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Genetic variability studies of garlic (*Allium sativum* L.) germplasam in Terai region of West Bengal

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ABSTRACT

The genotypic variations among the characters related to growth, yield, and quality were investigated in 14 garlic genotypes. For all traits, the analysis of variance indicated a highly significant difference among the genotypes, emphasizing the presence of variability. The phenotypic coefficients of variations were found to be slightly greater than the genotypic coefficients of variations, showing that apparent variation was influenced by the growing environment as well as presence of genetic variability. High heritability and high genetic advance were observed in oleoresin content, number of cloves bulb^{-1}, weight of 10 cloves, clove breadth, bulb yield hectare^{-1} at four months after storage, bulb yield hectare^{-1}, bulb weight, bulb yield plot^{-1}, number of bulbs Kg^{-1}, ascorbic acid, TSS, bulb breadth, clove length. The genotypes Pundibari Local and Phule Nilima proved their superiority with respect to yield and quality attributing traits. The presence of additive gene action for the expression of these attributes, as well as high heritability and genetic advance gave a clear picture of the traits during the selection process, indicating that the cultivar Pundibari Local may be selected for further breeding programme and can be recommended for cultivation among the growers of this region.

***Keywords*:** Garlic, GCV, heritability, PCV, quality, yield

Garlic (*Allium sativum* L.), member of the family of Alliaceae is one of the most important cultivated species of the genus Allium (Paredes *et al*., 2008). It is a sterile diploid species (2n=2x=16) propagated vegetatively through its cloves (Ipek *et al*., 2005). Garlic is a commonly used spice and flavoring agent valued for its antimicrobial and anti carcinogenic effects (Harris *et al*., 2001). The major component in garlic volatile oil is the compounds of volatile sulfur in the form of di-allyl disulphide. India is the second largest producer of garlic next to china. The area under crop is about 352.64 thousand hectares with an annual production of 2926.09 thousand tonnes having productivity of 8.29 t ha^{-1} during 2019-20. Madhya Pradesh is the leading state with acreage of 183.71 thousand hectare and production of 1869.43 thousand tonnes, followed by Rajasthan, Uttar Pradesh, Orissa, and Gujarat (DASD, 2021). In West Bengal, the crop is grown in 3.93 thousand hectares with a production of 37.47 thousand tonnes having productivity of 9.54 t ha.

Yield is the most important quantitative parameter for the development of any superior variety of a particular crop however it is the resultant of many other inherited contributing parameters. Study of genetic variability paves the way for any crop improvement programme (Lin *et al*., 2007). And also the detailed information related to genetic variability, genotypic and phenotypic coefficient of variation and heritability have better importance in the crop improvement programme of garlic (Belaj *et al*., 2002). The existing variability study can be a useful tool for increasing yield of the existing cultivar (Ogunniyan and Olakojo, 2015). The present investigation was carried out to study the extent of genotypic and phenotypic variation, heritability, and genetic advance along with the genetic gain of growth, yield, and quality contributing traits among the fourteen genotypes of garlic in the Terai region of West Bengal.

MATERIALS AND METHODS

An experiment was carried out in winter season of 2019-20 and 2020-21 as a *rabi* crop at the Instructional Farm of the Department of Plantation Crops and Processing, Faculty of Horticulture, Uttar Banga Krishi Vishwavidyalaya, Pundibari, Cooch Behar to study the performance of garlic cultivars in Terai-agro climatic zone of West Bengal. Present experimental site is geographically located at an elevation of 43 meters above mean sea level, 26^0 19'86" N latitude and 89^0 23'53"E longitude. The soil was acidic in nature with sandy loam in texture having pH 5.26 and EC 0.07 dsm^{-1}. The soil had a low in available nitrogen content (157 kg ha^{-1}), a medium in available phosphorus content (21.82 kg ha^{-1}) and low in available potassium content (102.50 kg ha^{-1}). Fourteen popular varieties of *A. sativum* collected from four different states of India with wider adaptability in areas of their recommendation. The

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varieties were Agrifound White (G-41), Yamuna Safed-1 (G-1),Yamuna Safed -2 (G-50),Yamuna Safed-3 (G-282), Yamuna Safed -4 (G-323),Yamuna Safed -5 (G-189), Yamuna Safed -8 (G-384), Yamuna Safed -9 (G-386)), Gujarat Garlic-4, Gujarat Junagadh Garlic-5, Gujarat Anand Garlic-6, Phule Nilima, Phule Baswant and one local cultivar from Terai region of West Bengal.

The experiment was laid out in randomized block design with three replications having individual plot size of 2 m^2. The larger outer cloves weighing more than 1gm were planted at a spacing of 20×10 cm. From each replication ten randomly selected plants were selected to observe twenty different growth, yield and quality characters viz., plant height (cm), number of leaves $plant^{-1}$, leaf length (cm), leaf width(cm), neck thickness (mm) recorded after 120 days after planting, bulb length (cm), bulb breadth (cm), clove length (cm), clove breadth (cm), number of cloves $bulb^{-1}$, weight of 10 cloves (gm), bulb dry weight (gm), bulbs kg^{-1}, yield $plot^{-1}$(kg), yield per $hectare^{-1}$(t ha^{-1}) and days to maturity recorded after harvesting. Different quality parameters of each genotype like total soluble solids (0 Brix), ascorbic acid content (mg g^{-1}) and oleoresin content (%) were computed as follows.

Total soluble solids (0 Brix)

Total soluble solids were assessed by handheld refractometer. A drop of juice was placed on the measuring prism of the refractometer and recorded the reading when the refractometer (0-30 and 30-60 obrix) was pointed against a light source representing the concentration of soluble solids in the garlic extract in ºBrix.

Ascorbic acid (mg g^{-1})

Ascorbic acid, known as vitamin C is present in all fresh vegetables and fruits. The fresh bulbs preferably of uniform size from representative plants were picked and cut into small pieces. Chopped fresh bulbs of 100g weight from each variety were used for estimation of vitamin C content in the laboratory following 2,6 dichloro-phenol indophenol visual titration method (A.O.A.C., 1975) and expressed in mg $100g^{-1}$of fresh bulbs.

Oleoresin (%)

Oleoresin content in garlic was analyzed by solvent extraction in Soxhlet apparatus (Pelican Equipment's, model: Socsplus-SCS 04R).Hexane was used as the solvent for extraction. Crushed cloves of 10g were filled into the cellulose thimble and sufficient volume of 100 ml of solvent (hexane) was introduced into the solvent cup. Thereafter, the sample containing beakers placed in Soxhlet apparatus and set the temperature just above the boiling point of the solvent (hexane i.e. 69^0C) which is 90^0C for 60 minutes (for extraction) and 180 ^{0}C for 30 min (for evaporation the solvent). After evaporation of solvent oil containing beakers carefully taken out and weighed and the weight of the oil expressed in terms of grams.

$$\frac{Weight\ of\ the\ oleoresin\ in\ the\ sample\ (g)}{Weight\ of\ the\ sample\ (g)} \times 100$$

Analysis of variance was made following the approach suggested by Panse and Sukhatme (1988). The genetic parameters *viz*., genotypic and phenotypic coefficient of variation, heritability and genetic advance were estimated using the formulae recommended by Burton (1952) and Lush (1949).

RESULTS AND DISCUSSION

The pooled analysis of variance of the years 2019-20 and 2020-21 observed significant differences among the genotypes for most of the characters studied and disclosed the presence of wide variability among the genotypes. The extent of variability in fourteen genotypes was measured in terms of coefficients of variation along with the amount of heritability, genetic advance and genetic gain.

The pooled results with respect to different growth parameters, yield and quality attributes showed a significant variation among the genotypes and indicates an wide diversity among the germplasam. The cultivar Pundibari Local observed significantly higher plant height (73.17 cm), number of leaves (9.41), leaf length (52.92 cm) and the leaf width, neck thickness, number of cloves $bulb^{-1}$ showed significant variation among all the genotypes and proved it's superiority over all the germplasams collected from different parts of the country which might be due to better adaptability to the particular location. The mean values range were supported by the findings of Bhatt *et al*. (2017) and Kumar *et al*. (2017). Different yield attributing traits also recorded a wide range of variability and ultimately reflected on weight of 10 cloves (9.01-16.13 g), bulb yield $plot^{-1}$ (1.45-2.58 kg), fresh bulb yield $hectare^{-1}$ (7.25-12.90 t ha^{-1}) and the yield attributing characters like clove length, clove breadth, bulb length, bulb breadth showed significant variation among all the genotypes. The mean values range are in conformity with the findings of Panse *et al*. (2013), Vatsyayan *et al*. (2013) and Kumari (2021).The extent of variability also recorded a significant variation among the germplasam with respect to different quality traits. A perusal of data indicated with respect to total soluble solids (0 Brix) revealed a significant variation from 24.84 for Yamuna Safed-2 to 37.42 for Pundibari Local. The findings are in close agreement with Singh *et al*. (2018) and Kumari (2021). The cultivar Phule Nilima recorded maximum ascorbic acid content (15.09 mg g^{-1}) and higher oleoresin content (0.35%) closely followed by Pundibari Local. Higher vegetative growth

Table 1: Mean performance of plant height (cm), number of leaves, leaf length (cm), leaf width (cm) in different genotypes of garlic at 120 DAP

Genotypes	Plant height (cm)			Number of leaves			Leaf length (cm)			Leaf width (cm)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Agrifound White	63.86^{bcd}	57.77^{efg}	60.81 ^{cd}	8.53 ^{b}	8.43^{bcd}	8.48^{b}	46.49 ^{cd}	43.13 ^{fgh}	44.81^{ef}	1.66^{bcd}	1.47 ^{e}	1.56^{ef}
Yamuna Safed -4	63.70 ^{bcd}	51.48 ^{i}	57.59 ^{ef}	8.07^{bced}	7.93 ^{de}	8.00^{cde}	47.41^{bcd}	45.32 ^{de}	46.36^{cde}	1.66 ^{bcd}	1.47 ^{de}	1.56^{ef}
Yamuna Safed -5	66.87 ^{b}	60.93 ^{cd}	63.90 ^{b}	8.27 ^{bcd}	8.43 ^{bcd}	8.35^{bc}	49.61 ^{bc}	46.21 ^{cd}	47.91^{bc}	1.81^{ab}	1.74 ^{a}	1.78^{ba}
Yamuna Safed -8	64.86 ^{bc}	54.72 ^{h}	59.79 ^{def}	8.47 ^{b}	8.13 ^{bcde}	8.30^{bcd}	50.43 ^{b}	48.34 ^{b}	49.39^{b}	1.89 ^{a}	1.56 ^{abc}	1.72^{abc}
Yamuna Safed -2	63.29 ^{bcd}	60.89 ^{cd}	62.09 ^{bcd}	7.87 ^{ced}	7.93 ^{de}	7.90^{de}	48.36^{bc}	46.37 ^{bcd}	47.37^{bcd}	1.83^{ab}	1.70 ^{abc}	1.77^{ab}
Yamuna Safed-3	65.07^{bc}	63.64 ^{c}	64.35 ^{b}	8.27 ^{bcd}	8.10 ^{bcde}	8.18^{bcd}	49.27 ^{bc}	47.52 ^{bc}	48.39^{bc}	1.81^{ab}	1.64 ^{cd}	1.73^{abc}
Yamuna Safed-1	66.30 ^{b}	58.79 ^{def}	62.54 ^{bc}	8.00 ^{bced}	7.83 ^{e}	7.92^{de}	48.59^{bc}	45.71 ^{cd}	47.15^{cd}	1.77^{ab}	1.58 ^{bc}	1.68^{bcd}
Yamuna Safed -9	63.97 ^{bcd}	60.47 ^{de}	62.22 ^{bcd}	8.53 ^{b}	8.57 ^{bc}	8.55^{b}	45.95 ^{cd}	43.59 ^{efg}	44.77^{gef}	1.75 ^{abc}	1.67 ^{ab}	1.71^{abc}
G G-4	59.21 ^{de}	55.37 ^{gh}	57.29 ^{f}	7.73 ^{de}	8.10 ^{bcde}	7.92^{de}	43.97 ^{d}	41.37 ^{h}	42.67^{g}	1.53 ^{de}	1.49 ^{ef}	1.51^{f}
G J G-5	62.65^{bcd}	57.18 ^{fgh}	59.92 ^{de}	8.00 ^{bced}	8.07 ^{cde}	8.03^{cde}	47.72 ^{bcd}	45.06 ^{def}	46.39^{cde}	1.56^{cde}	1.53 ^{de}	1.55^{ef}
G A G-6	55.22^{e}	49.58 ^{i}	52.40 ^{g}	7.67^{e}	7.87 ^{e}	7.77^{e}	39.99 ^{e}	37.97 ^{i}	38.98^{h}	1.41 ^{e}	1.40 ^{f}	1.41^{g}
Phule Nilima	60.71 ^{cd}	66.75 ^{b}	63.73 ^{b}	8.40^{bc}	8.53 ^{bc}	8.47^{b}	44.27 ^{d}	42.14 ^{gh}	43.20^{fg}	1.70^{abcd}	1.50 ^{cd}	1.60^{def}
PhuleBaswant	63.08^{bcd}	57.23 ^{fgh}	60.15 ^{cde}	7.73 ^{de}	8.60 ^{b}	8.17^{bcde}	46.39 ^{cd}	44.62 ^{def}	45.50 ^{de}	1.70^{abcd}	1.56 ^{e}	1.63^{cde}
Punibari Local	76.18^{a}	70.16 ^{a}	73.17 ^{a}	9.53^{a}	9.28 ^{a}	9.41^{a}	54.98 ^{a}	50.85 ^{a}	52.92^{a}	1.87 ^{a}	1.70 ^{cd}	1.78^{a}
Mean	**63.92**	**58.92**	**61.42**	**8.21**	**8.27**	**8.24**	**47.38**	**44.87**	**46.12**	**1.71**	**1.57**	**1.64**
SEm(±)	1.73	0.98	2.40	0.21	0.18	0.13	1.25	0.68	0.71	0.07	0.03	0.03
LSD (0.05)	5.04	2.86	2.60	0.60	0.53	0.40	3.77	2.04	2.13	0.20	0.09	0.10

Table 2: Mean performance of Neck thickness (mm), Bulb length (cm), Bulb breadth (cm), Bulb weight (g) in different genotypes of garlic

PGenotypes	Neck thickness (mm)			Bulb length (cm)			Bulb breadth (cm)			Bulb weight (g)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Agrifound White	10.04 ^{e}	9.93 ^{efgh}	9.99^{e}	3.01 ^{d}	2.87 ^{cd}	2.94 ^{c}	3.48 ^{cd}	3.01 ^{de}	3.24 ^{e}	18.48 ^{f}	17.53 ^{gh}	18.00 ^{f}
Yamuna Safed -4	11.46^{bcd}	10.19 ^{defgh}	10.83^{cd}	2.60 ^{f}	2.52 ^{f}	2.56 ^{d}	2.71 ^{e}	2.32 ^{h}	2.51 ^{h}	14.96 ^{h}	14.03 ^{j}	14.49 ^{h}
Yamuna Safed -5	11.58^{bc}	10.84 ^{cd}	11.21^{c}	2.95 ^{de}	2.89 ^{cd}	2.92 ^{c}	3.20 ^{d}	2.69 ^{g}	2.95 ^{g}	23.03 ^{bc}	20.49 ^{cd}	21.76 ^{c}
Yamuna Safed -8	11.76^{bc}	10.51 ^{cde}	11.14^{cd}	2.94 ^{de}	2.83 ^{cd}	2.89 ^{c}	3.42 ^{d}	3.17 ^{bcd}	3.30 ^{de}	15.03 ^{h}	14.94 ^{ij}	14.99 ^{h}
Yamuna Safed -2	11.22 ^{bcde}	10.41 ^{cdefg}	10.81^{cd}	3.04 ^{cd}	2.92 ^{c}	2.98 ^{c}	3.47 ^{cd}	3.21 ^{bcd}	3.34 ^{de}	21.20 ^{d}	20.08 ^{de}	20.64 ^{d}
Yamuna Safed-3	12.05 ^{bc}	10.96 ^{c}	11.51^{bc}	3.02 ^{d}	2.87 ^{cd}	2.95 ^{c}	3.35 ^{d}	2.97 ^{def}	3.16 ^{efg}	22.55 ^{c}	21.70 ^{c}	22.12 ^{c}
Yamuna Safed-1	11.89^{bc}	10.57 ^{cde}	11.23^{c}	2.96 ^{de}	2.75 ^{de}	2.86 ^{c}	3.41 ^{d}	3.03 ^{cd}	3.22 ^{ef}	16.52 ^{g}	15.63 ^{i}	16.08 ^{g}
Yamuna Safed -9	11.70^{bc}	10.03 ^{efgh}	10.87^{cd}	3.34^{bc}	3.19 ^{b}	3.26 ^{b}	3.82^{bc}	3.28 ^{bc}	3.54 ^{cd}	21.38 ^{d}	19.37 ^{def}	20.38 ^{d}
G G-4	10.24 ^{de}	9.66 ^{h}	9.95^{e}	2.97 ^{de}	2.75 ^{de}	2.86 ^{c}	3.48 ^{cd}	3.09 ^{cd}	3.29 ^{e}	18.59 ^{f}	17.01 ^{h}	17.81 ^{f}
G J G-5	10.95^{cde}	9.84 ^{fgh}	10.39^{de}	3.12 ^{cd}	2.93 ^{c}	3.02 ^{c}	3.95 ^{b}	3.42 ^{b}	3.68 ^{c}	20.00 ^{e}	19.05 ^{ef}	19.52 ^{e}
G A G-6	10.20 ^{de}	9.79 ^{gh}	10.00^{e}	3.04 ^{cd}	2.89 ^{cd}	2.96 ^{c}	3.21 ^{d}	2.72 ^{fg}	2.97 ^{fg}	15.57 ^{h}	17.78 ^{gh}	16.68 ^{g}
Phule Nilima	12.48 ^{b}	11.67 ^{b}	12.08^{b}	3.51^{ab}	3.28 ^{b}	3.39 ^{b}	4.17 ^{b}	3.74 ^{a}	3.96 ^{b}	23.56 ^{b}	23.55 ^{b}	23.55 ^{b}
PhuleBaswant	11.18^{cde}	10.48 ^{cdef}	10.83^{cd}	2.66^{ef}	2.63 ^{ef}	2.64 ^{d}	3.19 ^{d}	2.77 ^{efg}	2.98 ^{fg}	19.66 ^{e}	18.63 ^{fg}	19.14 ^{e}
Punibari Local	13.89 ^{a}	13.29 ^{a}	13.58^{a}	3.79 ^{a}	3.63 ^{a}	3.71 ^{a}	4.67 ^{a}	3.95 ^{a}	4.31 ^{a}	26.11 ^{a}	25.47 ^{a}	25.79 ^{a}
Mean	**11.47**	**10.58**	**11.03**	**3.06**	**2.92**	**2.99**	**3.53**	**3.09**	**3.31**	**19.76**	**18.94**	**19.35**
SE(m)±	0.45	0.22	0.26	0.10	0.05	0.06	0.13	0.08	0.08	0.22	0.42	0.26
CD	1.30	0.66	0.76	0.31	0.16	0.20	0.38	0.26	0.25	0.62	1.22	0.77

Table 3: Mean performance of Clove length (cm), Clove breadth (cm), Weight of 10 cloves (g), Number of cloves bulb^{-1} in different genotypes of garlic

Genotypes	Clove length (cm)			Clove breadth (cm)			Weight of 10 cloves (g)			Number of cloves bulb^{-1}		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Agrifound White	2.76^{bc}	2.59 ^{bcd}	2.67 ^{cd}	0.73 ^{h}	0.64 ^{f}	0.69 ^{i}	10.70 ^{d}	10.00 ^{ef}	10.35 ^{d}	16.16 ^{gh}	14.86 ^{fg}	15.51 ^{de}
Yamuna Safed -4	2.09 ^{g}	2.02 ^{i}	2.06 ^{h}	0.62 ^{i}	0.56 ^{g}	0.59 ^{j}	9.34 ^{e}	8.69 ^{gh}	9.01 ^{e}	14.49 ^{h}	13.22 ^{g}	13.86 ^{g}
Yamuna Safed -5	2.73^{bcd}	2.49 ^{def}	2.61 ^{d}	0.88 ^{ef}	0.76 ^{d}	0.82 ^{e}	12.82 ^{c}	11.69 ^{c}	12.26 ^{c}	21.28 ^{cd}	21.06 ^{ab}	21.17 ^{b}
Yamuna Safed -8	2.57^{cde}	2.54 ^{cde}	2.56 ^{de}	0.77 ^{gh}	0.71 ^{d}	0.74 ^{gh}	9.35 ^{e}	9.33 ^{fg}	9.34 ^{e}	14.51 ^{h}	13.40 ^{fg}	13.96 ^{fg}
Yamuna Safed -2	2.50 ^{def}	2.41 ^{efg}	2.45 ^{ef}	0.84 ^{fg}	0.75 ^{d}	0.80 ^{ef}	11.04 ^{d}	10.42 ^{ed}	10.73 ^{d}	20.24 ^{de}	17.56 ^{e}	18.90 ^{c}
Yamuna Safed-3	2.76^{bc}	2.61^{bcd}	2.69 ^{cd}	0.96 ^{cd}	0.86 ^{c}	0.91 ^{cd}	12.51 ^{c}	11.69 ^{c}	12.10 ^{c}	22.72 ^{bc}	19.72 ^{bcd}	21.22 ^{b}
Yamuna Safed-1	2.76 ^{bc}	2.55^{cde}	2.65 ^{d}	0.84 ^{fg}	0.73 ^{d}	0.78 ^{efg}	10.19 ^{de}	8.70 ^{gh}	9.44 ^{e}	14.93 ^{h}	14.41 ^{fg}	14.67 ^{efg}
Yamuna Safed -9	2.57^{cde}	2.35^{fg}	2.46 ^{ef}	0.94 ^{cde}	0.83 ^{c}	0.88 ^{d}	12.48 ^{c}	11.57 ^{c}	12.02 ^{c}	20.41 ^{de}	18.94 ^{cde}	19.68 ^{c}
G G-4	2.70 ^{cd}	2.55^{ced}	2.63 ^{d}	0.93 ^{de}	0.83 ^{c}	0.88 ^{d}	10.73 ^{d}	11.09 ^{cd}	10.91 ^{d}	16.24 ^{gh}	15.11 ^{f}	15.68 ^{de}
G J G-5	2.94^{ab}	2.74 ^{b}	2.84 ^{b}	1.01 ^{c}	0.87 ^{c}	0.94 ^{c}	11.02 ^{d}	10.23 ^{e}	10.62 ^{d}	18.67 ^{ef}	18.28 ^{de}	18.47 ^{c}
G A G-6	2.41^{ef}	2.25^{gh}	2.33 ^{fg}	0.75 ^{h}	0.65 ^{ef}	0.71 ^{ih}	9.42 ^{e}	8.59 ^{h}	9.01 ^{e}	16.12 ^{gh}	14.33 ^{fg}	15.22 ^{def}
Phule Nilima	2.94 ^{ab}	2.68 ^{bc}	2.81 ^{bc}	1.12 ^{b}	0.99 ^{b}	1.06 ^{b}	14.27 ^{b}	14.81 ^{b}	14.54 ^{b}	23.99 ^{b}	20.56 ^{bc}	22.27 ^{b}
PhuleBaswant	2.31^{fg}	2.09 ^{hi}	2.20 ^{gh}	0.83 ^{fg}	0.71 ^{de}	0.77 ^{fg}	10.81 ^{d}	10.04 ^{e}	10.42 ^{d}	17.02 ^{fg}	15.20 ^{f}	16.11 ^{d}
Punibari Local	3.16 ^{a}	3.00 ^{a}	3.08 ^{a}	1.23 ^{a}	1.14 ^{a}	1.19 ^{a}	16.37 ^{a}	15.89 ^{a}	16.13 ^{a}	25.96 ^{a}	22.52 ^{a}	24.24 ^{a}
Mean	**2.64**	**2.49**	**2.57**	**0.88**	**0.78**	**0.84**	**11.50**	**10.91**	**11.20**	**18.76**	**17.08**	**17.92**
SE(m)±	0.08	0.05	0.05	0.03	0.02	0.02	0.34	0.23	0.22	0.65	0.62	0.46
CD	0.24	0.16	0.15	0.15	0.07	0.06	1.00	0.68	0.63	1.89	1.81	1.35

Table 4: Mean performance of Number of bulbs kg^{-1}, Bulb yield plot^{-1} (kg), Bulb yield hectare^{-1} (t ha^{-1}), Bulb yield (t ha^{-1}) at 4 months after storage in different genotypes of garlic

Genotypes	Number of bulbs kg^{-1}			Bulb yield plot^{-1}(Kg)			Bulb yield hectare^{-1} (t/ha)			Bulb yield hectare^{-1} at (t/ha) 4MAS		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Agrifound White	56.12 ^{d}	59.07 ^{c}	57.60 ^{e}	1.85 ^{f}	1.75 ^{gh}	1.80 ^{f}	9.24 ^{f}	8.76 ^{gh}	9.00 ^{f}	7.22 ^{f}	6.79^{gh}	7.00 ^{f}
Yamuna Safed -4	68.86 ^{a}	73.31 ^{a}	71.08 ^{a}	1.49 ^{i}	1.40 ^{j}	1.45 ^{h}	7.48 ^{h}	7.01 ^{j}	7.25 ^{h}	5.79 ^{i}	5.38 ^{j}	5.59 ^{h}
Yamuna Safed -5	45.43 ^{gh}	50.80 ^{gh}	48.12 ^{h}	2.30 ^{bc}	2.05 ^{cd}	2.18 ^{c}	11.52 ^{bc}	10.25 ^{cd}	10.88 ^{c}	9.07 ^{c}	8.00 ^{cd}	8.53 ^{c}
Yamuna Safed -8	68.57 ^{a}	69.02 ^{b}	68.79 ^{b}	1.50 ^{ih}	1.50 ^{ij}	1.50 ^{h}	7.52 ^{h}	7.47 ^{ij}	7.49 ^{h}	5.80 ^{i}	5.72 ^{ij}	5.76 ^{h}
Yamuna Safed -2	49.20 ^{f}	51.94 ^{fg}	50.57 ^{g}	2.12 ^{d}	2.01 ^{de}	2.06 ^{d}	10.60 ^{d}	10.04 ^{de}	10.32 ^{d}	8.34 ^{d}	7.83 ^{de}	8.08 ^{d}
Yamuna Safed-3	46.36 ^{g}	48.08 ^{h}	47.23 ^{h}	2.26 ^{c}	2.17 ^{c}	2.21 ^{c}	11.27 ^{c}	10.85 ^{c}	11.06 ^{c}	8.87 ^{c}	8.47 ^{c}	8.67 ^{c}
Yamuna Safed-1	62.58 ^{c}	66.02 ^{b}	64.30 ^{c}	1.65 ^{g}	1.57 ^{i}	1.61 ^{g}	8.26 ^{g}	7.81 ^{i}	8.04 ^{g}	6.46 ^{g}	6.06 ^{i}	6.26 ^{g}
Yamuna Safed -9	48.78 ^{f}	53.72 ^{efg}	51.25 ^{g}	2.14 ^{d}	1.94 ^{def}	2.04 ^{d}	10.69 ^{d}	9.69 ^{def}	10.19 ^{d}	8.41 ^{d}	7.56 ^{def}	7.99 ^{d}
G G-4	55.78 ^{d}	60.78 ^{c}	58.28 ^{e}	1.86 ^{f}	1.70 ^{h}	1.78 ^{f}	9.30 ^{f}	8.51 ^{h}	8.90 ^{f}	7.28 ^{f}	6.61 ^{h}	6.95 ^{f}
G J G-5	52.03 ^{e}	54.53 ^{ef}	53.28 ^{f}	2.00 ^{e}	1.91 ^{ef}	1.95 ^{e}	10.00 ^{e}	9.53 ^{ef}	9.76 ^{e}	7.84 ^{e}	7.41 ^{ef}	7.62 ^{e}
G A G-6	66.26 ^{b}	58.26 ^{cd}	62.26 ^{d}	1.56 ^{h}	1.78 ^{gh}	1.67 ^{g}	7.79 ^{h}	8.89 ^{gh}	8.34 ^{g}	6.08 ^{h}	6.89 ^{gh}	6.48 ^{g}
Phule Nilima	44.49 ^{h}	44.54 ^{i}	44.51 ^{i}	2.36 ^{b}	2.35 ^{b}	2.36 ^{b}	11.78 ^{b}	11.78 ^{b}	11.78 ^{b}	9.34 ^{b}	9.26 ^{b}	9.30 ^{b}
PhuleBaswant	52.91 ^{e}	55.68 ^{de}	54.29 ^{f}	1.97 ^{e}	1.87 ^{fg}	1.91 ^{e}	9.83 ^{e}	9.32 ^{fg}	9.57 ^{e}	7.69 ^{e}	7.23 ^{fg}	7.46 ^{e}
Punibari Local	40.33 ^{i}	41.32 ^{j}	40.82 ^{j}	2.61 ^{a}	2.55 ^{a}	2.58 ^{a}	13.05 ^{a}	12.74 ^{a}	12.90 ^{a}	10.36 ^{a}	10.03 ^{a}	10.19 ^{a}
Mean	**54.12**	**56.21**	**55.17**	**1.98**	**1.89**	**1.93**	**9.88**	**9.47**	**9.67**	**7.75**	**7.37**	**7.56**
SE(m)±	0.60	1.06	0.66	0.02	0.04	0.03	0.10	0.21	0.13	0.08	0.16	0.10
CD	1.74	3.08	1.92	0.06	0.12	0.08	0.31	0.61	0.38	0.24	0.47	0.30

Table 5: Mean performance of Days to maturity, TSS (°brix), Ascorbic acid(mg g^{-1}), Oleoresin (%) in different genotypes of garlic

Genotypes	Days to maturity			TSS(°brix)			Ascorbic acid(mg g^{-1})			Oleoresin(%)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Agrifound White	149.85 ^{d}	152.51 ^{c}	151.18 ^{d}	32.87 ^{e}	32.52 ^{d}	32.70 ^{d}	8.20 ^{g}	7.87 ^{g}	8.04 ^{g}	0.20 ^{c}	0.18 ^{c}	0.19 ^{c}
Yamuna Safed -4	146.81 ^{f}	151.48 ^{d}	149.14 ^{f}	36.41 ^{abc}	36.26 ^{b}	36.34 ^{b}	10.60 ^{de}	10.26 ^{de}	10.43 ^{de}	0.11 ^{e}	0.09 ^{e}	0.10 ^{f}
Yamuna Safed -5	144.79 ^{g}	145.25 ^{g}	145.02 ^{g}	33.96 ^{de}	34.31 ^{c}	34.14 ^{c}	10.33 ^{e}	9.99 ^{e}	10.16 ^{e}	0.33 ^{a}	0.31 ^{a}	0.32 ^{a}
Yamuna Safed -8	155.93 ^{b}	155.63 ^{b}	155.78 ^{b}	27.18 ^{g}	25.76 ^{g}	26.47 ^{g}	9.25 ^{f}	8.91 ^{f}	9.08 ^{f}	0.11 ^{e}	0.11 ^{de}	0.12 ^{ef}
Yamuna Safed -2	158.96 ^{a}	158.74 ^{a}	158.85 ^{a}	24.92 ^{h}	24.75 ^{h}	24.84 ^{h}	11.35 ^{d}	11.02 ^{d}	11.19 ^{d}	0.27 ^{b}	0.25 ^{b}	0.27 ^{b}
Yamuna Safed-3	154.91 ^{c}	155.63 ^{b}	155.27 ^{c}	30.15 ^{f}	29.96 ^{e}	30.06 ^{e}	10.96 ^{de}	10.63 ^{de}	10.80 ^{de}	0.29 ^{b}	0.27 ^{b}	0.28 ^{b}
Yamuna Safed-1	141.75 ^{h}	143.18 ^{h}	142.46 ^{h}	35.11 ^{cd}	34.89 ^{c}	35.00 ^{c}	10.62 ^{de}	10.28 ^{de}	10.45 ^{de}	0.18 ^{c}	0.16 ^{c}	0.17 ^{cd}
Yamuna Safed -9	132.64 ^{k}	137.99 ^{k}	135.31 ^{k}	28.61 ^{g}	28.10 ^{f}	28.36 ^{f}	12.89 ^{bc}	12.56 ^{bc}	12.73 ^{bc}	0.28 ^{b}	0.26 ^{b}	0.27 ^{b}
G G-4	134.66 ^{j}	140.06 ^{j}	137.36 ^{j}	37.08 ^{ab}	36.92 ^{ab}	37.00 ^{ab}	10.46 ^{e}	10.13 ^{e}	10.30 ^{e}	0.13 ^{de}	0.11 ^{de}	0.12 ^{ef}
G J G-5	127.58 ^{m}	132.80 ^{m}	130.19 ^{m}	35.11 ^{cd}	34.33 ^{c}	34.72 ^{c}	12.44 ^{c}	12.11 ^{c}	12.28 ^{c}	0.19 ^{c}	0.17 ^{c}	0.18 ^{c}
G A G-6	131.63 ^{l}	136.95 ^{l}	134.29 ^{l}	35.70 ^{bc}	34.59 ^{c}	35.15 ^{c}	11.00 ^{de}	10.67 ^{de}	10.84 ^{de}	0.20 ^{c}	0.18 ^{c}	0.19 ^{c}
Phule Nilima	148.84 ^{e}	149.40 ^{f}	149.12 ^{f}	36.58 ^{abc}	36.30 ^{b}	36.44 ^{b}	15.25 ^{a}	14.92 ^{a}	15.09 ^{a}	0.36 ^{a}	0.34 ^{a}	0.35 ^{a}
PhuleBaswant	136.69 ^{i}	141.10 ^{i}	138.89 ^{i}	25.66 ^{h}	25.70 ^{gh}	25.68 ^{gh}	13.41 ^{b}	13.08 ^{b}	13.25 ^{b}	0.15 ^{d}	0.13 ^{d}	0.14 ^{de}
Punibari Local	149.85 ^{d}	150.44 ^{e}	150.14 ^{e}	37.81 ^{a}	37.42 ^{a}	37.62 ^{a}	13.47 ^{b}	13.14 ^{b}	13.31 ^{b}	0.34 ^{a}	0.32 ^{a}	0.33 ^{a}
Mean	**143.07**	**146.51**	**145.75**	**32.65**	**32.27**	**32.46**	**11.44**	**11.11**	**11.28**	**0.22**	**0.20**	**0.21**
SE(m)±	0.07	0.06	0.01	0.52	0.33	0.37	0.27	0.13	0.14	0.001	0.006	0.006
CD	0.21	0.16	0.03	1.51	0.96	1.08	0.78	0.38	0.40	0.030	0.017	0.018

Table 6: Estimates of genetic parameters for the twenty characters in garlic

Characters	Coefficients of variability		Heritability (%)	Genetic advance	Genetic advance as % mean
	Phenotypic	Genotypic			
Plant height	7.56	7.42	96.28	9.21	15.00
Number of leaves	5.04	4.75	88.83	0.76	9.22
Leaf length	7.19	7.01	95.12	6.50	14.10
Leaf width	6.97	6.63	90.40	0.21	12.99
Neck thickness	8.63	8.30	92.43	1.81	16.44
Bulb length	9.77	9.50	94.55	0.57	19.04
Bulb bredth	13.58	13.33	96.32	0.89	26.95
Bulb weight	16.96	16.90	99.35	6.71	34.71
Clove length	10.29	10.10	96.24	0.52	20.41
Clove bredth	18.33	18.24	99.05	0.31	37.40
Weight of 10 cloves	18.54	18.43	98.91	4.23	37.77
Number of cloves bulb^{-1}	18.88	18.70	98.13	6.84	38.16
Number of bulbs Kg^{-1}	16.37	16.33	99.47	18.51	33.55
Bulb yield plot^{-1}	16.92	16.87	99.34	0.67	34.63
Bulb yield hectare^{-1}	16.97	16.91	99.36	3.36	34.73
Bulb yield hectare^{-1} 4MAS	17.69	17.64	99.42	2.74	36.24
Days to maturity	6.16	6.16	100	18.43	12.69
TSS	13.83	13.78	99.32	9.18	28.30
Vit-C	16.48	16.31	97.94	3.75	33.25
Oleoresin	38.91	38.60	98.37	0.17	78.86

of the Pundibari Local and Phule Nilima might be the reason to contribute directly or indirectly towards yield attributing and quality parameters.

Genetic variability parameters

Significant differences were found among the genotypes for all the traits studied indicating a considerable amount of variability among them. The estimates of genetic variability parameters for all the characters are presented in Table 6. The estimates of the genotypic and phenotypic coefficient of variation indicated that the values of phenotypic coefficient of variation were slightly higher than that of corresponding genotypic coefficient of variation for all the characters except days to maturity indicating the marginal control of environment in governing those characters. Data showed that the GCV is slightly lower than PCV. The moderate values of genotypic and phenotypic coefficient of variation were observed for bulb length, bulb breadth, clove length, clove breadth, the weight of 10 cloves, number of cloves per bulb, number of bulbs per kg, yield per plot, yield per hectare, yield per hectare after 4 months of storage, TSS, ascorbic acid. The results are in accordance with the findings of Tesga *et al*. (2011), Yadav *et al*. (2012) and Panse *et al*. (2013), while low values of genotypic and phenotypic coefficient of variation were observed for plant height, number of leaves. The results are in accordance with the findings of Kumari (2021). Leaf length, leaf width, neck thickness, bulb length indicated narrow genetic variation among the different cultivar studied.

Very high heritability estimates were observed for days to maturity (100%), number of bulbs kg^{-1} (99.47%), bulb yield hectare^{-1} 4 months after storage (99.42%), bulb yield hectare^{-1}(99.36%), bulb weight (99.35%), bulb yield plot^{-1} (99.34%), TSS (99.32%), clove breadth (99.05%), weight of 10 cloves (98.91%), oleoresin (98.37%), number of cloves bulb^{-1} (98.13%), ascorbic acid (97.94%), bulb breadth (96.32%), plant height (96.28%), clove length (96.24%), leaf length(95.12%), bulb length (94.55%), neck thickness (92.43%), leaf width (90.40%). High heritability estimates were observed for the number of leaves (88.83 %). High heritability for the above traits clarified that they were least affected by environmental fluctuations and selection based on phenotypic performance would be reliable. The results are supported by the findings of Jabeen *et al*. (2010) and Tesga *et al*. (2010).

The heritability estimates accompanying genetic advances are more beneficial than the heritability values alone for selecting the best individual. High heritability coupled with high genetic advance (78.86%)expressed as a per cent of mean were observed for oleoresin content, number of cloves bulb^{-1} (38.16%), weight of 10 cloves (37.77%), clove breadth (37.40%), bulb yield hectare^{-1} 4months after storage (36.24%), bulb yield hectare^{-1} (34.73%), bulb weight (34.71%), bulb yield plot^{-1}(34.63%), number of bulbs Kg^{-1} (33.55%), ascorbic acid (33.25%), TSS (28.30%), bulb breadth (26.95%), clove length (20.41 %) followed by bulb length (19.04%), neck thickness (16.44%), leaf length (14.10 %), leaf width (12.99%), days to maturity

(12.69%) which showed moderate genetic advance as % mean and the number of leaves showed low genetic advance as % mean are supported by the finding of Singh *et al*. (2012).

CONCLUSION

It can be concluded from the present findings high heritability coupled with high genetic advance as % mean indicates additive gene action among the different cultivars of garlic. The selection was effective with respect to the following yield attributing traits like weight of bulb, number of cloves bulb^{-1}, weight of 10 cloves, clove length and breadth, fresh bulb yield hectare^{-1} as well as after four months of storage and qualitative parameters viz. ascorbic acid, TSS and oleoresin content. These characters can be used for further crop improvement programme in Pundibari Local and can be recommended for cultivation in Terai region of West Bengal.

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