), Pottangi	The rhizomes of this variety are plumpy flat with bright glazy skin and brown scales. The colour of the rhizome core is whitish yellow.
Suravi	Mutant of Rudrapur Local	HARS (Orissa University of Agril. & Technology), Pottangi	It has plumpy, cylindrical rhizomes with dark glazy skin and deep brown scales. It matures in 225 days. The colour of the rhizome core is deep yellow. It can be grown both under irrigated and rainfed condition.

Table 2: Description of environments where trials were conducted during 2009-2012.

Environments	Geographical coordinates	Altitude (m above msl)	Temperature(⁰C)		Rainfall (mm)	Soil type	Cultivation system
			Max.	Min.			
Barapani, Meghalaya	25.71°N 91.98°E	893	31.0	3.0	2578.8	Lateritic	Raised bed, rainfed
Chintapalli, Andhra Pradesh	16.53°N 78.60°E	408	32.6	10.5	911.6	Lateritic	Raised bed, rainfed
Kalyani, West Bengal	22.99°N 88.45°E	13.13	35.3	13.8	1960	Alluvial soil	Raised bed, rainfed
ICAR Coplex, Kolasib, Mizoram	23.36°N 92.8°E	722	35.5	12.9	1500	sandy loam, clay loam	Raised bed, rainfed
Pasighat, Arunachal Pradesh	28.07°N 95.33°E	153	27.9	19.0	4388	Sandy loam to sandy clay loam	Raised bed, rainfed
Pottangi, Odisha	''180 34 N 82052 E	914.4	35	10	1542	Sandy loam to clay loam	Raised bed, rainfed
Pundibari, West Bengal	26.41°N 89.38°E	43	33.9	9.6	2095.3	Sandy loam	Ridges and furrows, irrigated
Solan, Himachal Pradesh	30.905°N 77.097°E	1502	32.0	-2.0	1411	Deep alluvial, clay	Raised bed, rainfed

Table 3: Combined analysis of variance for yield, dry recovery, oleoresin and essential oil of six cultivars at 8 different locations during 2009-2012

Sources of variation	df	Mean Square							
		Fresh yield(t/ha)	% of total ss	Dry recovery(%)	% of total ss	Oleoresin %	% of total ss	Essential oil%	% of total ss
Replications in locations in Years	48	223.965	0.11	0.885	1.64	0.18	0.13	0.011	1.13
Varieties	5	6267.655	3.06	15.106	27.93	112.591	81.75	0.808	83.30
Locations	7	169355.400	82.72	26.177	48.40	0.024	0.02	0.042	4.33
Years	2	13346.470	6.52	1.194	2.21	18.328	13.31	0.017	1.75
Variety x Location	35	6545.021	3.20	6.274	11.60	0.124	0.09	0.024	2.47
Variety x Year	10	247.195	0.12	1.298	2.40	5.916	4.30	0.029	2.99
Location x Year	14	8064.370	3.94	1.804	3.34	0.165	0.12	0.012	1.24
Variety x Location x Year	70	575.970	0.28	0.852	1.58	0.151	0.11	0.014	1.44
Pooled error	240	96.948	0.05	0.497	0.92	0.25	0.18	0.013	1.34

Table 4: Fresh rhizome yield(t/ha) of six cultivars at 8 different locations during 2009-2012

Cultivars	Pottangi	Mizoram	Barapani	Solan	Pundibari	Kalyani	Chintapalli	Pasighat	Mean
Suprabha	17.91	9.15	4.48	12.89	3.01	13.63	15.50	18.71	11.91
Suravi	18.57	8.89	2.83	11.71	7.32	11.75	13.64	20.88	11.95
IISR Rejitha	15.34	7.80	23.80	9.84	6.94	6.29	14.00	17.58	10.02
IISR Varada	18.72	12.62	2.97	9.27	4.66	11.56	22.46	20.23	12.81
IISR Mahima	15.59	12.28	4.16	11.04	6.48	5.57	14.77	19.84	11.22
Himgiri	15.05	18.09	3.04	17.60	2.94	5.52	12.88	18.93	11.76
Mean	16.86	11.47	3.31	12.08	5.22	9.05	15.54	19.36	11.61
CV%									

Table 5: Dry recovery per cent of six cultivars at 8 different locations during 2009-2012

Cultivars	Pottangi	Mizoram	Barapani	Solan	Pundibari	Kalyani	Chintapalli	Pasighat	Mean
Suprabha	21.4	22.64	20.62	18.89	21.76	20.57	20.40	20.54	20.85
Suravi	20.8	21.3	21.4	22.24	22.2	22.6	22.3	21.8	21.81
IISR Rejitha	22.6	22.5	20.6	18.8	20.6	20.6	20.6	20.7	20.87

IISR Varada	21.1	21.4	19.0	20.8	20.9	21.2	20.1	20.8	20.65
IISR Mahima	21.9	21.7	20.7	17.6	20.8	20.8	20.8	20.8	20.64
Himgiri	22.2	22.0	20.7	19.9	20.6	19.9	19.7	20.0	20.62
Mean	21.7	21.9	20.5	19.7	21.2	20.9	20.8	20.6	20.91

Table 6: Oleoresin per cent of six cultivars at 8 different locations during 2009-2012

Cultivars	Pottangi	Mizoram	Barapani	Solan	Pundibari	Kalyani	Chintapalli	Pasighat	Mean
Suprabha	8.56	8.93	8.90	8.81	8.88	8.99	8.50	8.69	8.82
Suravi	7.57	7.44	7.64	7.40	7.52	7.42	7.39	7.42	7.47
IISR Rejitha	5.40	5.51	5.49	5.44	5.44	5.54	5.49	5.59	5.49
IISR Varada	6.31	6.16	6.11	6.18	6.18	5.91	5.92	6.22	6.12
IISR Mahima	6.01	6.14	6.06	6.01	5.83	5.98	6.12	6.10	6.03
Himgiri	7.69	7.53	7.50	7.56	7.64	7.60	7.69	7.40	7.58
Mean	6.92	6.95	6.95	6.90	6.91	6.91	6.90	6.90	6.92

Table 7: Essential oil per cent of six cultivars at 8 different locations during 2009-2012

Cultivars	Pottangi	Mizoram	Barapani	Solan	Pundibari	Kalyani	Chintapalli	Pasighat	Mean
Suprabha	1.41	1.48	1.47	1.48	1.54	1.59	1.54	1.43	1.49
Suravi	1.29	1.50	1.54	1.52	1.52	1.48	1.53	1.58	1.50
IISR Rejitha	1.23	1.23	1.24	1.29	1.32	1.29	1.24	1.26	1.26
IISR Varada	1.30	1.43	1.43	1.40	1.33	1.32	1.39	1.37	1.37
IISR Mahima	1.27	1.33	1.29	1.22	1.20	1.21	1.26	1.23	1.25
Himgiri	1.38	1.41	1.44	1.39	1.36	1.37	1.35	1.40	1.39
Mean	1.31	1.40	1.40	1.38	1.38	1.38	1.39	1.38	1.38

Table 8: Stability analyses for fresh rhizome yield (t/ha), dry recovery(%), oleoresin (%) and essential oil (%) of six ginger cultivars at eight environments during 2009-2012

Cultivars	Fresh rhizome yield (t/ha)			Dry recovery(%)			Oleoresin (%)			Essential oil (%)		
	Mean	b	Sd2	Mean	b	Sd2	Mean	b	Sd2	Mean	b	Sd2
Suprabha	11.91	0.971	554.1	20.85	1.492	0.122	8.82	1.7	-0.007	1.49	0.912	0.002
Suravi	11.95	0.987	432.5	21.81	-0.462	0.265	7.47	0.85	-0.022	1.5	0.881	0.00
IISR Rejitha	10.02	0.888	235.3	20.87	1.681	0.109	5.49	-0.26	-0.024	1.26	0.181	-0.001
IISR Varada	12.81	1.193	792.3	20.65	0.538	0.468	6.12	1.6	-0.006	1.37	1.442	-0.001
IISR Mahima	11.22	0.942	265.7	20.64	1.668	0.376	6.03	1.17	-0.017	1.25	0.213	0.000
Himgiri	11.76	1.019	1699.3	20.62	1.083	0.407	7.58	-0.94	-0.017	1.39	0.372	-0.001
Mean	11.61			20.91			6.92			1.38		

3. RESULTS AND DISCUSSION

3.1. Cultivar by environment interaction

The results of combined analysis of variance for yield, dry recovery, oleoresin and essential oil per cent traits are presented in the Table 3. There were significant differences among the cultivars, environments and for cultivar by environment interactions for all the four the traits. A large proportions of variation (82.72 %) on fresh yield was attributed to the environments. Source of variation on fresh yield by cultivar(G) X environment (E) and cultivar accounted, respectively, for 0.12% and 3.06% of total variation. Also, high variation (48.0%) due to environment was observed for dry recovery per cent. The variations due to cultivar were 27.9%, 81.75% and 83.30% for dry recovery per cent, oleoresin and essential oil per cent in this study, respectively.

Mean square due to environment (linear) was found highly significant for all the four characters, indicating differences between environments and their influence on genotypes for expression of these characters (Table 3). Further, the higher magnitude of mean squares due to environments (linear) as compared to genotype x environment (linear) exhibited that linear response of enverонments accounted for major parts of total variation for all the traits studied. The environment + (genotype x environment) was significant for all the traits indicating distinct nature of environments and genotype x environment interaction in phenotypic expression. The genotype x environment (linear) interaction component showed significance for all the traits. This indicated significant differences among the genotypes as an outcome of the linear function of environmental components enabling to predict the stable behaviour of genotypes over environments more precisely.

3.2 Environmental interaction

Due to highly significant differences among cultivar by environment interactions, the mean of six cultivars for yield, dry recovery per cent, oleoresin and essential oil per cent traits from each environment was used to rank the environmental effects on each trait as suggested by Finley and Wilkinson(1963). Among the genotypes , IISR Varada produced high mean fresh rhizome yield (12.81t/ha) across 8 environments, however it was not significantly different from other cultivars(Table 4). Passighat was the most favourable environment with mean fresh yield of 19.36t/ha. The variation for fresh yield was from 3.31t/ha at Barapani to 19.36t/ha at Pasighat (Table 4).

Dry recovery per cent showed similar response among the cultivars across the locations. Suravi recorded the highest dry recovery per cent (21.81) among the cultivars, across all the environments (Table 5). Environment means for dry recovery per cent (21.9) was highest at Mizoram followed by Pottangi(21.7) and lowest at Solan (19.7). In summary dry recovery per cent among cultivars followed the ranking: Suravi > IISR Rejitha> Suprabha>IISR varada > IISR Mahima > Himgiri.

It was observed from oleoresin per cent of different genotypes at different locations (Table-6) that the cultivar Suprabha had the highest oleoresin per cent(8.82) across the locations in three years followed by Himgiri (7.58) and Suravi(7.47). The lowest oleoresin was observed in IISR Rejitha across the locations. The oleoresin per cent(6.95) of entries in Barapani and Mizoram centres was the highest among the locations studied, whereas , it was observed lowest(6.90%) in Chintapalli, Pasighat and Solan.

The essential oil per cent in different cultivars in different years showed similar response in different environments over the years(Table 7). Suravi had highest oil per cent (1.50) followed by Suprabha (1.49) across the locations over the years studied. The lowest oil per cent was observed in IISR Mahima across the locations. The oil per cent(1.40) of entries in Barapani and Mizoram centres was the highest among the locations studied, whereas , it was observed lowest(1.31%) in Pottangi.

3.3 Stability for yield, dry recovery, oleoresin and essential oil

Stability for yield, dry recovery, oleoresin and essential oil are shown in Table 8. Five cultivars for fresh rhizome yield viz.

Suprabha, Suravi, IISR Varada, IISR Mahima and Himgiri ; four cultivars viz., Suprabha, IISR Rejitha, IISR Mahima and Himgiri for dry recovery per cent; four cultivars viz., Suprabha, IISR Varada, IISR Mahima and Himgiri for oleoresin and two cultivars viz., Suprabha and IISR Varada had values near to unit regression. Hence, these genotypes are suitable for overall environmental conditions and are considered as stable genotypes. Himagiri produced high fresh yield (11.76t/ha) and showed stability near to one(1.019), but high and significant deviation from regression (1699.3), implying that this cultivar is very sensitive to changes in environment.

Oleoresin and essential oil per cent in ginger were highly inherited characters and less influenced by environments. Varada ginger was the most stable genotype for fresh rhizome yield with above average yield across all the environments. Rejitha was performing well at specific locations as the fresh rhizome yield was the highest and was highly responsive to favourable environment. Passighat was most favourable environment among all for fresh rhizome yield (19.36t/ha). Himgiri showed good stability (b= 1.083), high mean and less deviation from regression that it was stable for dry recovery per cent across the locations. Mahima and Himgiri had average mean with b=1.17 and -0.94 and less non-significant deviation from regression were stable for oleoresin per cent across the locations. Suprabha and Suravi had regression coefficient near to one, high mean and less deviation , predicted that they are stable for essential oil per cent across the location. Four varieties like Himgiri, Mahima, Suprabha and Suravi could serve as a good genetic source for dry ginger, oleoresin and essential oil content in ginger.

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