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D Basak
M.Sc. Research Scholar, Department of Genetics and Plant Breeding, UBKV, Pundibari, Coochbehar, West Bengal, India

S Chakraborty
Assistant Professor and corresponding Author, Department of Genetics and Plant Breeding, UBKV, Pundibari, Coochbehar, West Bengal, India

A Sarkar
Professor, Department of Genetics and Plant Breeding, UBKV, Pundibari, Coochbehar, West Bengal, India

A Kundu
Assistant Professor, Department of Genetics and Plant Breeding, UBKV, Pundibari, Coochbehar, West Bengal, India

S Khalko
Assistant Professor, Department of Plant Pathology, UBKV, Pundibari, Coochbehar, West Bengal, India

MK Debnath
Assistant Professor, Department of Agricultural Statistics, UBKV, Pundibari, Coochbehar, West Bengal, India

Correspondence
D Basak
M.Sc. Research Scholar, Department of Genetics and Plant Breeding, UBKV, Pundibari, Coochbehar West Bengal, India

Multivariate analysis and variability studies of ginger genotypes in Terai region of West Bengal

D Basak, S Chakraborty, A Sarkar, A Kundu, S Khalko and MK Debnath

Abstract
The investigation was done in experimental farm in Uttar Banga Agricultural University to evaluate the genetic diversity, characterization and suitability of growing ginger genotypes in the terai region of West Bengal. Characterization of 18 genotypes was done according to DUS descriptors as per IISR (Indian Institute of Spices Research) and grouped them according to their qualitative and quantitative characters. From the evaluation it was found that SG-2640, SE-8681 and ACC-247 gave very high yield than the yield of national check VARADA.GCP-39, SEHP-9, SE-8640, SG-2640, SE-8681 and ACC-247 gave very high yield than the yield of local check GCP-5 (Garubathan). GCP-39 has maximum number of shoots and leaf width. ACC-247 has maximum rhizome thickness and yield. Principal Component Analysis has found to have Eigen values where major positive association with plant height (0.39), shoot length (0.41), number of leaves (0.39), leaf length, (0.39), number of shoots (0.41) and leaf width (0.30). PC2 has major positive association with rhizome thickness (0.683) and rhizome yield (0.402). So rhizome thickness is considered to be one of important characters for evaluation of rhizome yield. From the investigation, SG-2640, SE-8681 and ACC-47 were found to be greater in yield in both local and national check varieties and best suited genotypes for cultivation in this region of West Bengal.

Keywords: Genotypes, characterization, RBD, principle component analysis, eigen value, national check, local check, Terai region

Introduction
The ginger family, *Zingiberaceae*, is a monocotyledenous family in the order *Zingiberales*. The family comprises some 52 genera with a total about 1100 species. The family is essentially tropical in distribution, with few species occurring in temperate climates, and is particularly richly represented in the Indo-Malesian flora, i.e. from India to New Guinea. *Zingiberaceae* species typically have thickened rhizomes with secretory cells producing essential oil. Mabberley, 1997 [8]. Ginger is a monocotyledon belonging to family *Zingiberaceae*. Ginger is an important spice and medicinal crop originated in South-East Asia and introduced in many parts of the world. Park and Pizutto, 2002 [10], Burkill, 1996 [2]. Ginger is herbaceous perennial crop which grows stems near about a meter tall in length bearing narrow green leaves and yellow flowers. Indian ginger mainly from Kerala is well known for its quality in the world markets. Among the states Orissa occupies 11.94% of total area and Assam is the largest producer with 18.67 % of total production of the country. Goudar *et al*., 2017 [4].

Materials and Methods
The present investigation was conducted during the summer season of 2016-2017 and 2017-2018 at the University Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar. The farm is situated at 26°19¢ 86² N latitude, 89°23¢ 53² E longitude with an altitude of 43 m above the mean sea level.

Physico-Chemical Properties of Soil
The soil of the experimental plot is *Teesta* alluvial plain group, which is sandy loam in texture with poor water holding capacity and moderate fertility status. The physico-chemical properties of the soil of experimental field are given in Table-1.

Table 1: Important physico-chemical properties of soil

Parameters	Value	Status
Soil reaction (pH) (1:2.5)	5.07	Acidic
Oxidizable organic carbon (%)	0.42	Medium
Sand (%)	61.28	High
Silt (%)	18.35	Low
Clay (%)	20.37	Low
Soil texture	Sandy loam	-
Available nitrogen (N) /kg ha^{-1}	116.87	Low
Available phosphorous (P) /kg ha^{-1}	18.24	Low
Available potassium (K) /kg ha^{-1}	108.43	Low
Available iron (Fe) / mg kg^{-1}	192.86	High

***Source*:** Dept. of Soil Science, U.B.K.V. Pundibari.

Table 2: List of genotypes under the study

S. No.	Name of Genotype	Place of origin	S. No.	Name of Genotype	Place of origin
1	GCP-51	Dinhata, Cooch Behar,West Bengal	10	ACC-578	IISR, Kerala
2	GCP-56	Totopara, Alipurduar, West Bengal	11	SE-8631	Telengana
3	GCP-5 (Garubathan) Local check	Garubathan, Darjeeling, West Bengal	12	ACC-219	IISR, Kerala
4	GCP-46	Mangalabari, Jaigaon, West Bengal	13	SE-8640	TNAU, Tamil Nadu
5	GCP-30	Majhian, South Dinajpur, West Bengal	14	SG-26-40	Kerala
6	GCP-36	Uttar Madarihat, Alipurduar, West Bengal	15	SE-8681	Telengana
7	GCP-39	Totopara, Alipurduar, West Bengal	16	ACC-247	IISR, Kerala
8	GCP-14	Jambari, Cooch Behar, West Bengal	17	VARADA National check	IISR Variety, Kerala
9	SEHP-9	Telengana	18	KARTHIKA	Kerela Agricultural University

Preparation of seed materials

For planting 1 ha area 1500 kg of rhizomes free from pests and diseases are selected one month before planting. Rhizomes are treated with Mancozeb 75%WP before sowing for 24 min. Sprouted rhizomes are broken into pieces keeping 2 to 3 sprouted eye buds on each rhizomes.

Table 3: Different morphological and rhizome characteristics according to PPV & FRA act

S. No.	Characteristics	States	Stage of observation	Type of Assessment
1	Plant: Height (cm)	Short (<100), Medium (100 - 120), Tall (>120)	At the end of the growing phase	MS
2	Plant: Number of shoots	Few (<10), Medium (10 - 15) Many(>15)	At the end of the growing phase	MS
3	Plant: Height of shoot (cm)	Short (<75), Medium (75 - 90) Tall (> 90)	At the end of the growing phase	MS
4	Shoot: Number of leaves on main shoot	Few (<25) Medium (25-35) Many (>35)	Full expansion of leaves achieved	MS
5	Leaf: Length (cm)	Short (<25), Medium (25 - 30), Long (>30)	Full expansion of leaves achieved	MS
6	Leaf: Width (cm)	Narrow (<2.5), Medium (2.5 - 3.5), Broad (>3.5)	Full expansion of leaves achieved	MS
7	Rhizome: Thickness (cm)	Thin (<2), Medium (2-3), Bold (>3)	At the time of harvest	MS
8	Rhizome: Shape	Straight, Curved, Zigzagged	At the time of harvest	VG

***Source*:** Guidelines for the Conduct of Test for Distinctiveness, Uniformity and Stability on Ginger

MG: Measurement by a single observation of a group of plants or parts of plants, MS: Measurement of a number of individual plants or parts of plants, VG: Visual assessment by a single observation of a group of plants or parts of plants, VS: Visual assessment by observations of individual plants or parts of plants.

Each piece was 2.5 to 5 cm long and 22 to 25 gm. in weight. The genotypes were sown in a randomized complete block design (RCBD) with 3 replications during two consecutive seasons of 2016 - 2017 and 2017- 2018. The rhizomes of each genotype were sown in the raised bed in onset of summer, in each season. Pre sowing irrigation was given and planting done at 'wapsa' condition. During planting the tip of eye buds should face upwards. The rhizomes are planted at the depth of 5 cm. The data collected on different qualitative and quantitative characters (Plant characters and rhizome characters as in Table-3) were used to calculate the mean value for each character and the replicated mean data were subjected to statistical analysis.

Analysis of Variance (ANOVA)

Analysis of variance was done using standard procedure. Singh and Chaudhary, 1977 [14]. The variation among the genotypes for different characters was tested for significance by 'F' test at 5% level of significance using analysis of variance technique. The analysis of the variance of 18 genotypes of ginger pooled over two crop growing seasons for 8 quantitative characters viz. plant height, height of shoot, number of leaves, leaf length, number of shoots, leaf width, rhizome thickness and rhizome yield are presented in Table-4. Mean sum of square due to season for all the above characters were highly significant indicating the role of season for expression of characters. The mean sum of square due to genotypes for all above the characters was highly significant indicating the genetic variability among these genotypes.

Morphological characteristics of ginger

Plant Height (cm): Plant height of pooled data was found to be varied from 70.63 cm (GCP-30) to 50.72 cm (SE-8681) (Table-6). The overall mean value for the character was 59.59 cm. Maximum plant height was observed in GCP-30 (70.63 cm) was statistically at par with 4 genotypes namely GCP-5 (65.31 cm), GCP-46 (65.93 cm), GCP-36 (65.38 cm) and GCP-39 (65.34 cm) (Table-6). Minimum plant height was observed in SE-8681 (50.72 cm) (Table- 6). Wide range of variation in plant height and also suggested rhizome yield per plant was positively associated with plant height. Pandey and

Dobhal 1993 [11]. Plant height had positive significant association with rhizome yield. Sasikumar *et al.* 1992 [15].

Height of shoot (cm): Height of shoot of pooled data was found to be varied from 53.72 cm (GCP-30) to 33.18 cm (SEHP-9) (Table-6). The overall mean value for the character was 42.46 cm. Maximum shoot height was observed in GCP-30 (53.72 cm) was statistically at par with 9 genotypes namely GCP-51 (45.68 cm), GCP-56 (47.29 cm), GCP-5 (47.38 cm), GCP-46 (50.02 cm), GCP-36 (49.65 cm), GCP-39 (46.12 cm), ACC-219 (45.61 cm), SG-2640 (43.00 cm) and KARTHIKA (48.49 cm) (Table- 6). Minimum shoot height was observed in SEHP-9 (33.18 cm) (Table-6). Shoot height for variability analysis and character association and found shoot height was positively correlated with yield. Saikia and Shadeque 1992 [16].

Table 4: Analysis of variance for eight quantitative characters in ginger

Source	df	Plant height (cm)	Height of shoot (cm)	Number of leaves	Leaf length (cm)	Number of shoots	Leaf width (cm)	Rhizome thickness (cm)	Rhizome yield (t/ha)
Season	1	15266.00***	4517.10***	104.04***	699.42***	80.08***	0.42*	0.15***	823.03***
Season X Replication	2	12.80	47.80	4.82	4.50	2.35	0.19	0.02	2.56**
Genotypes	17	221.70***	255.40***	21.31***	22.57***	13.57***	0.14**	0.34***	16.64***
Genotypes X Season	17	110.90***	95.40*	14.06**	9.67	8.26***	0.09*	0.03***	9.20***
Error	68	22.10	50.50	5.66	5.66	1.84	0.06	0.01	0.51

Significant '***', '**' and '*' P= 0.001, P= 0.01 and P= 0.05, respectively

Number of leaves: Number of leaves of pooled data was found to be varied from 16.67 (GCP-46) to 10.67 (SEHP-9) (Table-6). The overall mean value for the character was 14.31. Maximum number of leaves were observed in GCP-46 (16.67) was statistically at par with 10 genotypes namely GCP-51 (14.83), GCP-56 (16.50), GCP-5 (15.67), GCP-30 (15.83), GCP-36 (14.83), GCP-39 (15.83), SE-8631 (14.00), ACC-219 (16.56), SG-2640 (15.00) and KARTHIKA (16.00) (Table-6). Minimum number of leaves was observed in SEHP-9 (10.67) (Table- 6). High positive and significant association of fresh rhizome yield per hectare with number of leaves on main shoot was observed. Ravi *et al.* 2017 [12]. Leaf number for character association and found that number of leaves had positive significant association with rhizome yield. Sasikumar *et al.* (1992) [15]. Number of leaves was found to have direct influence on rhizome yield. Jatoi *et al.* (2013) [7].

Leaf length (cm): Leaf length of pooled data was found to be varied from 23.79 cm (GCP-46) to 17.64 cm (SEHP-9) (Table-6). The overall mean value for the character was 21.25 cm. Maximum leaf length was observed in GCP-46 (23.79 cm) was statistically at par with 10 genotypes namely GCP-51 (23.45 cm), GCP-56 (22.17 cm), GCP-5 (22.87 cm), GCP-30 (23.55 cm), GCP-36 (21.65 cm), GCP-39 (23.15 cm), GCP-14 (21.32 cm), ACC-578 (21.21 cm), SE-8631 (21.33 cm) and SG-2640 (22.29 cm) (Table-6). Minimum leaf length was observed in SEHP-9 (17.64 cm) (Table- 6). Leaf length had positive significant association with rhizome yield. Sasikumar *et al.* 1992 [15]. Leaf length for genetic variability, character association and path coefficient analysis nineteen ginger (*Zingiber officinale* Rosc.) genotypes were investigated. Islam *et al.* (2008) [5]. Leaf length as a character for variability analysis and found high variability in this character. Jatoi and Watanabe 2013 [6].

Number of shoots: Number of shoots of pooled data was found to be varied from 8.33 (GCP-39) to 3.33 (SE-8640) (Table-6). The overall mean value for the character was 6.10. Maximum number of shoots were observed in GCP-39 (8.33) was statistically at par with 7 genotypes namely GCP-51 (7.67), GCP-56 (6.83), GCP-5 (8.33), GCP-46 (7.00), GCP-30 (8.00) and GCP-36 (7.50) (Table-6). Minimum number of shoots was observed in SE-8640 (3.33) (Table-6). All the genotypes were found differed significantly for number of shoots. Das *et al.* (2000) [3]. Number of shoots as a character for variability analysis was found high variability in this character. Jatoi and Watanabe 2013 [6]. High positive and significant association of fresh rhizome yield per hectare with number of shoots was investigated. Ravi *et al.* 2017 [12].

Leaf width (cm): Leaf width of pooled data was found to be varied from 2.61 cm (GCP-39) to 1.99 cm (SEHP-9) (Table-6). The overall mean value for the character was 2.21 cm. Maximum leaf width was observed in GCP-39 (2.61 cm) was statistically at par with 2 genotypes namely GCP-51 (2.37 cm) and GCP-30 (2.38 cm) (Table- 6). Minimum leaf width was observed in SEHP-9 (1.99 cm) (Table-6). Leaf width for character association had positive association with yield. Sasikumar *et al.* 1992 [15]. Leaf width for genetic variability, character association and path coefficient analysis for nineteen ginger (*Zingiber officinale* Rosc.) genotypes was investigated. Islam *et al.* 2008 [5].

Table 5: Grouping of genotypes according to PPV&FRA for morphological characters

S No.	Characteristics	States	Number of genotypes
1	Plant: Height (cm)	Short (<100)	18
		Medium (100 - 120)	0
		Tall (>120)	0
2	Plant: Number of shoots	Few (<10)	18
		Medium (10 - 15)	0
		Many(>15)	0
3	Plant: Height of shoot (cm)	Short (<75)	18
		Medium (75 - 90)	0
		Tall (> 90)	0
4	Shoot: Number of leaves on main shoot	Few (<25)	18
		Medium (25-35)	0
		Many (>35)	0
5	Leaf: Length (cm)	Short (<25)	18
		Medium (25 - 30)	0
		Long (>30)	0
6	Leaf: Width (cm)	Narrow (<2.5)	18
		Medium (2.5 - 3.5)	0
		Broad (>3.5)	0

All the eighteen ginger genotypes were found under short category for plant height, shoot length and leaf length. Number of shoots and number of leaves for all genotypes were found under few category. Leaf width was narrow for all the genotypes (Table- 6).

Rhizome characters

Rhizome thickness: Rhizome thickness of pooled data was found to be varied from 2.95 cm (ACC-247) to 1.88 cm

(VARADA) (Table-7). The overall mean value for the character was 2.24 cm. Maximum rhizome thickness was observed in ACC-247 (2.95 cm) which differed significantly with all other genotypes. Minimum leaf width was observed in VARADA (1.88 cm) (Table-7). All characters studied were found to have positive correlation with yield and direct selection of rhizome thickness could help to improve the yield. Abraham and Latha 2003 [1]. Rhizome thickness for character association and was found that it has positive association with yield. Nandkangre *et al.* 2016 [9].

Net plot weight (kg/3m^2): Net plot weight of rhizome of pooled data was found to be varied from 4.41 kg/plot (ACC-247) to 1.55 kg/plot (KARTHIKA) (Table-7).The overall mean value for the character was 2.66 kg/plot. Maximum net plot weight of rhizome was observed in ACC-247 (4.41 kg/plot) and was statistically at par with SE-8681 (4.21 kg/plot). Minimum net plot weight of rhizome was observed in KARTHIKA (1.55 kg) (Table-7). Wide range of variation for most of the characters was studied. Pandey and Dobhal (1993) [11]. Rhizome yield per plant was positively associated with plant height, number of fingers per plant weight of fingers and weight of primary rhizome. Rhizome yield as a dependent character and other characters like rhizome yield had significant positive correlation with length of primary finger, ascorbic acid content, number of primary fingers, plant height and diameter of primary finger. Ravishanker *et al.* 2014 [13].

Rhizome yield (t/ha): Rhizome yield (t/ha) of pooled data was found to be varied from 8.89 tonnes (ACC-247) to 3.13 tonnes (KARTHIKA) (Table- 7).The overall mean value for the character was 5.37 t/ha. Maximum rhizome yield (t/ha) was observed in ACC-247 (8.89 t/ha) and was statistically at par with ACC-8681 (8.49 tonnes). Minimum net plot weight of rhizome was observed in KARTHIKA (3.13 t/ha) (Table-7). Rhizome yield (t/ha) for genetic variability, character association and path coefficient analysis was investigated. Islam *et al.* 2008 [5]. All the genotypes differed significantly for rhizome yield (t/ha). Das *et al.* 2000 [3]

Table 6: Pooled mean data of morphological characters

	Plant height			Shoot length			No of leaves			Leaf length (cm)			No. of Shoots			Leaf width (cm)		
GENOTYPES	2016-17	2017-18	POOLED	2016-17	2017-18	POOLED	2016-17	2017-18	POOLED	2016-17	2017-18	POOLED	2016-17	2017-18	POOLED	2016-17	2017-18	POOLED
GCP-51	51.1	73.34	62.22	39.8	51.55	45.68	14.67	15.00	14.83	21.19	25.7	23.45	6.67	8.67	7.67	2.27	2.48	2.37
GCP-56	53.07	71.53	62.3	42.32	52.25	47.29	14.33	18.67	16.50	20.33	24.00	22.17	5.67	8.00	6.83	2.23	2.25	2.24
GCP-5	49.14	81.48	65.31	36.97	57.8	47.38	11.67	19.67	15.67	18.93	26.81	22.87	7.00	9.67	8.33	2.27	2.35	2.31
GCP-46	45.59	86.27	65.93	39.04	61.00	50.02	15.33	18.00	16.67	20.40	27.18	23.79	6.33	7.67	7.00	1.93	2.36	2.15
GCP-30	51.85	89.41	70.63	40.30	67.14	53.72	12.00	19.67	15.83	20.75	26.36	23.55	7.00	9.00	8.00	2.53	2.23	2.38
GCP-36	51.57	79.18	65.38	41.10	58.20	49.65	13.00	16.67	14.83	19.00	24.30	21.65	3.33	11.67	7.50	1.90	2.33	2.12
GCP-39	55.44	75.25	65.34	44.14	48.10	46.12	16.00	15.67	15.83	21.00	25.30	23.15	8.67	8.00	8.33	2.57	2.66	2.61
GCP-14	40.60	69.9	55.25	27.93	45.20	36.56	12.67	14.00	13.33	20.43	22.20	21.32	5.33	7.00	6.17	1.93	2.23	2.08
SEHP-9	46.87	57.84	52.35	33.84	32.52	33.18	12.33	9.00	10.67	14.93	20.35	17.64	4.67	5.00	4.83	1.77	2.20	1.99
ACC-578	43.24	62.11	52.68	29.04	41.05	35.04	10.67	13.33	12.00	16.73	25.69	21.21	3.33	8.33	5.83	2.1	2.41	2.26
SE-86-31	44.28	60.58	52.43	31.99	41.51	36.75	12.33	15.67	14.00	16.78	25.87	21.33	4.00	6.33	5.17	2.17	2.34	2.26
ACC-219	49	70.63	59.82	36.2	55.01	45.61	15.78	17.33	16.56	18.72	21.67	20.19	5.00	7.00	6.00	2.42	2.17	2.29
SE-8640	45.47	58.42	51.94	33.48	36.90	35.19	12.00	12.00	12.00	13.89	21.87	17.88	2.67	4.00	3.33	1.97	2.12	2.04
SG-26-40	43.25	77.09	60.17	30.24	55.76	43.00	12.33	17.67	15.00	19.54	25.03	22.29	4.00	6.00	5.00	1.90	2.25	2.08
SE-8681	42.98	58.46	50.72	31.69	36.14	33.91	13.00	11.67	12.33	17.39	21.9	19.64	3.33	4.00	3.67	2.13	2.31	2.22
ACC-247	46	76.61	61.31	33.91	44.99	39.45	13.67	12.67	13.17	15.29	21.32	18.31	4.33	5.67	5.00	2.00	2.10	2.05
VARADA	45.23	64.47	54.85	34.12	40.50	37.31	12.67	12.00	12.33	19.62	20.8	20.21	7.00	4.00	5.50	2.30	2.14	2.22
KARTHIKA	53.91	74.00	63.95	41.84	55.13	48.49	15.33	16.67	16.00	19.98	20.18	20.08	6.00	5.33	5.67	2.25	1.96	2.11
SE(m)	2.636	2.79	1.92	2.514	5.23	2.89	1.101	1.59	0.97	0.962	1.69	0.91	0.641	0.93	0.55	0.178	0.09	0.10
C.D.	7.61	8.02	5.41	7.257	15.02	8.18	3.178	4.59	2.74	2.778	4.85	2.74	1.851	2.59	1.56	0.51	0.27	0.28
C.V. (%)	9.573	6.76	7.88	12.097	18.5	16.72	14.304	18.00	16.62	8.959	12.34	11.25	21.198	22.48	22.24	14.369	7.27	11.2

Table 7: Pooled mean data of rhizome characters

	Rhizome Thickness (cm)			Net Plot Weight(kg/3m2)			YIELD(t/ha)		
GENOTYPES	2017-18	2016-17	POOLED	2017-18	2016-17	POOLED	2017-18	2016-17	POOLED
GCP-51	2.3	2.03	2.17	3.75	0.67	2.21	7.57	1.34	4.46
GCP-56	1.9	2.07	1.98	3.45	0.77	2.11	6.95	1.55	4.25
GCP-5	2.4	2.23	2.32	3.89	0.9	2.39	7.84	1.81	4.82
GCP-46	2.2	2.13	2.17	3.83	0.9	2.37	7.73	1.82	4.78
GCP-30	2.3	2	2.15	3.43	0.71	2.07	6.91	1.43	4.17
GCP-36	2.1	2.1	2.1	3.59	0.82	2.21	7.23	1.66	4.45
GCP-39	2	2	2	5.19	1.17	3.18	10.46	2.37	6.41
GCP-14	2.7	2.3	2.5	4.33	0.32	2.33	8.74	0.64	4.69
SEHP-9	2.6	2.33	2.47	4.46	1.53	3	8.99	3.09	6.04
ACC-578	2.3	2.17	2.23	2.8	0.76	1.78	5.64	1.53	3.59
SE-86-31	2.5	2.27	2.38	4	0.65	2.32	8.06	1.3	4.68
ACC-219	2.2	2.27	2.23	2.3	1.73	2.02	4.64	3.49	4.07
SE-8640	2.3	2.17	2.23	5.59	0.77	3.18	11.28	1.54	6.41
SG-26-40	2.5	2.37	2.43	4.23	3.63	3.93	8.52	7.32	7.92

SE-8681	2.2	2	2.1	6.52	1.9	4.21	13.14	3.83	8.49
ACC-247	3	2.9	2.95	5.61	3.2	4.41	11.32	6.46	8.89
VARADA	1.8	1.97	1.88	3.53	1.8	2.66	7.11	3.63	5.37
KARTHIKA	2.1	2.07	2.08	2.07	1.03	1.55	4.17	2.08	3.13
SE(m)	0.036	0.057	0.033	0.202	0.21	0.144	0.407	0.415	0.291
C.D.	0.103	0.164	0.095	0.581	0.593	0.407	1.172	1.197	0.821
C.V.	2.793	4.503	3.71	8.056	27.55	13.282	8.057	27.559	13.287

Table 8: Characterization of plant rhizome characters according to PPV&FRA

Genotypes	Rhizome Thickness(cm)	Rhizome shape
GCP-51	Medium	Curved
GCP-56	Thin	Curved
GCP-5	Medium	Curved
GCP-46	Medium	Curved
GCP-30	Medium	Curved
GCP-36	Medium	Curved
GCP-39	Medium	Curved
GCP-14	Medium	Curved
SEHP-9	Medium	Curved
ACC-578	Medium	Zigzagged
SE-86-31	Medium	Zigzagged
ACC-219	Medium	Curved
SE-8640	Medium	Straight
SG-26-40	Medium	Curved
SE-8681	Medium	Curved
ACC-247	Medium	Curved
VARADA	Thin	Curved
KARTHIKA	Medium	Zigzagged

Characterization of plant rhizome characters: Rhizome thickness was thin for GCP-56 and VARADA. All other genotypes were found under medium category for rhizome thickness (Table-7). Rhizome shape was straight for only SE-8640. Zigzagged rhizome shape was observed for ACC-578, SE-8631 and Karthika and for remaining 14 genotypes rhizome shape was curved (Table-9).

Table 9: Grouping of genotypes for plant rhizome characters according to PPV&FRA

S. No.	Characteristics	States	Number of genotypes
1	Rhizome: Thickness (cm)	Thin (<2)	2
		Medium (2-3)	16
		Bold (>3)	0
2	Rhizome: Shape	Straight	1
		Curved	14
		Zigzagged	3

Characterization of DUS characters

All the eighteen ginger genotypes were found under short category for plant height, shoot length, and leaf length (Table-5). Number of shoots and number of leaves for all genotypes were found under few category (Table-5). Leaf width was narrow for all the genotypes. Rhizome thickness was thin for GCP-56 and VARADA (Table-8). All other genotypes were found under medium category for rhizome thickness. Rhizome shape was straight for only SE-8640. Zigzagged rhizome shape was observed for ACC-578, SE-8631 and Karthika and for remaining 14 genotypes rhizome shape was curved (Table-9).

Principal components analysis (PCA): Often, the variables under study are highly correlated. It may be useful to transform the original set of variables to a new set of uncorrelated variables called principal components. PCA is a linear dimensionality reduction technique, which identifies orthogonal directions of maximum variance in the original data, and projects the data into a lower-dimensionality space formed of a sub set of the highest variance components. PCA reveals the major contributor of the total variation at each distinct point. Generally, the sum of Eigen values is equal to the number of variance. The Eigen value is often used to determine number of major principal components to be explained.

The first two principal components (PCs) having Eigen value more than one accounted for 76.24% of total variability amongst 18 ginger genotypes (Table-10).

Table 10: Eigen values, proportion of total variance contributed by three principle components, cumulative percent variance and component loading of different characters in ginger.

Characters	PC1	PC2	PC3
Eigen value	2.21	1.09	0.9
Variance (%)	61.26	14.99	10.17
Cumulative var. (%)	61.26	76.24	86.42
Component Matrix			
Plant height	0.393	0.387	0.003
Height of the shoot	0.414	0.253	0.192
Number of leaves	0.395	0.21	0.11
Leaf length	0.392	0.002	-0.228
Number of shoots	0.409	-0.003	-0.101
Leaf width	0.302	-0.335	-0.637
Rhizome thickness	-0.215	0.683	-0.002
Yield	-0.246	0.402	-0.692

The first principal component (PC1) contributed maximum towards variability (61.26%) followed by PC2 (14.99%) and PC3 (10.17%) respectively. PC1 has major positive association with plant height (0.39), shoot length (0.41), number of leaves (0.39), leaf length, (0.39), number of shoots (0.41) and leaf width (0.30). PC1 has major negative association with rhizome thickness (-0.215) and yield (-0.246) (Table- 10). PC2 has major positive association with rhizome thickness (0.683) and rhizome yield (0.402) (Table- 10). Ravishanker *et al.* 2013 [13] and Jatoi *et al*. 2013 [7].

Conclusion

GCP-30 has the maximum plant height and shoot length. GCP-46 has maximum number of leaves and leaf length. GCP-39 has maximum number of shoots and leaf width. ACC-247 has maximum rhizome thickness and yield. SG-2640, SE-8681 and ACC-247 gave very high yield 20% more than the yield of national check VARADA. GCP-39, SEHP-9, SE-8640, SG-2640, SE-8681 and ACC-247 gave very high yield 20% more than the yield of local check GCP-5. From the present investigations it is concluded that for rhizome yield, genotypes SG-2640, SE-8681 and ACC-247 excelled the national check VARADA. Genotypes GCP-39, SEHP-9, SE-8640, SG-2640, SE-8681 and ACC-247 excelled the local check GCP-5 for rhizome yield.

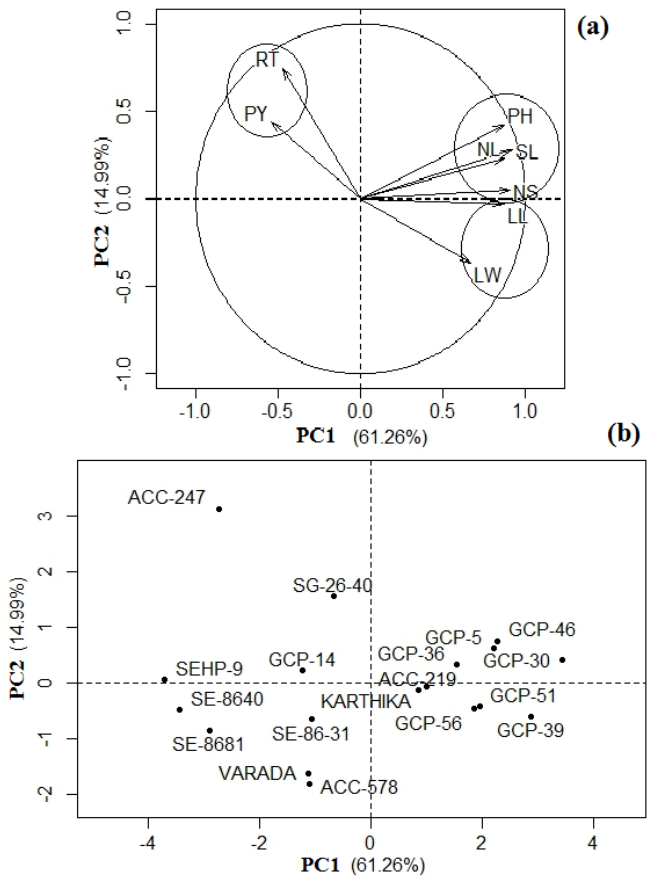

Fig 1: Representation of (a) PCA Biplot and (b) Scattered diagram of first two principal components (PCs) based on diverse traits and genotypes of ginger.

Rhizome thickness is considered to be one of the important characters for evaluation of yield. These genotypes performed better for majority of the characters as well. Hence these genotypes can be recommended for cultivation in this particular region.

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