**Research Article** **AJAR (2020), 5:90**


**American Journal of Agricultural Research**
**(ISSN:2475-2002)**

# Genetic Variability, Heritability and Genetic Advance for Yield and Yield Related Traits in Garlic (*Allium sativum L.*) Genotypes

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**ABSTRACT**

Garlic production in most areas of Ethiopia especially in Amhara region is constrained by shortage of varieties, occasional ice storm raining, poor agronomic practice coupled with susceptibility to pests. Forty nine garlic genotypes were evaluated to determine magnitude of genetic variability for bulb yield and yield related traits in garlic accessions recently collected by Debreziet Agricultural Research center and Fogera National Rice Research and Training Center (FNRRTC) from different parts of Ethiopia. The experiment was laid out using 7x7 simple lattice design with two replications at FNRRTC in 2017/18. Data were collected for ten agronomic traits and analysis of variance revealed significant differences ($p<0.01$) among the genotypes for all traits except bulb length and yield per plant. Bulb yield per plant ranged from 1 to 38.35 gram with a mean of 12.4 gram. Moreover, three genotypes (G-17, G-22 and G-47) produced higher yield ranging from 15.7 to 38.35gram than the yield of four check varieties Tseday(G-1), Chefe(G-4), Kurfitu(G-30) and HL(G-36).Ten (20.4%) genotypes were early maturing than the check varieties. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) ranged from 5.1 and 5.4% for days to maturity to 55.5 and 68.9% for yield per plant. All traits had high broad sense heritability while genetic advance as percent of mean (GAM) ranged from 10.0 for days to maturity to 98.4% for neck diameter. Except days to maturity, all characters had high heritability coupled with high GAM which reflecting the presence of additive gene action for the expression of these traits and improvement of these traits could be done through selection.

**Keywords**: Garlic (Allium sativum L.), Genetic advance, Genetic variability, Heritability

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**How to cite this article:**
Dejen Bekis. NGenetic Variability, Heritability and Genetic Advance for Yield and Yield Related Traits in Garlic (Allium sativum L.) Genotypes . American Journal of Agricultural Research, 2020,5:90.

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## INTRODUCTION

Garlic (*Allium sativum* L.2n=16), is one of the most important edible bulbous crop of the world, which belongs to the family Alliaceae and genus Allium (Dejen, 2018). Garlic has a wide area of adaptation and cultivation throughout the world. Today, garlic is grown in temperate and tropical regions all over the world and many varieties have been developed to suit different climates (Dejen, 2018). On global basis, leading producers are China, Korea, Thailand, Spain, Egypt and India. In some countries like China, garlic production exceeds dry onion production (Nonnecke, 1989). Worldwide the area covered by garlic exceeds 1,199,929 ha with a production of 17,674,893tonnes (FAO, 2012). In Ethiopia, 16,411.19 ha of land were covered in garlic cultivation with a production of 159,093.58 tones (CSA, 2014; Dejen, 2018).

Currently, it is spread throughout the country being cultivated under irrigated as well as rain fed condition. Garlic is produced mainly in the mid and high lands of the country. Libokemikem, Debre Tabor, Debrework, Adiet, Ambo, Sinnana and many other areas of Ethiopian highlands produce the bulk of garlic (Getachew and Asfaw, 2000). However, cultivated area and total production of garlic in Ethiopia is very low as compared to world production. (10.47 tonnes/ha is below 50% as compared to its productivity in Uzbekistan (24.80tonnes/ha) and Egypt (24.34 tonnes/ha) (FAO, 2012).

Major cause of low production and productivity of garlic in the country were lack of improved varieties coupled with susceptibility to pests (onion thrips, garlic rust, downy mildew, basal rot, white rot and purple blotch), the nature of propagation, lack of proper planting materials, inappropriate agronomic practices, unbalanced fertilizer use, lack of irrigation facilities, poor storability and lack of proper marketing system (Tewdrose *et al.,* 2014; Mohamed *et al.,* 2014). Among these problems, lack of improved varieties for different agro ecologies of the country is the most serious.

Garlic has been clonally propagated from a longer period, since plant sterility usually precludes crop improvement through cross hybridization that was a major bottleneck for widening genetic variation in garlic. Clonal selection is a major breeding method for garlic which showed high degree of variation in bulb size, color, growth habits, plant height, number and size of the cloves, days to harvesting, resistance to storage capacity, dormancy and adaptation to agro-climatic situations (Singh, 2013). Yield reflects the performance of all plant components and might be considered as the final result of many other traits. i.e. every plant contains an inherent physiological production capacity that operates on energy required for normal plant performance. Not all accessions have the same inherent physiological capacity to yield. Breeders commonly find yield to be a very complex array of plant component interactions and by the manipulation of these genetic systems yield is improved as the result of plant efficiency improvement (Welsh, 1981).

Yield improvement is the ultimate goal in virtually every plant-breeding program. Variability observed among different clones of garlic is due to mutation providing opportunities through natural and human selection for adaptation to various growing environments(Welsh, 1981).The basic pre-requisite for yield improvement is the presence of genetic variability in genetic stocks(Sharma and Saini, 2010). Because of its diverse economic and dietary importance, improving yield of garlic needs to be given top priority. It is, therefore, necessary to study the genetic variability available in the Ethiopian accessions of garlic that new varieties with higher bulb yield and better bulb quality can be developed through selection from this rich source.

## MATERIALS AND METHODS

### Experimental Site Description

The experiment was conducted in the North Western part of Ethiopia at Fogera National Rice Research and Training Center (FNRRTC) during the rainy season of 2017/18. FNRRTC is located in Amhara Regional state, in the North Western part of Ethiopia, 607 km far from Addis Ababa. The experimental site is found at Woreta and located $11^{0}$58' N latitude, 37° 41' E longitude and at an elevation of 1810m above sea level. Based on ten years' average meteorological data, the annual rainfall, and mean annual minimum, maximum and average air temperatures are 1300mm, 11.5°C, 27.9°C and 18.3°C, respectively. The soil type is black *Vertisol* with pH of 5.90 (Dessie and Birhanu, 2017). The main water source for crop production in the study area is rain-fall water. Irrigation water from rivers Rib and Gumara was also used in the off season for production of vegetables as second crop after rice.

**Treatments and Design**

Forty nine genotypes consisting of 45 garlic accessions and four released varieties were included in this study. The accessions were found at FNRRTC and Debreziet Agricultural Research Center. The accession code and its area of collection are listed below (Table1).

The experiment was laid out in a 7x7 simple lattice design with two replications. Plot was 1.5 m wide and consists of six rows each 2 m long. A spacing of 30 *10cm between rows and plants was used. The spacing between plots, blocks and replications was 0.3 m, 0.5 m and 1 m, respectively. Healthy and uniform cloves of each accession was selected and planted on ridges of about 20cm height by hand with a planting depth of 4cm and covered lightly with soil. To increase the nutrient content of the soil, Nitrogen and Phosphorus, fertilizer were applied in the form of urea (46% N) and DAP/Diammonium Phosphate (18%N and 46% P) at a rate of 100Kg/ha and 200 Kg/ha respectively. DAP fertilizer applied at the time of planting whereas urea was applied one third during planting, one-third at active vegetative growth (three weeks after plant emergence) and the rest, five weeks after plant emergence or six weeks just before bulbing. Pesticide and fungicide were applied according to the recommended rates in full collaboration with the protection department. All other non-experimental agronomic practices were applied uniformly to the entire plot as recommended by Getachew *et al., (*2009).

**Data collected**

All agronomic, bulb yield and yield related data were recorded from ten randomly sampled plants in the middle four rows of each experimental unit/plot. However; phenological parameter was taken on plot basis. The collected quantitative traits were days to maturity (DM), plant height (PH) (cm), pseudo stem length (PSL), number of leaves per plant (LN), leaf width (LW) (cm), Leaf length (LL) (cm), neck diameter (ND) (cm), bulb length (BL) (cm), bulb diameter (BD)(cm) and yield per plant (YP)(gram).

## RESULT AND DISCUSSION

**Analysis of Variance**

Analysis of Variance (ANOVA) was carried out for the characters as per the procedure outlined by Gomez and Gomez (1984). The result is presented in (Table2). The mean squares due to accessions were highly significant ($p<0.01$) for most studied traits, except for bulb length and yield per plant, indicating the existence of sufficient genetic variability. There was less coefficient of variation in most of the characters indicating good precision of the experiment. In line with this study, Sandhu *et al.* (2015) reported that the analysis of variance showed significant difference among all the genotypes for all the characters under study. Gaurav *et al*. (2015) found a significant difference in bulb diameter, plant height, leaf number, leaf length and leaf width.

**Range and mean performance of garlic genotypes**

Estimates of range and mean for the characters studied are presented in Table 3. Days to maturity from date of emergence was found to vary from 83 in G-31 to 95 in G-46. Plant height exhibited a wide range of variation across the accessions in that the shortest accession G-17 was 42.5 cm and the tallest G-39 was 68.6cm. Similar to this study Gaurav *et al.* (2015)

reported that garlic displayed great variation for plant height and other morphological characters. The range for number of leaves per plant was 6.9 for G-29 and 11.9 for G-49. Leaf length was ranged from 21cm for G-29 to 42.70cm for G-40. Neck diameter ranged from 0.15cm to 1.05 cm with mean value of 0.6cm. Pseudo stem length varies from 11 to 32.5cm with mean value of 21.7cm. Leaf width showed a wide range of variation from 0.5 cm for G-3 to 1.5 cm for G-49. Bulb diameter varied across the accessions in that it was narrow for G-41 (8.1 cm) and relatively wide for G-47 (37.8 cm). Bulb length was found to vary from 11.3cm in G-44 to 36cm in G-36. Yield per plant varies from 1.0 gram for G-42, G-44 and G-48 to 38.35gram for G-22 with a mean value of 12.4gram. Out of the tested genotypes in this study, only one genotype G-22 (2 %) were found to give high yield (>25 g/plant); medium yield(15g-25g/plant) were found from two genotypes G-17 and G-47(4%) and 94% of the genotypes were given low yield (<15g/plant). Most genotypes damaged due to severity of purple blotch couple with occurrence of ice storm rain at its active vegetative stage, of which 94% of it grouped under low yielder in this study. In harmony with this study, Sharma *et al*. (2016) reported that yield of garlic showed a wide variation which ranged from 4.94 - 52.95g. Abebech (2013) also reported that garlic genotypes varied in most of studied characters like days to maturity, leaf length, and leaf width, leaf number per plant, neck diameter and yield per plant. In general, the range and mean in this study suggested the existence of sufficient variability among the tested genotypes for majority of traits studied and considerable potential were found for improvement of garlic.

**Table 1: Description of the garlic genotypes used for this study**

| S.N | Genotypes | Genotype code | Source | Place of collection | |
|---|---|---|---|---|---|
| | | | | Zone | District |
| 1 | Tseday | G-1 | DZARC** | | |
| 2 | G45-1 | G-2 | FARC | South Gondar | Addis Zemen |
| 3 | 041/04 | G-3 | DZARC | East Shewa | Gimbichu |
| 4 | Chefe | G-4 | DZARC** | | |
| 5 | 006/09 | G-5 | FARC | South Gondar | Farta |
| 6 | 052/02 | G-6 | DZARC | East Shewa | Chefedensa |
| 7 | G37-1 | G-7 | FARC | S/Gondar | Libokemikem |
| 8 | 079/06 | G-8 | DZARC | East Shewa | Gimbichu |
| 9 | G49-1 | G-9 | FARC | South Gondar | Libokemikem |
| 10 | 001/09 | G-10 | FARC | South Gondar | Farta |
| 11 | 070/06 | G-11 | DZARC | East Shewa | Gimbichu |
| 12 | 019/09 | G-12 | FARC | South Gondar | Fogera |
| 13 | 058/06 | G-13 | DZARC | East Shewa | Chefedensa |
| 14 | G51-1 | G-14 | FARC | South Gondar | Libokemikem |
| 15 | 127/06 | G-15 | DZARC | East Shewa | Gimbichu |
| 16 | 009/09 | G-16 | FARC | South Gondar | Farta |
| 17 | 009/06 | G-17 | DZARC | East Shewa | Chefedensa |
| 18 | 011/09 | G-18 | FARC | South Gondar | Estie |
| 19 | 025/04 | G-19 | DZARC | East Shewa | Gimbichu |
| 20 | 013/09 | G-20 | FARC | South Gondar | DebreTabor |
| 21 | 095/06 | G-21 | DZARC | East Shewa | Chefedensa |
| 22 | G37-2 | G-22 | FARC | South Gondar | Libokemikem |
| 23 | 034/06 | G-23 | DZARC | East Shewa | Gimbichu |
| 24 | G43-2 | G-24 | FARC | North Gondar | Makisegnit |
| 25 | G53-1 | G-25 | FARC | South Gondar | Addis Zemen |
| 26 | 022/04 | G-26 | DZARC | East Shewa | Gimbichu |
| 27 | 012/09 | G-27 | FARC | South Gondar | DebreTabor |
| 28 | G38-1 | G-28 | FARC | North Gondar | Chinchaye |
| 29 | G46-1 | G-29 | FARC | South Gondar | Libokemikem |
| 30 | Kurfitu | G-30 | DZARC** | | |
| 31 | 018/09 | G-31 | FARC | South Gondar | Fogera |
| 32 | 119/06 | G-32 | DZARC | East Shewa | Chefedensa |
| 33 | 008/09 | G-33 | FARC | South Gondar | Farta |
| 34 | 057/02 | G-34 | DZARC | East Shewa | Gimbichu |

| | | | | | |
|---|---|---|---|---|---|
| 35 | 003/09 | G-35 | FARC | South Gondar | Farta |
| 36 | HL | G-36 | DZARC** | | |
| 37 | 020/09 | G-37 | FARC | South Gondar | Farta |
| 38 | 080/04 | G-38 | DZARC | East Shewa | Gimbichu |
| 39 | 014/09 | G-39 | FARC | South Gondar | Gayint |
| 40 | 083/04 | G-40 | DZARC | East Shewa | Chefedensa |
| 41 | G52-1 | G-41 | FARC | South Gondar | Libokemikem |
| 42 | G06-1 | G-42 | FARC | South Gondar | Addis Zemen |
| 43 | 015/06 | G-43 | DZARC | Chefedensa | Gimbichu |
| 44 | 002/09 | G-44 | FARC | South Gondar | Fogera |
| 45 | G47-1 | G-45 | FARC | South Gondar | Libokemikem |
| 46 | 004/09 | G-46 | FARC | South Gondar | Debre Tabor |
| 47 | 091/06 | G-47 | DzARC | East Shewa | Gimbichu |
| 48 | 010/09 | G-48 | FARC | South Gondar | Libkemikem |
| 49 | G40-2 | G-49 | FARC | North Gondar | Dilkana |

DZARC** = Varieties Released by DebreZeit Agricultural Research Center

**Table 2: Mean square of 10 quantitative characters of 49 garlic genotypes evaluated in 2017/18 main cropping season at Woreta, South Gondar, Ethiopia**

| Traits | MSR(df=2) | MSGG(df=49) | MSE (df=42) | CV (%) |
|---|---|---|---|---|
| **DM** | 96.010204** | 23.49256** | 3.316084** | 2.040699 |
| **PH** | 117.263673 | 117.151146** | 23.301562 | 8.956126 |
| **LN** | 31.5444898 | 2.6602976** | 0.6009815 | 8.629321 |
| **LL** | 545.443265 | 77.71125** | 10.764072 | 9.756182 |
| **ND** | 0.15520408 | 0.11626488** | 0.02348154 | 29.38789 |
| **PSL** | 65.960816 | 34.368036** | 8.647804 | 13.5785 |
| **LW** | 0.00826531 | 0.15261905** | 0.02148688 | 14.94822 |
| **BD** | 24.5 | 90.61997** | 9.456497 | 12.24957 |
| **BL** | 151.38 | 61.541964NS | 52.78932 | 31.13386 |
| **YP** | 0.02949 | 73.691131NS | 56.719451 | 101.0904 |

Where,* = significant at (P≤0.05), and **= significant at (P≤ 0.01), MSR = mean Squares of replications, MSG = mean squares of genotypes, MSE = mean squares of error, CV = coefficient of variation, df= degree of freedom, DM = number of days from emergence to physiological maturity, PH= Plant Height, LN= Leaf Number, LL= Leaf length, ND= Neck Diameter, PSL= Pseudo stem Length, LW= Leaf Width, BD= Bulb Diameter, BL= Bulb Length, YP= Yield per plant

**Table 3: Mean for phenology, growth parameters, yield and yield related components**

| Genotype | DM | PH | LN | LL | ND | PSL | LW | BD | BL | YP |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 89 | 45.4 | 8.1 | 33.4 | 0.55 | 13.6 | 0.7 | 20.9 | 21.2 | 3.45 |
| **2** | 87.5 | 45.8 | 7.9 | 31.5 | 0.4 | 13.8 | 0.65 | 16.75 | 24.6 | 6.05 |
| **3** | 91 | 46.9 | 7.2 | 33.8 | 0.35 | 19.6 | 0.5 | 12 | 21.2 | 1.6 |
| **4** | 86.5 | 49 | 7.8 | 28.4 | 0.35 | 20.5 | 0.7 | 21.9 | 21.1 | 5 |
| **5** | 91 | 55.6 | 8.2 | 35.6 | 0.5 | 17.8 | 0.85 | 20 | 18.7 | 2.9 |
| **6** | 88.5 | 47.3 | 7.9 | 33.5 | 0.65 | 14.3 | 0.8 | 23.45 | 23.8 | 2.4 |
| **7** | 92 | 54 | 7.6 | 39.4 | 0.55 | 15.4 | 0.95 | 15.2 | 20.2 | 2.55 |
| **8** | 92 | 50.05 | 8.7 | 35.9 | 0.35 | 17.6 | 0.85 | 24.15 | 26.2 | 5.7 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **9** | 92 | 50.3 | 8.6 | 38.7 | 0.4 | 11 | 0.85 | 12 | 16.1 | 1.05 |
| **10** | 93 | 50.6 | 7.9 | 35.3 | 0.5 | 16.5 | 0.75 | 21.2 | 19.5 | 5.5 |
| **11** | 86.5 | 43.8 | 8.8 | 28.9 | 0.35 | 20.8 | 0.95 | 27.85 | 20.3 | 6.2 |
| **12** | 85.5 | 57.2 | 9.2 | 35.6 | 0.4 | 21.8 | 0.8 | 28.25 | 24.9 | 7.5 |
| **13** | 87.5 | 46.9 | 8.2 | 28.9 | 0.25 | 21.7 | 0.7 | 26.1 | 24.4 | 7.9 |
| **14** | 84 | 42.5 | 8 | 28 | 0.35 | 19.4 | 0.85 | 25.9 | 24.8 | 6.6 |
| **15** | 86.5 | 50.5 | 8.6 | 31.5 | 0.3 | 20.4 | 0.9 | 26.65 | 26.9 | 7 |
| **16** | 84 | 50 | 9.2 | 26.5 | 0.25 | 25.3 | 0.8 | 26.2 | 22.1 | 6.2 |
| **17** | 84 | 42.5 | 8.1 | 24.1 | 0.3 | 21.7 | 0.85 | 24.7 | 23.3 | 23.9 |
| **18** | 92 | 53.4 | 9.1 | 39.3 | 0.6 | 16.9 | 0.95 | 21.7 | 29.3 | 5.25 |
| **19** | 91 | 57.3 | 9.2 | 34.7 | 0.5 | 18.2 | 0.95 | 24.35 | 29.1 | 7.05 |
| **20** | 84 | 50.9 | 9 | 26.8 | 0.3 | 24.3 | 0.85 | 26 | 22.6 | 6.5 |
| **21** | 90 | 49.1 | 9.1 | 33 | 0.6 | 17.7 | 0.8 | 28.15 | 20 | 6.7 |
| **22** | 89 | 52.8 | 9.6 | 34.9 | 0.5 | 25 | 1.3 | 31.95 | 26.2 | 38.35 |
| **23** | 84 | 46.3 | 8.1 | 24.5 | 0.2 | 22.8 | 0.65 | 24.05 | 21.1 | 4.7 |
| **24** | 89 | 54.4 | 9.1 | 33.2 | 0.45 | 21.8 | 1.35 | 27.8 | 25.2 | 7.9 |
| **25** | 84 | 43.6 | 8 | 23.8 | 0.15 | 24.8 | 0.7 | 26.15 | 24.9 | 6.4 |
| **26** | 88.5 | 50.8 | 7.7 | 26.3 | 0.2 | 25.7 | 0.8 | 29.95 | 23.3 | 7.1 |
| **27** | 84 | 46.7 | 7.6 | 24.6 | 0.25 | 24.8 | 0.7 | 28.7 | 24.1 | 6.9 |
| **28** | 84 | 45 | 8.2 | 24.2 | 0.3 | 24.3 | 0.65 | 26.95 | 22.5 | 6.9 |
| **29** | 84 | 43.6 | 6.9 | 21 | 0.25 | 22.1 | 0.55 | 25.6 | 20.6 | 5.7 |
| **30** | 87.5 | 53.5 | 9.2 | 28.3 | 0.4 | 25.2 | 1.35 | 28.5 | 28.4 | 9.3 |
| **31** | 83 | 46.65 | 7.7 | 24 | 0.25 | 25.6 | 0.8 | 28.3 | 23.1 | 7.8 |
| **32** | 90 | 54.8 | 9.2 | 37.3 | 0.45 | 21.6 | 1.1 | 29.6 | 29.8 | 9 |
| **33** | 90 | 54.6 | 9.5 | 30.7 | 0.5 | 24.2 | 1.3 | 33.6 | 29.3 | 11.95 |
| **34** | 89 | 55.8 | 9.1 | 32.8 | 0.6 | 22.6 | 1.35 | 31.45 | 25.1 | 10.7 |
| **35** | 91 | 61.2 | 11 | 39.7 | 1.05 | 21.9 | 1.45 | 31.8 | 34 | 9.75 |
| **36** | 92 | 59.7 | 9.9 | 36.1 | 0.7 | 26.5 | 1.15 | 33.3 | 36 | 13.7 |
| **37** | 92 | 56.8 | 8.4 | 40.5 | 0.65 | 14.5 | 0.85 | 21.65 | 31.7 | 6.35 |
| **38** | 89 | 60.3 | 9.7 | 32.5 | 0.6 | 24.6 | 1 | 26.55 | 31.8 | 8.7 |
| **39** | 93 | 68.6 | 10.8 | 40.6 | 0.95 | 27.7 | 1.25 | 28.1 | 22.9 | 5.9 |
| **40** | 94 | 64.3 | 10.5 | 42.7 | 0.9 | 22.4 | 1.3 | 29.5 | 12.4 | 1 |
| **41** | 94 | 66.2 | 10.8 | 41.8 | 1 | 24.7 | 1.25 | 8.1 | 12.3 | 7.5 |
| **42** | 92 | 66.1 | 10.2 | 42 | 0.8 | 23.3 | 1.2 | 8.1 | 11.9 | 1 |
| **43** | 93 | 68.1 | 10.1 | 42.1 | 0.9 | 26.7 | 1.45 | 35 | 22 | 9.45 |
| **44** | 94 | 67.1 | 10 | 41.9 | 0.9 | 21.9 | 1.05 | 19.8 | 11.3 | 1 |
| **45** | 93 | 64.3 | 9.4 | 42 | 1 | 25.2 | 1.5 | 33.9 | 24.7 | 8.25 |
| **46** | 95 | 66.3 | 11.7 | 42.4 | 0.9 | 22.7 | 1.15 | 30.9 | 22.6 | 8.9 |
| **47** | 89 | 60.5 | 10.8 | 32 | 0.45 | 32.5 | 1.5 | 37.8 | 31.9 | 15.7 |
| **48** | 93 | 58.3 | 8.7 | 42.2 | 0.5 | 20.8 | 0.85 | 8.1 | 12.7 | 1 |
| **49** | 94 | 65.6 | 11.9 | 40.9 | 0.95 | 27 | 1.5 | 31.5 | 21.4 | 7.15 |
| **max** | 95 | 68.6 | 11.9 | 42.7 | 1.05 | 32.5 | 1.5 | 37.8 | 36 | 38.35 |
| **min** | 83 | 42.5 | 6.9 | 21 | 0.15 | 11 | 0.5 | 8.1 | 11.3 | 1 |

DM = number of days from emergence to physiological maturity, PH= Plant Height, LN= Leaf Number, LL=Leaf length, ND=Neck Diameter, PSL= Pseudo stem Length, LW= Leaf Width, BD= Bulb Diameter, BL= Bulb Length,

YP= Yield per plant in gram

**Estimation of phenotypic (PCV), genotypic (GCV) coefficients of variation, heritability ($h^2$) in broad sense and expected genetic advance (GA)**

The extent of variability to all studied quantitative traits for different garlic genotypes were measured in terms of range, variance, genotypic coefficient of variations (GCV), phenotypic coefficient of variations (PCV), along with heritability ($h^2$), genetic advance and genetic advances as percent of mean(Table 4). All studied traits showed considerable amount of variation. PCV and GCV values showed a slight difference which indicating lesser influence of the environmental factors. This observation was agreed with the foundation of Sharma *et al.* (2016) in garlic, Fasika (2004) in shallot and Abayneh (2001) in onion. A very narrow difference between PCV and GCV was observed in characters like days to maturity, plant height, leaf length and pseudo-stem length, which indicated less influence of the environmental factors in determining such traits. High phenotypic and genotypic coefficient of variation (>20%) was observed for leaf length (26.2, 25%), neck diameter (52.3, 49.9%), pseudo-stem length (27.1, 26.5%), leaf width (39.8, 37.6%), bulb diameter (37.9, 35.9%), bulb length (33.6, 24.30%) and yield per plant (68.9, 55.5%). Moderate PCV and GCV values were recorded for plant height and leaf number. However, days to maturity had low genotypic and phenotypic coefficient of variations. Similar results were found in some important traits by Abebech(2013) and Sharma *et al*.(2016).Wide difference between PCV and GCV showed sensitiveness to environmental fluctuations whereas narrow difference indicated less environmental interference on the expression of these traits. The traits that showed high PCV and GCV would be effective and offer good opportunity for crop improvement through selection. Garlic displays great morphological diversity even a single garlic accession frequently showed a high degree of phenotypic plasticity that dependent up on soil type, moisture, latitude, altitude and cultural practices. Existence of natural variation, even in respect of the plant part has its own economic importance and suggested the possibility of garlic improvement (Abebech, 2013).

**Table 4: Phenotypic (PCV)and genotypic (GCV) coefficients of variation, phenotypic ($\sigma^2 p$) and genotypic($\sigma^2 g$) variances, heritability ($h^2$),genetic advance(GA) and genetic advance as percent of mean for 10 traits in 49 garlic genotypes at Woreta, Ethiopia during 2017/18**

| Traits | Mean | Min | Max | $\sigma^2 p$ | $\sigma^2 g$ | PCV (%) | GCV (%) | $h^2$ (%) | GA | GAM (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| DM | 89.2 | 84.0 | 95.0 | 23.5 | 21.1 | 5.4 | 5.1 | 89.6 | 9.0 | 10.0 |
| PH | 53.9 | 42.5 | 68.6 | 117.2 | 115.6 | 20.1 | 19.9 | 98.7 | 22.0 | 40.9 |
| LN | 9.0 | 6.9 | 11.9 | 2.7 | 1.8 | 18.2 | 15.0 | 68.3 | 2.3 | 25.6 |
| LL | 33.6 | 21.0 | 42.7 | 77.7 | 70.8 | 26.2 | 25.0 | 91.1 | 16.6 | 49.3 |
| ND | 0.6 | 0.2 | 1.1 | 0.1 | 0.1 | 52.3 | 49.9 | 91.1 | 0.6 | 98.4 |
| PSL | 21.7 | 11.0 | 32.5 | 34.4 | 32.8 | 27.1 | 26.5 | 95.5 | 11.5 | 53.3 |
| LW | 1.0 | 0.5 | 1.5 | 0.2 | 0.1 | 39.8 | 37.6 | 88.8 | 0.7 | 73.0 |
| BD | 25.1 | 8.1 | 37.8 | 90.6 | 81.1 | 37.9 | 35.9 | 89.4 | 17.6 | 70.0 |
| BL | 23.3 | 11.3 | 36.0 | 61.5 | 32.1 | 33.6 | 24.3 | 52.2 | 8.4 | 36.2 |
| YP | 12.4 | 1.0 | 38.4 | 73.7 | 47.8 | 68.9 | 55.5 | 64.9 | 11.5 | 92.3 |

DM = number of days from emergence to physiological maturity, PH= Plant Height, LN= Leaf Number, LL= Leaf length, ND= Neck Diameter, PSL= Pseudo stem Length, LW= Leaf Width, BD=Bulb Diameter, BL= Bulb Length, YP= Yield per plant

Except bulb length all studied traits have high heritability in broad sense value which ranged from 52.2-98.70%. High value of heritability was recorded for plant height (98.7%) followed by pseudo-stem length (95.5%), leaf length (91.1%), neck diameter (91.1%), days to maturity (89.6%), number of leaves per plant (68.3%), bulb diameter (89.4%), leaf width (88.8%) and yield per plant (64.9%). The traits with high heritability were less affected by environmental fluctuations and selection based on phenotypic performance would be reliable. This investigation is in consonance with the observations of Singh *et al*. (2012) and Samaptika *et al*. (2014).

The heritability estimates along with genetic advance are more useful than the heritability values alone for selecting the best individual. The genetic advance as percent of mean ranged from 10 to 98.4. High estimates of genetic advance was showed by neck diameter (98.4%) followed by yield per plant (92.3%), leaf width (73.0%), bulb diameter (70.0%), pseudo-stem length (53.3%),leaf length(49.3),plant height(40.9%) and bulb length(36.2), and the rest two traits leaf number and days to maturity showed moderate to low genetic advance. High values of heritability, GCV and genetic advance as percent of mean was observed for leaf length, neck diameter, pseudo-stem length, leaf width, bulb diameter, bulb length and yield per plant, suggesting that all these traits are genetically controlled by additive gene action (Singh *et al*.,2012) and can be improved through mass selection and family selection. However, days to maturity had high heritability coupled with low genetic advance as percent of mean with low GCV which suggested that this trait was governed by non additive gene action and has high genotype × environment interaction. The values of heritability, GCV and genetic advance as percent of mean for most studied traits were agreed with the finding of Sharma *et al*. (2016).

## CONCLUSION

Garlic production in most areas of Ethiopia is constrained by lack of improved varieties coupled with susceptibility to pests (onion thrips, garlic rust, downy mildew, basal rot, white rot and purple blotch), the nature of propagation, lack of proper planting material, inappropriate agronomic practices, and unbalanced fertilizer use, lack of irrigation facilities, poor storability and lack of proper marketing system. Among these problems, lack of improved varieties coupled with susceptibility to pests is the most serious for farmers of Fogera and surrounding districts in South Gondar, Ethiopia. Information on the extent and pattern of genetic variability from collected garlic accessions is essential to design breeding strategies in garlic improvement. To generate such information 49 garlic genotypes obtained from Debreziet Agricultural Research Center and Fogera National Rice Research and Training Center (FNRRTC) were evaluated using 7x7 simple lattice design at FNRRTC experimental site during 2017/2018 main cropping season. The data generated from the experiment were subjected to analysis of variance, computation of genotypic and phenotypic coefficients of variations, estimations of heritability in broad sense and expected genetic advance. Except bulb length and yield per plant, analysis of variance showed highly significant difference among the tested genotypes for all characters studied. GCV and PCV values ranged from 5.1 and 5.4% for days to maturity to 55.5 and 68.9% for yield per plant, respectively. Moderate GCV values were recorded for plant height and leaf number. GCV and PCV were high for leaf length, neck diameter, pseudo-stem length, leaf width, bulb diameter, bulb length and yield per plant. High GCV coupled with high heritability and high genetic advance as percent of mean was observed for leaf length, neck diameter, pseudo-stem length, leaf width, bulb diameter, bulb length and yield per plant. These characters are governed by additive genes and selection will be rewarding for improvement of such traits. This will help to increase the chance for selecting and developing high yielding and pest resistance garlic varieties. The current findings must be further studied over years and locations to confirm the genotypes performance for yield and pest reaction.

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