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Collection and characterization of garlic (*Allium sativm* L.) germplasm for growth and bulb yield at Debre Markos, Ethiopia

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Garlic (*Allium sativm* L.) is the most widely used crop among cultivated *Allium* species in Ethiopia and it has a wide range of climatic and soil adaptation. Production of the crop is confronted with a number of problems and the total production and productivity in the country is low. Among many contributing factors, lack of improved varieties and garlic rust are the major ones. In view of this, an experiment was carried out to screen garlic germplasm for yield and diseases tolerance at Debre Markos University College of Agriculture and Natural Resource research field during 2013/14-2016/2017. The experiment was arranged in randomized complete block design with three replications. The result of the study showed high heritability together with high and medium genetic advance for days to physiological maturity, bulb weight, clove number, clove weight and total bulb yield between germplasms and significant variation among the germplasms tested with regard to plant height (cm), leaf length, (cm), maturity date, leaf number, bulb weight (g), clove number, clove weight (g), bulb diameter (cm) and total bulb yield (kg/ha). Different germplasms resulted in better performance with respect to recorded parameters. Germplasms 5 and 18 were found to be superior followed by germplasms 13 and 38. In addition, they recorded maximum plant height, leaf length, bulb weight, clove weight, bulb diameter, total yield, shorter maturity date and moderately susceptibility to rust. The result generally indicated that germplasms G5 (7640 kg), G18 (6929 kg), G38 (4626 kg) and G13 (4601 kg) are promising germplasm in the study area. It will be good to repeat the experiment at multi locations for National Variety Trail test.

Key words: Garlic, germplasm, growth, yield.

INTRODUCTION

Garlic (*Allium sativum* L.) is the second most widely cultivated *Allium* next to onion (Brewster, 1994). Garlic is primarily grown for its cloves used mostly as a food-flavouring condiment. Green tops are eaten fresh or

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cooked. In tropical areas, consumption of immature bulbs for salad is also popular (Rubatzky and Yamaguchi, 1997; Fritsch and Friesen, 2002). Garlic is one of the best-studied medicinal plants that have antibacterial and antiseptic properties (Keusgen, 2002).

Allium crops are planted in many parts of Ethiopia, including East and West Gojam Zones of the Amhara Regional State and it has been used long ago as vegetable and spice for flavoring a variety of Ethiopian local dishes (Alemu, 1998). Besides, it is used as traditional medicine for relief from any painful condition occurring inside the body. Today, the importance of garlic is well known all over the world, especially in pharmaceutical industries as well as botanicals against some plant diseases and insect pests (Brewster, 1994). Regarding its economic importance to a grower, as high value crop, it is sold for higher price when compared with other *Allium* vegetables such as onion, shallot and leek. *Allium* groups are important bulb crops in Ethiopia and produced by small and commercial growers for local use and export to Europe, the Middle East and USA, to earn foreign currency (Metasebia and Shimelis, 1998). These crops are also produced for home consumption and as a source of income to many peasant farmers in many parts of the country (Getachew and Asfaw, 2000). Metasebia and Shimelis (1998) reported that the per capita consumption of these crops is estimated to be over 1.74 and 5.9 kg in the rural and urban center, respectively.

In Ethiopia, the total area under garlic production in 2015/16 reached 11,845.53 ha and the production is estimated to be 107,743.5 tonnes (FAOSTAT, 2015/2016). The production is spread throughout the country both under irrigation and rain fed conditions in different agro climatic regions (CACC, 2002). It has a wide range of climatic and soil adaptation (Lemma and Herath, 1994).

In Ethiopia, garlic is produced mainly in the mid and high altitudes of the country (Getachew and Asfaw, 2000; CACC, 2002). It had also been under commercial production by Horticultural Development Corporation at Debre Zeit, Guder and Tseday State Farmers (Getachew and Asfaw, 2000). Being a cash crop in many parts of the country, increasing its productivity per unit area and production will enable farmers to get encouraging returns and contribute its role in achieving food security (DZARC, 2006). However, major production constraints of garlic include lack of improved varieties, garlic rust, downy mildew, basal rot, white rot, purple blotch and onion thrips (Getachew and Asfaw, 2000). Because of its diverse economic and dietary importance, improving its yield need to be given top priority in breeding study.

Hence, considering garlic as one of the potential vegetable crop for consumption as well as for the market, it is imperative to increase its productivity together with desirable attributes through genetic manipulation. In many countries, garlic is a long established crop and cultivars that are well adapted to local conditions and the local market have been selected (Rabinowitch and Currah, 2002). Great efforts have been made in the selection and breeding of locally adapted cultivars and the development of cultural techniques because many traits of garlic including bulb size, shape, maturity date, the percentage of thick-necked and double bulbs are influenced by the environment (Rabinowitch and Brewster, 1990). For the development of suitable varieties of garlic, it is essential to evaluate the characters of the available germplasm properly for selection (Alam et al., 2010).

Garlic germplasm is diverse in Ethiopia and in recent years, collection has been carried out by the Ethiopian Institute of Agricultural Research (EIAR) at Debre Zeit Agricultural Research Center and screening trials were conducted on-station at Debrezeit. However, this screening was locality specific and materials were tested only under Central and South central garlic growing areas to evaluate their performance and may not perform well beyond these locations. Therefore, it is necessary to conduct regional based germplasm screening for further breeding work and to screen varieties for disease reaction. This study was therefore, conducted to collect and screen potential garlic germplasm for growth, yield, disease tolerance and further varietal improvement and also to estimate the nature and magnitude of variability for yield and yield related characters.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Debre Markos University College of Agriculture and Natural Resource research field during 2013/14-2016/2017. Debre Markos University is geographically located at about 10° 21' latitude North and 37°43' longitude East; its elevation was estimated to be 2509 m above sea level. The annual average temperature was 18.5°C, while the maximum and minimum recorded temperatures were 24 and 4°C, respectively. Annual average rainfall was 1380 mm. the general climatic condition of Debre Markos is humid, characterized by sub-tropical weather condition (Planning and Economic Development of East Gojjam, 2004 cited by Yeshiwas, 2017).

Experimental materials and design (collected germplasm)

Fifty garlic germplasms were collected from 14 Districts of East Gojjam, West Gojam and Awi zone and used as planting materials. The 50 garlic germplasms collected were considered as the treatments for the experiment. In the first phase, 50 collected garlic germplasms were planted in a non-replicated trial in blocks. Germplasms were strictly tagged in blocks. 34 best performing lines were selected based on vegetative, disease, yield and yield component parameters. In the second phase, the already screened materials were evaluated by using simple lattice design to start variety preliminary yield trial. The materials were evaluated using standard check obtained from Debrezeit Agricultural Research Center. During the third phase, best performing 14 lines were selected based on vegetative, disease, yield and yield component parameters and pre-regional variety trial were started at on-station (Debre Markos), using randomized complete block design in three replications.

Experimental procedures

Fifty germplasms of garlic were collected and stored for planting. At planting time, cloves were separated from the bulbs, sorted and graded according to their size category: large (2.0 to 2.5 g), medium (1.5 to 1.9 g) and small (1.0 to 1.49 g) (Fikreyohannes, 2005). Land preparation was started in April. The experimental plots were planted at the beginning of June, 2013/2014 to 2016/2017 at the depth of 3 cm by sticking the clove into the raised bed by hand. The cloves were spaced 10 cm between plants and 30 cm between rows. The space between block and between plots was 1 and 0.5 m, respectively. There were four rows per plot and 10 plants per row with a total of 40 plants per plot. Fertilizers were applied according to the national recommendation at the rate of 200 kg di ammonium phosphate at planting and 150 kg urea: 75 kg of urea at time of planting and the other 75 kg at after two months of planting (EARO, 2004). Hand weeding was done every 15 days interval.

Data collected

Data were recorded on the middle twelve plants and the plot averages were used for analysis by adapting IPGRI (2001). Data were collected for plant height (cm), leaf length (cm): leaf number per plant, days to physiological maturity, average bulb weight (g), bulb diameter, bulb color, shape of dry bulb, number of cloves per bulb, clove weight (g), total yield (kg/ha) and rust severity.

Rust severity

Garlic rust severity was assessed from 10 plants which were randomly pre-tagged with red ropes in the middle two rows of each plot (five plants per row). Assessment started 70 days after planting. The final date of disease assessment (98 days after planting) was used for analysis. Disease severity was estimated in percentage of leaf surface covered with lesions. Disease severity was rated using standard disease scales of 1-5 for rust severity, where, 1 = 1 - 10%, 2 = 11 - 25%, 3 = 26 - 50%, 4 = 51 - 75%, and 5 = 76 - 100% of the leaf surface covered with lesion (Koike et al., 2001) and average severity of the 10 plants per plot was used for statistical analysis. The scores were changed into percentage severity index (PSI) for analysis using the formula of Wheeler (1969).

$$PSI = \frac{Snr}{NprxMsc} x100 \quad (1)$$

Where, Snr = the sum of numerical ratings, Npr = the number of plant rated, Msc = the maximum score of the scale. Mean disease severity from each plot was used in data analysis.

Data analysis

The data obtained were subjected to analysis of variance (ANOVA) by using SAS software version 9.2 (SAS, 2008). The ANOVA model used for the analysis was

$$Y_{ij} = \mu + T_{\iota} + \beta_{\varphi} + \varepsilon_{\iota\varphi} \quad (2)$$

Where, Yij is any observation for which *i* is the treatment factor, *j* is the blocking factor, μ is overall mean, *T*i is is the effect for being in treatment *I, B*j is the effect for being in block *j,* $\varepsilon_{\iota\varphi}$ = error term due to the uncontrolled factors.

When ANOVA showed significant differences, mean separation was carried out using least significant difference (LSD) test at 5% significance level (Gomez and Gomez, 1984). Genetic parameters including genotypic and phenotypic variance, genotypic and phenotypic coefficient of variance, heritability (broad sense) and the expected genetic advance (GA), were calculated using the formula given by Falconer (1981), Jim et al. (2003) and Johnson et al. (1955).

RESULTS AND DISCUSSION

Plant height

The analysis of variance indicated that there were significant ($p<0.0001$) differences between germplasm (Table 1). Accordingly, the tallest plant height of 72.83 cm was recorded from germplasm G5 collected from Dembecha- Senseb Gebriel area which was at par with germplasms G13 and G11 collected from Dejen – Gibgib (66.78) and Dejen – Jeva (66.22), respectively. The shortest plant height was attained from germplasm G24 collected from Sekela - Yedem Mariyam (43.44 cm) (Table 1). The difference of germplasms for plant height was due to genetic difference. This finding was in line with the findings of Alam et al. (2010) who reported significant variation for plant height due to the difference between genotypes. Islam et al. (2004) also reported significant variation for plant height due to varietal difference.

Days to physiological maturity

Germplasm showed very highly significant *(p*<0.0001*)* variations with respect of days to maturity (Table 1.). The shortest period of maturity was shown by germplasms G5 (108 days) and G18 collected from Awebel - Yazera giorgis (109.33 days), G13 collected from Dejen – Gibgib (109.33 days), G5 obtained from Dembecha- Senseb Gebriel (109 days), G38 collected from Banja – Satma (108.66 days) and G11 collected from Dejen – Jeva (108 days). Germplasm G48 from Sekela - Yedem Mariyam, G50 obtained from Sekela-Menbeta took the maximum (136 and 131.33) days respectively, to bulb maturity (Table 1).

Leaf length

There were very highly significant differences ($p<0.001$) between germplasm for leaf length (Table 1). The longest (46.11 cm) leaf length was recorded from germplasm G5 obtained from Dembecha- Senseb Gebriel, which was to par with values recorded by germplasm G11 collected from Dejen – Jeva (41.44 cm) and G13 from Dejen – Gibgib (42.72 cm). While the shortest (32.16 and 31.22 cm) leaf length was obtained from germplasm G15 (Dejen- Borbor) and G48 (Sekela - Yedem Mariyam), respectively (Table 1). The longest leaf length was

Table 1. Plant height, maturity date, leaf length, and leaf number of bulbs of 16 selected garlic germplasms.

Germplasms code	Collection area	Plant height (cm)	Maturity date	Leaf length (cm)	Leaf number
G-45	Sekela – Lijima	62.22^{bcdef}	128.33^{abc}	37.72^{bcde}	9.33^{bcde}
G-14	Dejen – Koncher	53.94^{efg}	119.66^{dc}	32^{fg}	9^{cde}
G-17	Awebel –Dehguma	57.11^{cdefg}	113d^{e}	34.11^{cdefg}	9.33^{bcde}
G-15	Dejen- Borbor	49.39^{gh}	121.33^{dc}	32. 16 ^{efg}	9.22^{bcde}
G-10	Bure – Kebsa	55.89^{defg}	127.33^{abc}	37.44^{bcdef}	8^{ef}
G-24	Sinan - Debre Zeit	62.33^{bcde}	124^{bc}	41.44^{ab}	9.44^{bcd}
G-48	Sekela - Yedem Mariyam	43.44^{h}	136^{a}	31.22^{g}	7^{f}
G-38	Banja – Satma	65.11^{abcd}	108.66^{e}	42.11^{ab}	9.89^{abc}
G-16	Awebel – Abkejit	57.00^{cdefg}	125.33^{bc}	38.22^{bcd}	9.11^{bcde}
G-50	Sekela-Menbeta	58.61^{cdefg}	131.33^{ab}	41.32^{ab}	9.55^{bcd}
G-18	Awebel - Yazera giorgis	65.28^{abc}	109.33^{e}	39.61^{bc}	9.11^{bcde}
G-13	Dejen – Gibgib	66.78^{ab}	109.33^{e}	42.72^{ab}	10.44^{ab}
G-11	Dejen – Jeva	66.22^{abc}	109^{e}	41.44^{ab}	10.22^{abc}
G-5	Dembecha- Senseb Gebriel	72.83^{a}	108^{e}	46.11^{a}	8.33^{def}
Kuriftu	Standard Cheak	52.89^{fg}	128^{abc}	33.94^{defg}	9.77^{abc}
Bishoftu	Standard Cheak	54.67^{efg}	129.^{abc}	34.94^{cgdef}	11^{a}
LSD (5%)		9.38	9.34	5.65	1.39
CV (%)		9.539	4.65	8.95	9.02

Means followed by the same letter(s) within a column are not significantly different at 5% level of significance

obtained from germplasms having the largest clove weight. This is because large-sized cloves have higher food reserves which might have enabled the plants to produce larger leaves as compared to small-sized cloves with relatively smaller reserve food. This result is in agreement with the findings of Ahmed et al. (2007) and Danna et al. (2000) who reported that availability of more food reserves in cloves allowed young garlic plants to be more vigorous in their growth and development.

Number of leaf per plant

There were highly significant ($p<0.01$) differences in number of leaves per plant (Table 1). The highest number of leaves (11) was obtained from variety *bishoftu* (standard cheak) which was at par with germplasm G13 (Dejen – Gibgib, 10.44), G11 *Dejen – Jeva, 10.22) and G38 (Banja – Satma, 9.89). The lowest number of leaves (7 and 8) was recorded from germplasms G48 (Sekela - Yedem Mariyam) and G10 (Bure – Kebsa), respectively (Table 1).

Bulb weight

Highly significant *(p<0.01)* difference was observed between collected germplasm for the bulb weight (Table 2). The result indicates that germplasm G18 Awebel - Yazera giorgis had the highest weight of bulb (21.24 g). However, it was not significantly different from G13 (Dejen – Gibgib, 17.51) and G5 (Dembecha- Senseb Gebriel, 19.90). The lowest weight of bulb (6.63 and 5.34 g) was recorded from germplasm G14 (Dejen – Koncher) and G48 (Sekela-Yedem Mariyam), respectively (Table 2).

The present finding is in agreement with the results of Islam et al. (2007) who reported significant variation for bulb weight due to genotypic difference. They also reported that higher bulb weight in garlic is correlated with higher leaf length of plants. Similar trend was also found in the present study.

Number of cloves per bulb

The statistical analysis indicated that varieties have very highly significant ($p<0.001$) difference on clove number (Table 2 and Appendix Table 1). The maximum number of cloves per plant was obtained from G 50 (Sekela-Menbeta; 21.06) and G 48 (Sekela - Yedem Mariyam; 20.40), which was not significantly different from G10 (18.5) Bure – Kebsa, Kuriftu (17.53). The lowest number of cloves (10.40, 11.03 and 11.06) was recorded from germplasm G14, G17 and G15, respectively.

Generally, the lowest number of cloves per bulb was recorded from medium sized cloves. Similar observations were made by Fikeryohhanis (2005) who reported that clove size had significant effects on the number of cloves per bulb.

Table 2. Bulb weight (g), clove number, clove weight (g), bulb diameter (cm) and total yield (q/ha) of bulbs of 16 selected garlic germplasms.

Germplasms code	Collection area	Bulb weight (g)	Clove number	Clove weight (g)	Bulb diameter (cm)	Total yield (kg/ha)
G-45	Sekela – Lijima	14.33^{abcde}	13.8^{defg}	1.03^{bc}	3.6^{a}	4134^{dc}
G-14	Dejen - Koncher	6.63^{f}	10.40^{g}	0.63^{def}	2.28^{cd}	2425 ^{dce}
G-17	Awebel -Dehguma	11.32^{cdef}	11.03^{fg}	1.07^{bc}	3.22^{ab}	4097^{dc}
G-15	Dejen- Borbor	7.57^{ef}	11.06^{fg}	0.69^{cde}	2.46^{bc}d	2685^{cde}
G-10	Bure – Kebsa	7.36^{ef}	17.53^{abc}	0.42^{ef}	2.54^{bcd}	2082de
G-24	Sinan - Debre Zeit	10.11^{def}	14.51^{cdef}	0.71^{cde}	2.71^{bcd}	2776 ^{cde}
G-48	Sekela - Yedem Mariyam	5.34^{f}	20.40^{a}	0.26^{f}	2.1 ^{d}	1349^{e}
G-38	Banja – Satma	14.71^{abcd}	14.91^{bcde}	0.97^{bc}d	3.15^{ab}	4626^{bc}
G-16	Awebel - Abkejit	11.02^{cdef}	11.66^{efg}	0.96^{bcd}	2.77^{bcd}	3090^{cde}
G-50	Sekela-Menbeta	10.01^{def}	21.06^{a}	0.46^{ef}	2.76^{bcd}	2288^{cde}
G-18	Awebel - Yazera giorgis	21.24^{a}	14.20^{cdef}	1.5^{a}	3.8^{a}	6929^{ab}
G-13	Dejen – Gibgib	17.51^{abc}	16.13	1.06^{bc}	3.12^{ab}	4601^{bc}
G-11	Dejen – Jeva	14.02^{bcde}	14.4^{cdef}	0.98^{bcd}	3.07^{abc}	4420^{dc}
G-5	Dembecha- Senseb Gebriel	19.90^{ab}	14.33^{cdef}	1.32^{ab}	3.28^{ab}	7640^{a}
Kuriftu	Standard Cheak	4.87^{f}	18.5^{ab}	0.26^{ef}	2.16^{d}	1399^{e}
Bishoftu	Standard Cheak	6.51^{f}	11.89^{efg}	0.52^{ef}	2.22^{d}	1695^{e}
LSD(5%)		7.11	3.64	0.39	0.83	23.79
CV (%)		37.42	14.83	29.66	17.62	40.59

Means followed by the same letter(s) within a column are not significantly different at 5% level of significance.

Clove weight

Very highly significant ($p<0.001$) difference was observed between germplasm for average clove weight (Table 2). The largest average clove weight was recorded from germplasm G18 (1.5 g). However, it was not significantly different from G 5 (1.32). The lowest average clove weight (0.26 g) was recorded for G 48.

Bulb diameter

The ANOVA result for the mean bulb diameter of germplasm showed highly significant ($p<0.01$) difference (Table 2 and Appendix Table 1). The result indicated that the germplasm G18 and G45 gave the highest (3.8 and 3.6 cm) diameter of bulb, respectively. The lowest diameter of bulb (2.1, 2.16 and 2.22 cm) was obtained from germplasm G48, standand checks Kuriftu and Bishoftu, respectively.

Total bulb yield

Different germplasm showed very highly significant *($p<0.001$)* variations on yield of garlic per hectar (Table 2). Germplasm G5 gave the highest yield (7640 kg) per hectar. But it was statistically similar with germplasm G18 (6929 kg) yield per hectar followed by germplasm G38 (4626 kg) and G13 (4601 kg) yield per hectar. The lowest yield per hectar (1471 kg/ha) was obtained from germplasm G48 (1349 kg/ha), Kuriftu (1399 kg/ha) and Bishoftu (1695 kg/ha) (Table 2). This is because total bulb yield in garlic is significantly correlated with leaf length ($r=0.89^{***}$), leaf number ($r=0.39^{*}$), bulb weight ($r=0.71^{***}$) and clove weight ($r=0.64^{***}$). The present finding is in agreement with the results of Fikeryohhanis (2005) who reported significant variation for bulb yield due to germplasm difference.

Rust severity

The statistical analysis indicated that varieties have no significant ($p>0.05$) difference on rust severity (Table 3). None of the germplams showed high resistance to rust. The higher disease severity of rust in garlic might be attributed to the availability of favorable temperature and high rain/moisture for disease development during the growing season of the crop. Dixon (1981) reported that rust flourished vigorously at 15°C and 95% relative humidity.

Table 3. Rust severity, shape of bulbs and bulb skin color of bulbs of 16 selected garlic germplasms.

Germplasms code	Collection area	Rust severity (%)	Shape of dry bulb	Bulb skin color
G-45	Sekela – Lijima	84.444	Ciruclar	Creamy
G-14	Dejen – Koncher	80	Ciruclar	Light violet
G-17	Awebel –Dehguma	86.667	Broadly ovate	White
G-15	Dejen- Borbor	84.444	Ciruclar	White
G-10	Bure – Kebsa	83.889	Ciruclar	Violate
G-24	Sinan - Debre Zeit	88.88	Ciruclar	Light violet
G-48	Sekela - Yedem Mariyam	81.667	Ciruclar	Violet
G-38	Banja – Satma	88.333	Heart shaped	White strip
G-16	Awebel – Abkejit	78.889	Broadly ovate	Light violet
G-50	Sekela-Menbeta	76.111	Ciruclar	Violet
G-18	Awebel - Yazera giorgis	89.44	Broadly ovate	White
G-13	Dejen – Gibgib	89.44	Broadly ovate	Creamy
G-11	Dejen – Jeva	86.333	Broadly ovate	Light violet
G-5	Dembecha- Senseb Gebriel	85	Ciruclar	Light violet
Kuriftu	Standard Cheak	78.889	Ciruclar	Creamy
Bishoftu	Standard Cheak	88.889	Ciruclar	White
LSD (5%)		13.41		
CV (%)		9.52		

Means followed by the same letter(s) within a column are not significantly different at 5% level of significance.

Genotypic and phenotypic variances

Genetic variability alone is a prerequisite for response to selection; and knowledge of the extent and nature of phenotypic variability is, then, one of the basic needs for the breeders to manage the crop successfully (Adam, 2006). The amount of genotypic and phenotypic variability that exists in a species is essential in developing better varieties and in initiating a breeding program. Estimated components of genotypic, phenotypic and environmental variances studied are presented in Table 4.

Plant height (45.156 cm), days taken for physiological maturity (80.556), bulb weight (20.183 g), leaf length (16.133) and total bulb yield (27393kg) had larger genotypic variance. Therefore, the larger proportion of phenotypic variance observed on these traits was attributed to the genotypic variance than the environment variance and hence, can be exploited in breeding program. For those traits which had large genetic variance relative to the environmental, accessions may be evaluated adequately by testing few replicates, location and years (Miller et al., 1957).

Leaf number (0.683), clove weight (0.1143 g) and bulb diameter (0.1866 cm) had low genotypic variability when compared with their environmental variability. Miller et al. (1957) also suggested that traits with high environmental variances should be tested in sufficient number of replications, years and location. The partitioning of the total phenotypic variance into its components allows understanding the role of heredity and environment (Mayer and Deshmukh, 2003).

Phenotypic and genotypic coefficient of variability

The results revealed a wide range of variability among 14 garlic genotypes for quantitative traits (Table 4). The phenotypic variance (σ2P) of all traits was higher than the genotypic variance (σ2G); similarly, the phenotypic coefficient of variation (PCV) was also higher than genotypic coefficient of variation (GCV). The highest PCV was recorded for the traits bulb weight (54.33%), clove weight (51.37%) and total bulb yield which were 62.173%. In contrast, the lowest PCV belonged to the characters: days to physiological maturity (8.78%). The GCV ranged from 7.45 (days to physiological maturity) to 47.08% (total bulb yield). The next highest GCV contained the characters clove weight (41.96%). Coefficients of variation studies indicated that the estimates of PCV were slightly higher than the corresponding GCV estimates for all the traits studied, indicating that the characters were less influenced by the environment. Therefore, selection on the basis of phenotype alone can be effective for the improvement of these traits.

Heritability

Heritability is a good index of characters transmission from parents to its progeny. The estimates of heritability

Table 4. Estimation of parameters of variability (genotypic variances, phenotypic variances, environmental variances, genotypic coefficient of variation (GCV %), phenotypic coefficient of variation (PCV %), heritability in broad sense (H %), and genetic advance as percent of mean (GAM) in garlic germlasms for different traits.

Character	Mean	$\partial^2\gamma$	$\partial^2\varepsilon$	$\partial^2\pi$	GCV%	PCV%	H%	GA	GAM
PH	58.98313	45.156	31,65	76.806	11.39	14.85	58.79	10.59	17.95
DM	120.47	80.556	31.39	111.946	7.45	8.78	71.959	15.65	12.99
LL	37.90958	16.133	11.51	27.643	10.59	13.86	58.36	6.308	16.64
LN	9.298750	0.683	0.70	1.383	8.88	12.65	49.38	1.1939	12.84
BW	11.40646	20.183	18.22	38.403	39.38	54.33	52.556	6.697	58.714
CN	14.74375	9.141	4.78	13.921	20.51	25.30	65.66	5.036	34.158
CW	0.805625	0.1143	0.057	0.1713	41.967	51.37	66.72	0.5677	70.38
BD	2.831458	0.1866	0.24	0.4266	15.25	23.06	43.74	0.587	20.73
TY	35.14833	273.93	203.61	477.54	47.089	62.173	57.36	25.77	73.32

PH = Plant height, DM= days to maturity, LL= leaf length, LN= leaf number, BW= bulb weight , CN= clove number, CW= clove weight, BD= bulb diameter, TY= total bulb yield.

Table 5. Simple correlation on growth, yield and rust of garlic germplasms.

Parameter	PH	MD	LL	LN	BW	CN	CW	BD	TY	RS
PH	1	-0.58***	0.89***	0.39*	0.71***	0.02ns	0.64***	0.64***	0.69***	0.21ns
MD		1	-0.41*	-0.22***	0.56***	0.34**	-0.64***	-0.43**	0.61***	-0.41*
LL			1	0.3 *	0.66***	0.24ns	-0.52**	-0.53***	0.6***	0.11ns
LN				1	0.20ns	-0.16ns	0.2Ns	0.17ns	0.14ns	0.12ns
BW					1	0.05ns	0.91***	0.78***	0.92***	0.25ns
CN						1	-0.30*	0.01ns	-0.06ns	-0.12Ns
CW							1	0.74***	0.89***	0.29*
BD								1	0.76***	0.21ns
TY									1	-0.27ns
RS										1

help the plant breeder in the selection of elite genotypes from diverse genetic population. Heritability is classified as low (below 30%), medium (30-60%) and high (above 60%). The characters studied in the present investigation expressed medium to high heritability estimates ranging from 43.74 to 71.959%. Among the yield characters, broad sense highest heritability was recorded by, days to maturity (71.959), clove number (65.66), clove weight (66.72g) and total bulb yield (57.36) whereas, leaf length (58.36 cm) and plant height (58.79 cm) recorded medium heritability value. High heritability values indicated that the characters under study were less influenced by environment in their expression. The plant breeder, therefore, may make his selection safely on the basis of phenotypic expression of these characters in the individual plant by adopting simple selection methods. High heritability indicates the scope of genetic improvement of these characters through selection.

Estimate of genetic advance

The genetic advance is a useful indicator of the progress that can be expected as a result of selecting the pertinent population. Heritability in conjunction with genetic advance would give a more reliable index of selection value (Johnson et al., 1955). Genetic advance was highly expressed as percentage of mean for characters (>20%), for bulb weight (58.714), clove number (34.158) clove weight (70.38) bulb diameter (20.73) and total bulb yield (73.32). Genetic advance was moderate (10-20%) for plant height (17.95), days to physiological maturity (12.99), leaf length (16.64) and leaf number (12.84). No low genetic advance (<20%) was observed.

Correlation

The present study showed the existence of significant and positive associations between yield and yield related parameters (Table 5). Plant height was positively and significantly correlated with leaf length, leaf number, bulb weight, clove weight, total yield per hectare and non-Plant height was non-significantly correlated with plant height. Maturity date was negatively and significantly correlated with leaf length, leaf number per plant and

clove weight. Leaf length was significantly and positively correlated with bulb weight and total yield. Bulb weight was significant and positively correlated with clove number and total yield. Clove number was negatively correlated with clove weight and total bulb yield. Positive correlation was observed between clove weight and total yield. There was a weak correlation between rust severity and, , leaf number and bulb weight. Rust severity was negatively correlated with clove number, maturity date and total bulb yield per hectare.

Conclusion

The results of the present study indicated that germplasms G5, G18, G13 and G38 gave the highest results in all the mentioned parameters due to genotypic difference. This might be due to the fact that germplasm had a good genetic potential which enhanced more cell division and cell elongation, resulting in best performance of germplasms G5, G18, G13 and G38, with outstanding performance for growth and yield characteristics. Future selected germplasms will be tested at multi location for National Variety Trail test and will be disseminated to the producers/end users.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix 1. Key for assessment of Puccinial rust and purple blotch in Garlic (Mohibullah, 1991).

0 to 5 rating scale	Percent severity leaf area infected (LAI)	
	Rust	**Purple blotch**
Highly resistant	1-4	1-4
Resistant	5-10	5-10
Moderately resistant	11-20	11-20
Moderately susceptible	21-50	21-50
Susceptible	51-80	51-90
Highly susceptible	Above 80%	Above 90%