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Genetic Variability in Ginger (*Zingiber officinale* Rosc.)

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ABSTRACT

The present investigations were carried out at the Experimental Farm of the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during *kharif* season (April–November), 2011. The objective of the study was to assess the genetic variability of 40 diverse genotypes of ginger collected from different parts of the country including one recommended variety Himgiri as check. These genotypes had shown considerable variability for all the parameters studied. The observations were recorded on emergence, number of tillers and leaves plant^{-1}, leaf length and breadth, plant girth and height, length, girth, core diameter and weight of mother, primary and secondary rhizomes, number of primary and secondary rhizomes plant^{-1}, yield plant^{-1} plot^{-1}ha^{-1}, incidence of rhizome rot, dry matter and oleoresin content. The genotypic coefficients of variability (GCV) were moderate for number of secondary rhizomes plant^{-1}, weight of primary and secondary rhizomes and yield plant^{-1} plot^{-1} ha^{-1}, whereas, the phenotypic coefficients of variability (PCV) were moderate for emergence, number of tillers and leaves plant^{-1}, number of secondary rhizomes plant^{-1}, weight of mother, primary and secondary rhizomes, yield plant^{-1} plot^{-1} ha^{-1}, oleoresin content and incidence of rhizome rot. High heritability coupled with high and moderate genetic gain was observed for yield plot^{-1} ha^{-1} and weight of mother, primary and secondary rhizomes indicating the importance of these characters for selection. It indicated that these traits were amenable to selection. The overall assessment showed that there was wide variability among ginger genotypes which has important implication for breeding ginger for yield and quality attributes.

KEYWORDS: Ginger, heritability, quality, variability, yield

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1. INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) belongs to family Zingiberaceae having generic name derived from Greek word *Zingiberis*, and owes its origin to the Sanskrit name, *Sringabera*, meaning horn shaped. Botanically it is herbaceous perennial, underground modified stem called rhizome, grown as an annual and is a shade loving plant (Anh et al., 2020, Kratky et al., 2013). The fresh ginger is consumed locally while dried is traded internationally (Ravindran et al., 2016). It is used for manufacturing various products like ginger oil, oleoresin, ginger candy, ginger preserve or 'murabba', ginger pickle etc. (Kushwah et al., 2013). Ginger contains many constituents (Zachariah, 2008) like minerals, fats, proteins, carbohydrates and fibre. It possesses numerous pharmacological properties (Nair, 2019). The main moieties in the volatile oil of ginger include zingiberene, curcumene, and farnesene in addition to 1, 8-cineole, linalool, borneol, neral, and geraniol (Bhattarai et al. 2001, Sasidharan et al., 2012, Mahomoodally et al., 2021). It cures digestion related problems, have anticancer properties, prevents obesity, asthma, bronchitis, nausea related to both motion and morning sickness and also effective against skin related problems (Wang et al., 2017, Mao et al., 2019, Crichton et al., 2019).

India, China, Japan, Sierra Leone, Taiwan, Thailand, Nigeria and Australia are the main producers of ginger (Pruthi, 1998). Total area under ginger cultivation in world is about 407843 has with production of 4328277 t. India is the largest producer of ginger and about half of the world's production of ginger comes from India. It is commercially cultivated in states like Assam, Odisha, Kerela, Karnataka, Tamil Nadu, Gujarat, West Bengal, Himachal Pradesh, Uttar Pradesh, Rajasthan and Maharashtra. In Himachal Pradesh, ginger is an important spice crop of mid and low hills, covering an area of 2300 has with an annual production of 15,300 t (Anonymous, 2017, Anonymous, 2018, Anonymous, 2021). Ginger can be grown up to 1500 msl in tropical and subtropical climate with a well distributed annual rainfall of 1500–2500 mm and optimum temperature between 28–35°C. It gives good yield under shade (Syamal, 2014). Light sandy loam soil is the best suited for growing ginger. The plant will not perform well under water-logged condition or in gravelly or sandy soil (Prasad and Bhardwaj, 2016). Ginger is propagated from bits of rhizomes. Each bit contains an eye or a bud 2.5 cm long. As ginger is propagated vegetatively, flowers are seldom formed and no seed setting takes place. Because of this nature of the crop it devoid the conventional breeding approaches like hybridization, therefore, selection is the easiest method of improving the crop other than mutation and polyploidy breeding (Babu et al., 2013) The greater the genetic diversity, the wider is the scope for selection and wide genetic variability exists in the crop with regard to yield and yield contributing traits (Pandey and Dobhal, 1993, Singh, 2001). This large variability can be utilized to improve the crop through selection (Shamita et al., 1997, Abraham and Latha, 2003, Anargha et al., 2020). However, not much work has been done on crop improvement through the selection of superior types having high yield. So, there is a great need of screening ginger germplasm to select elite genotypes having higher yield with resistance/ tolerance to rhizome rot and improved quality for direct selection. Hence, the study was carried out to estimate the extent of genetic variability in the ginger crop.

2. MATERIALS AND METHODS

The present investigations were carried out at the Experimental Farm of the Department of Vegetable Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during *kharif* (April–November), 2011. 40 diverse genotypes of ginger collected from different parts of the country including one recommended variety Himgiri as check were used for the present investigations. Uniform size of rhizomes was directly sown in the field in the month of April, 2011 at a spacing of 30×20 cm^2 in raised beds of 3×1 m^2 size, accommodating 50 plants $plot^{-1}$. Drainage channels were also made between plots. Each collection was sown in a Randomized Block Design with three replications. The standard cultural practices recommended in the Package of Practices for Vegetable Crops, were followed to ensure a healthy crop stand (Anonymous, 2009). Data were recorded from the mean of 10 plants selected randomly from each genotype in each replication on different characters, viz. emergence, number of tillers and leaves $plant^{-1}$, leaf length and breadth, plant girth and height, length, girth, core diameter and weight of mother, primary and secondary rhizomes, number of primary and secondary rhizomes $plant^{-1}$, yield $plant^{-1}$ and plot ha^{-1}, incidence of rhizome rot, dry matter recovery and oleoresin content. Genotypic and phenotypic variances were estimated according to Johnson et al. (1955). The genotypic and phenotypic coefficients of variation were calculated according to the formula suggested by Burton and Devane (1953). Heritability in broad sense was done according to Allard (1960). The expected genetic advance for different characters under selection was estimated using the formula suggested by Allard (1960). Genetic gain expressed as % ratio of genetic advance and population mean was calculated by the method given by Johnson et al. (1955).

3. RESULTS AND DISCUSSION

The results revealed highly significant differences for all the characters (Table 1 and 2). The germplasm

Table 1: Mean performance of ginger genotypes for growth, yield and quality characters

Gen	EME	NTP	NLP	LL	LB	PG	PH	Yield			IRR	DMR	OC
								PL	PL*	ha^{-1} (t)			
SG10-01	71.79 (57.90)*	8.27	100.07	25.30	2.55	2.83	65.93	160.60	5.70	11.444	11.46 (3.38)#	16.00 (4.00)#	3.09 (1.76)#
SG10-02	72.50 (58.37)	8.00	96.13	25.52	2.78	3.02	65.40	175.27	6.23	12.522	12.50 (3.52)	22.00 (4.69)	3.82 (1.95)
SG10-03	81.88 (64.82)	7.67	79.27	25.35	2.87	3.30	64.73	143.20	5.71	11.478	11.46 (3.38)	20.00 (4.47)	4.85 (2.20)
SG10-04	77.71 (62.07)	7.87	84.33	24.82	2.76	2.97	68.33	176.33	6.87	13.809	13.54 (3.67)	17.87 (4.23)	3.85 (1.96)
SG10-05	56.88 (48.95)	8.93	101.80	23.95	2.73	2.53	61.07	226.67	6.42	12.904	13.54 (3.67)	20.80 (4.56)	4.94 (2.22)
SG10-06	66.25 (54.51)	7.80	88.13	25.06	2.74	2.51	64.53	187.60	6.23	12.509	11.46 (3.38)	20.53 (4.53)	3.75 (1.94)
SG10-07	56.88 (48.95)	7.40	93.13	24.31	2.69	2.94	64.00	162.73	4.64	9.322	13.75 (3.62)	16.27 (4.03)	3.82 (1.95)
SG10-08	83.96 (66.49)	8.00	90.27	25.18	2.74	2.87	68.87	175.93	7.38	14.819	10.41 (3.22)	18.27 (4.27)	4.50 (2.12)
SG10-09	61.25 (51.66)	7.73	90.60	24.67	2.81	3.05	65.47	199.60	5.96	11.974	9.38 (2.95)	17.20 (4.15)	3.54 (1.88)
SG10-10	64.17 (53.27)	7.40	85.80	24.96	2.78	3.11	70.73	216.73	6.78	13.627	10.41 (3.22)	20.27 (4.50)	3.98 (1.99)
SG10-11	86.05 (68.14)	8.13	81.27	26.29	2.78	2.37	71.73	278.00	11.96	24.02	9.37 (3.06)	19.20 (4.38)	3.90 (1.97)
SG10-12	90.21 (72.63)	8.20	93.93	26.61	2.82	2.87	66.67	213.67	9.56	19.199	9.37 (3.06)	20.67 (4.55)	3.35 (1.83)
SG10-13	76.67 (61.13)	8.47	100.80	26.33	2.86	3.08	66.60	254.53	9.52	19.132	11.46 (3.38)	19.73 (4.44)	4.00 (2.00)
SG10-14	66.25 (54.54)	8.20	100.87	26.57	2.80	2.95	70.67	276.60	9.11	18.295	12.50 (3.54)	21.87 (4.68)	3.96 (1.99)
SG10-15	58.96 (50.36)	7.93	89.53	27.20	3.05	3.03	75.73	252.00	7.36	14.793	10.41 (3.22)	20.53 (4.53)	2.98 (1.73)
SG10-16	79.79 (64.46)	8.33	94.67	25.70	2.91	2.91	75.87	250.07	10.04	20.177	9.37 (3.06)	21.47 (4.63)	4.26 (2.06)
SG10-17	66.25 (54.56)	10.47	114.27	25.13	2.73	3.04	65.53	217.53	7.20	14.472	11.46 (3.38)	19.20 (4.38)	4.06 (2.01)
SG10-18	66.25 (54.58)	10.00	115.87	25.21	2.73	1.96	70.27	191.07	6.33	12.724	10.41 (3.22)	18.27 (4.27)	3.70 (1.92)
SG10-19	67.29 (55.19)	9.80	112.27	25.07	2.55	2.61	74.13	184.67	6.22	12.496	11.46 (3.38)	19.20 (4.38)	3.52 (1.87)
SG10-20	68.34 (55.76)	9.80	111.20	26.03	2.92	2.70	77.20	173.73	5.85	11.746	10.41 (3.22)	18.93 (4.35)	3.93 (1.98)
SG10-21	77.71 (62.02)	7.33	79.73	23.83	2.79	2.65	65.87	158.40	6.15	12.362	16.67 (4.06)	18.80 (4.34)	3.85 (1.96)

Table 1: Continue...

Gen	EME	NTP	NLP	LL	LB	PG	PH	Yield			IRR	DMR	OC
								PL	PL*	ha^{-1} (t)			
SG10-22	75.63 (60.39)	7.53	91.20	25.59	2.76	3.05	67.60	129.33	4.71	9.462	17.71 (4.19)	19.47 (4.41)	4.05 (2.01)
SG10-23	86.04 (69.00)	8.40	88.87	24.23	2.69	3.37	73.80	161.47	6.75	13.567	10.41 (3.22)	21.33 (4.62)	3.12 (1.76)
SG10-24	58.75 (50.03)	9.73	107.27	25.13	2.70	2.77	62.53	116.47	3.55	7.132	14.79 (3.78)	19.33 (4.40)	4.77 (2.18)
SG10-25	87.92 (69.64)	8.53	98.67	25.75	3.07	3.14	68.47	185.53	8.05	16.172	16.67 (4.06)	19.07 (4.37)	3.12 (1.77)
SG10-26	82.25 (65.45)	7.33	84.73	25.70	3.21	2.77	69.60	161.33	6.69	13.440	10.41 (3.22)	21.73 (4.66)	3.86 (1.96)
SG10-27	78.75 (62.91)	9.00	102.87	24.82	3.00	2.89	67.47	143.47	5.37	10.795	9.37 (3.06)	21.20 (4.60)	4.44 (2.11)

Gen: Genotype; Eme:Emergence (%); NTP: Number of tillers plant^{-1}; NLP; Number of leaves plant^{-1}; LL: Leaf length (cm); LB: Leaf breadth (cm); PG: Plant girth (cm); PH: Plant height (cm); Pl: plant^{-1} (g); PL*: plot^{-1} (kg); ha^{-1} (t); IRR: Incidence of rhizome rot (%); DMR; Dry matter recovery (%); OC; Oleoresin content (%); *Figures in the parenthesis are arc sine transformed values; #Figures in the parenthesis are square root transformed values

Table 2: Mean performance of ginger genotypes for characters of mother, primary and secondary rhizomes

Gen	Mother rhizome					Primary rhizome					Secondary rhizome			
	Len	Gir	CD	WT	NP	Len	Gir	CD	WT	NP	Len	Gir	CD	WT
SG10-01	7.50	7.56	2.46	61.70	2.60	4.73	7.53	2.27	88.40	7.53	4.73	6.59	2.17	66.53
SG10-02	9.83	7.48	2.58	60.77	2.20	4.30	7.16	2.36	86.27	8.47	4.60	7.68	2.35	87.60
SG10-03	9.60	7.24	2.60	73.63	2.73	4.14	6.96	2.28	68.13	8.07	4.32	7.23	2.29	73.63
SG10-04	8.87	6.94	2.10	59.83	2.47	5.31	7.09	2.25	81.37	9.53	4.77	7.89	2.34	94.37
SG10-05	9.40	7.69	3.07	62.33	2.40	4.36	6.83	2.23	96.83	10.27	4.61	7.22	2.33	125.47
SG10-06	8.40	6.85	2.28	55.07	2.00	4.27	8.28	2.42	87.77	8.93	3.99	7.23	2.31	99.37
SG10-07	10.97	7.77	2.57	75.40	2.20	4.11	5.73	2.33	73.47	8.67	4.37	6.39	2.25	88.47
SG10-08	10.87	7.14	2.73	67.70	2.53	4.43	6.16	2.21	82.40	9.80	4.25	6.26	2.22	99.27
SG10-09	7.13	6.86	2.56	49.30	2.80	3.97	5.46	2.28	98.57	8.33	4.20	7.17	2.43	99.90
SG10-10	9.53	7.57	2.62	67.97	2.40	4.61	6.56	2.42	90.30	11.53	4.49	6.89	2.17	123.90
SG10-11	11.37	6.94	2.69	66.10	2.73	4.63	6.09	2.37	105.70	13.87	5.05	7.49	2.47	168.50
SG10-12	6.63	7.29	2.39	41.50	2.20	4.03	6.77	2.36	76.43	11.87	4.60	7.63	2.42	132.97
SG10-13	9.83	6.66	2.63	52.03	2.60	4.15	5.71	2.38	94.37	11.40	4.33	6.37	2.53	156.30
SG10-14	10.03	7.42	2.56	52.63	2.53	4.77	6.47	2.40	100.40	13.67	5.04	6.71	2.35	172.10
SG10-15	8.83	6.73	2.53	55.17	2.67	4.76	5.60	2.72	92.83	14.27	4.62	6.39	2.45	159.50
SG10-16	8.80	7.60	2.50	69.03	2.87	5.14	5.64	2.43	94.27	13.00	4.79	7.09	2.52	153.80
SG10-17	7.50	6.72	2.30	46.77	3.00	4.61	6.43	2.56	94.83	11.20	4.68	6.83	2.52	121.47
SG10-18	8.80	7.57	2.65	65.50	2.23	4.37	5.59	2.33	77.90	9.80	4.69	6.78	2.49	109.77
SG10-19	8.37	7.68	2.50	70.00	2.80	5.25	5.63	2.30	78.63	9.47	4.47	6.33	2.43	103.80
SG10-20	8.07	7.71	2.52	55.47	2.60	4.15	5.77	2.32	81.13	10.20	4.71	7.01	2.26	91.33
SG10-21	8.77	8.55	2.67	55.07	2.47	4.99	5.31	2.15	61.53	8.07	4.28	6.01	2.29	94.90
SG10-22	9.10	8.08	2.72	65.70	2.20	4.69	5.32	2.26	55.03	6.83	3.57	5.07	2.19	72.33

Table 2: Continue...

Gen	Mother rhizome					Primary rhizome					Secondary rhizome			
	Len	Gir	CD	WT	NP	Len	Gir	CD	WT	NP	Len	Gir	CD	WT
SG10-23	11.00	7.47	2.92	76.00	2.27	4.21	5.52	2.16	58.77	8.60	4.36	6.11	2.13	120.40
SG10-24	8.00	8.18	2.69	59.00	2.00	4.51	5.07	2.21	51.20	8.07	4.09	4.34	1.87	67.60
SG10-25	10.50	9.57	3.32	73.83	2.73	4.55	5.14	2.31	56.77	10.07	4.21	5.48	2.04	127.03
SG10-26	7.77	6.75	2.50	62.23	2.47	4.17	5.10	2.31	71.00	8.20	3.63	5.19	2.32	100.60
SG10-27	9.20	7.22	2.60	56.30	2.13	3.92	6.00	2.35	61.37	8.00	3.97	5.81	2.33	80.63
SG10-28	9.40	7.30	2.42	64.07	1.87	4.43	5.01	2.30	70.53	8.40	4.60	5.45	2.34	85.93
SG10-29	11.50	8.23	2.83	80.47	2.07	4.65	5.55	2.42	68.63	9.47	4.69	7.09	2.32	149.63
SG10-30	11.00	8.64	2.78	68.77	2.00	4.53	6.28	2.45	70.20	8.60	4.89	7.44	2.50	142.70
SG10-31	8.13	8.70	2.99	55.27	2.53	4.44	6.41	2.35	92.00	9.53	4.89	6.66	2.53	118.90
SG10-32	10.00	7.71	2.66	59.30	2.53	4.44	6.77	2.33	86.70	10.27	5.35	7.73	2.41	156.57
SG10-33	8.60	9.17	2.91	53.57	2.40	4.56	6.65	2.61	94.17	9.27	4.36	6.55	2.42	105.73
SG10-34	8.37	7.34	2.33	52.90	2.93	4.61	6.51	2.40	99.97	14.27	5.17	8.24	2.52	156.87
SG10-35	9.20	7.98	2.42	54.50	3.00	5.15	7.59	2.46	104.70	9.73	5.27	8.20	2.22	130.27
SG10-36	10.90	7.69	2.51	83.60	2.47	4.29	6.95	2.42	92.90	10.93	4.77	7.05	2.44	115.23
SG10-37	9.33	8.81	2.65	64.23	2.40	4.86	6.52	2.39	67.87	8.60	4.57	7.52	2.30	100.23
SG10-38	9.47	8.42	2.65	73.77	2.87	4.71	6.04	2.25	85.07	10.73	4.88	6.53	2.43	137.47
SG10-39	8.40	7.19	2.34	68.73	2.20	4.51	5.98	2.41	83.17	8.13	4.83	6.64	2.67	115.00
Himgiri	10.63	7.10	2.33	73.77	2.33	4.37	6.08	2.33	76.27	9.67	4.13	6.57	2.36	136.40
Mean	9.24	7.64	2.60	62.72	2.46	4.52	6.18	2.35	81.45	9.88	4.55	6.72	2.35	116.06
Range	6.63-11.50	6.66-9.57	2.10-3.32	41.50-83.60	1.87-3.00	3.92-5.31	5.01-8.28	2.15-2.72	51.20-105.70	6.83-14.27	3.57-5.35	4.34-8.24	1.87-2.67	66.53-172.10
SEm±	0.29	0.20	0.06	1.81	0.13	0.07	0.17	0.03	3.18	0.80	0.11	0.21	0.04	6.70
CD (p=0.05)	0.83	0.57	0.17	5.14	0.38	0.19	0.48	0.08	8.99	2.26	0.31	0.58	0.11	18.97

Gen: Genotype; Len: Length (cm); Gir: Girth (cm); CD: Core diameter (cm); WT: Weight (g); NP: Number plant^{-1}

provided wide variation for emergence (56.88%–92.71%), number of tillers plant^{-1} (7.33–11.53), number of leaves plant^{-1} (79.27–134.87), leaf length (23.83–27.49 cm), leaf breadth (2.55–3.21 cm), plant girth (1.96–3.37 cm), plant height (61.07–77.20 cm), yield plant^{-1} (116.47–278.00 g), plot^{-1} (3.55–11.96 kg), ha^{-1} (7.132–24.028 t), incidence of rhizome rot (9.37%–17.71%), dry matter recovery (16.00%–23.73%) and oleoresin content (2.77%–5.30%) which warrants the scope for isolating the genotypes on the basis of these characters.

The estimates of variability parameters viz. range, coefficients of variation (GCV and PCV), heritability (broad sense), genetic advance and genetic gain were worked out and presented in table 3. Significant differences were found among the genotypes for all the characters studied. A rough estimate of degree of variation can be made from the range but the coefficients of variation are more reliable. The estimates of phenotypic and genotypic coefficients of variability gave a clear picture of amount of variations present in the available germplasm. For all the characters studied, phenotypic coefficients of variability were higher in magnitude than genotypic coefficients of variability, though differences were very less in majority of the cases.

Thus, showing that these traits are less influenced by environmental factors, which were also reported by Mohanty and Sarma (1979), Islam et al. (2008), Tiwari (2003a) and Tiwari (2003b). In the present studies a close relationship was found between the genotypic coefficient of variation and the phenotypic coefficient of variation for plant height, revealing very little influence of environment on this trait, which is also reported by Medhi et al. (2007). Coefficients of variability varied in magnitude from character to character (either moderate or low). Therefore, it indicated that there was a great variabilty in the experimental material used.

Table 3: Estimates of phenotypic and genotypic coefficients of variability, heritability, genetic advance and genetic gain for different traits in ginger

Characters	Range	Mean±SE(m)	Coefficients of variability (%)		Heritability (%)	Genetic advance	Genetic gain (%)
			Phenotypic	Genotypic			
1. Emergence (%)	56.88–92.71	73.85±3.08	16.02	12.26	58.50	14.26	19.31
2. Number of tillers plant^{-1}	7.33–11.53	8.75±0.56	15.36	10.69	48.40	1.34	15.31
3. Number of leaves plant^{-1}	79.27–134.87	100.36±6.03	15.39	11.33	54.20	17.24	17.18
4. Leaf length (cm)	23.83–27.49	25.52±0.26	3.58	3.13	76.20	1.43	5.60
5. Leaf breadth (cm)	2.55–3.21	2.84±0.05	5.53	4.59	69.00	0.22	7.75
6. Plant girth (cm)	1.96–3.37	2.87±0.11	10.21	7.74	57.40	0.35	12.20
7. Plant height (cm)	61.07–77.20	69.23±0.96	5.93	5.41	83.40	7.05	10.18
8. i) Length of mother rhizome (cm)	6.63–11.50	9.24±0.29	13.93	12.79	84.40	2.24	24.24
ii) Girth of mother rhizome (cm)	6.66–9.57	7.64±0.20	9.9	8.77	78.50	1.22	15.97
iii) Core diameter of mother rhizome (cm)	2.10–3.32	2.60±0.06	9.49	8.57	81.60	0.41	15.77
iv) Weight of mother rhizome (g)	41.50–83.60	62.72±1.81	15.72	14.90	89.90	18.26	29.11
9. i) Number of primary rhizomes plant^{-1}	1.87–3.00	2.46±0.13	14.28	10.75	56.70	0.41	16.67
ii) Length of primary rhizome (cm)	3.92–5.31	4.52±0.07	7.85	7.40	88.70	0.65	14.38
iii) Girth of primary rhizome (cm)	5.01–8.28	6.18±0.17	12.98	12.05	86.10	1.42	22.98
iv) Core diameter of primary rhizome (cm)	2.15–2.72	2.35±0.03	5.06	4.63	84.00	0.21	8.94
v) Weight of primary rhizome (g)	51.20–105.70	81.45±3.18	18.63	17.36	86.90	27.16	33.35
10. i) Number of secondary rhizomes plant^{-1}	6.83–14.27	9.88±0.8	22.34	17.43	60.90	2.77	28.04
ii) Length of secondary rhizome (cm)	3.57–5.35	4.55±0.11	9.39	8.44	80.80	0.71	15.60
iii) Girth of secondary rhizome (cm)	4.34–8.24	6.72±0.21	13.39	12.30	84.40	1.56	23.21
iv) Core diameter of secondary rhizome (cm)	1.87–2.67	2.35±0.04	6.80	6.22	83.60	0.28	11.91
v) Weight of secondary rhizome (g)	66.53–172.10	116.06±6.7	26.37	24.40	85.60	53.97	46.50
11. Incidence of rhizome rot (%)	9.37–17.71	11.62±0.18	24.68	14.59	35.00	2.07	17.81
12. Dry matter recovery (%)	16.00–23.73	19.83±0.05	8.54	7.79	83.20	2.90	14.62
13. Oleoresin content (%)	2.77–5.30	3.95±0.05	16.77	14.50	74.80	1.02	25.82
14. i) Yield plant^{-1} (g)	116.47–278.00	198.65±11.14	21.60	19.29	79.80	70.52	35.50
ii) Yield plot^{-1} (kg)	3.55–11.96	7.29±0.21	25.28	24.77	96.00	3.64	50.00
iii) Yield ha^{-1} (t)	7.132–24.028	14.638±0.426	2.529	2.479	9.60	7.322	5.002

Similar results on genetic variability in ginger have been reported by Rattan et al. (1988), Sasikumar et al. (1992), Kanjilal et al. (1997), Chandra and Govind (1999), Tiwari (2003a), Medhi et al. (2007) and Islam et al. (2008).

The phenotypic coefficients of variability (PCV) were found moderate for yield plant^{-1} plot^{-1} ha^{-1}, weight of mother, primary and secondary rhizomes, incidence of rhizome rot, number of secondary rhizomes plant^{-1}, oleoresin content, emergence, number of tillers and leaves plant^{-1}. This reflects existence of genetic variability among the genotypes for these characters for making further improvement through clonal selection. Whereas, low PCV were recorded for number of primary rhizomes plant^{-1}, length, girth and core diameter of mother, primary and secondary rhizomes, plant girth and height, dry matter recovery, leaf length and breadth. Similar results for different characters were reported to various extents by Rattan et al. (1988), Sasikumar et al. (1992), Medhi et al. (2007) and Islam et al. (2008).

The genotypic coefficients of variability (GCV) were moderate for yield plant^{-1}, plot^{-1}, ha^{-1}, weight of primary and secondary rhizomes and number of secondary rhizomes plant^{-1}. This reflects existence of genetic variability among the genotypes for these characters for making further improvement through clonal selection. Whereas, low GCV were recorded for weight of mother rhizome, incidence of rhizome rot, oleoresin content, length, girth and core diameter of mother, primary and secondary rhizomes, emergence, number of tillers and leaves plant^{-1}, number of primary rhizomes plant^{-1}, dry matter recovery, plant girth and height, leaf length and breadth. Sasikumar et al. (1992) reported moderate variation for plant height, leaf number and dry matter recovery; Yadav (1999) also reported moderately high GCV for weight of primary and secondary rhizomes, number of primary and secondary rhizomes and rhizome yield plant^{-1}. The little differences in levels of variability may be due to different experimental material evaluated under different environmental conditions.

The genotypic coefficients of variation do not offer full scope to estimate the variations that are heritable and therefore, estimation of heritability becomes necessary. The success of any selection programme depends upon the extent of heritability as well as on genetic gain which usually changes from population to population and environment to environment. Burton (1952) and Burton and Devane (1953) was of the opinion that the genetic coefficients of variation along with heritability gave the best picture of genetic advance to be expected from selection whereas, Johanson et al. (1955) advocated that heritability together with genetic advance is more useful than the heritability alone in predicting the resultant effect in selecting best individual.

The estimates of heritability (in broad sense) were found high for the characters viz. yield plot^{-1}, ha^{-1}, length, core diameter and weight of mother, primary and secondary rhizomes, girth of primary and secondary rhizomes, plant height and dry matter recovery and moderate for yield plant^{-1}, girth of mother rhizome, leaf length and breadth, oleoresin content, number of primary and secondary rhizomes plant^{-1}, emergence, plant girth and number of leaves plant^{-1}, while, it was low for number of tillers plant^{-1} and incidence of rhizome rot. The results of present studies are in line with those reported by Shamita et al., (1997), Tiwari (2003a), Tiwari (2003b), Medhi et al. (2007) and Islam et al. (2008). Yadav (1999) also reported high heritability for plant height and weight of primary rhizome. However, high heritability for leaf number by Islam et al. (2008); leaf breadth by Islam et al. (2008); secondary rhizome fingers and fresh rhizome yield by Yadav (1999), number of tillers plant^{-1} by Yadav (1999), Tiwari (2003a), Tiwari (2003b) and Islam et al. (2008) and leaf length and number of secondary rhizomes has been reported by Yadav (1999) and Islam et al. (2008). In the light of the heritability estimates obtained in the present studies, it is concluded that selection can be performed at phenotypic performance for highly heritable characters viz. yield plot^{-1}, ha^{-1}, length, core diameter and weight of mother, primary and secondary rhizomes, girth of primary and secondary rhizomes, plant height and dry matter recovery.

Genetic gain (expressed as % of population mean) was low to high in nature for different characters. It was found high for yield plot^{-1} and ha^{-1}. Moderate genetic gain was observed for yield plant^{-1}, weight of mother, primary and secondary rhizomes, number of secondary rhizomes plant^{-1} and oleoresin content. Whereas, it was recorded low for length, girth and core diameter of mother, primary and secondary rhizomes, emergence, incidence of rhizome rot, number of tillers and leaves plant^{-1}, number of primary rhizomes plant^{-1}, dry matter recovery, plant girth and height, leaf length and breadth (Pandey and Dobhal, 1993). The results are supported by Yadav (1999) and Islam et al. (2008). However, high genetic gain for number of secondary rhizomes by Yadav (1999) and Islam et al. (2008); for leaf number by Islam et al. (2008); for yield plant^{-1} by Yadav (1999); for number of tillers by Yadav (1999), Tiwari (2003a), Tiwari (2003b) and Islam et al. (2008); for leaf length and weight of primary rhizome by Yadav (1999) and Islam et al. (2008). This may be due to different environmental conditions and/or experimental material used.

High heritability coupled with high genetic gain was found for yield plot^{-1} and ha^{-1}. Whereas, high heritability coupled with moderate genetic gain was found in the characters weight of mother, primary and secondary rhizomes. The results are in line with Yadav (1999), Singh (2001), Islam et al. (2008) and Anargha et al. (2020) who also reported high heritability coupled with moderate to high genetic gain for yield and rhizome characters. However, high heritability and genetic gain has been reported by Islam et al. (2008) for leaf number; Yadav (1999) for weight of primary rhizome; and Yadav (1999) for fresh rhizome yield; Yadav (1999) and Islam et al. (2008) for leaf length and number of secondary rhizome; Islam et al. (2008) for tillers plant^{-1}, plant height, leaf breadth, number of primary rhizome plant^{-1}.

4. CONCLUSION

The GCV were moderate for number of secondary rhizomes plant^{-1}, weight of primary and secondary rhizomes and yield, whereas, the PCV were moderate for emergence, number of tillers and leaves plant^{-1}, number of secondary rhizomes plant^{-1}, weight of mother, primary and secondary rhizomes, yield, oleoresin and rhizome rot. High heritability coupled with high and moderate genetic gain was observed for yield and weight of mother, primary and secondary rhizomes indicating the importance of these characters for selection.

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