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# Genetic Variability, Heritability and Genetic advance of Growth and Yield Components of Garlic (Allium sativm L.) Germplasms

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**Abstract**
Thirty six garlic genotypes were evaluated at Debre Markos University College of Agriculture and Natural Resources research field during 2015 for seven quantitative traits to estimate the nature and magnitude of variability for yield and yield related characters with the help of genetic parameters. The experiment was arranged in simple lattice design with two replications. The analysis of variance revealed that there were highly significant ($p<0.01$) differences among the germplasms for most of the characters. The higher phenotypic variance (490.4) was obtained from total bulb yield and clove number (115.3). Plant height (19.81), Clove number (55.83), and Total bulb yield (290) had larger genotypic variance. High genotypic coefficient of variation (31.69%) was recorded from clove weight, clove number (23.1%), bulb weight (28.86%) and total bulb yield (28.87%). The lowest GCV was recorded from leaf number (5.71%). Medium heritability estimates ranging from (22.82 %) to (59.16 %). Among the yield characters, medium heritability was recorded by Plant height (31.5%), leaf length (43.85%), and clove weight (49.87%) clove number (48.4%), Bulb weight (59.16) and Total bulb yield (59.13). There is positive correlation of yield and yield related parameters. Generally, the present study indicated that the presence of the presence of diversity between germplasms to exploit the genetic improvement of the garlic crop through hybridization and simple selection methods.
**Keywords:** *Heritability, GCV, PCV, Genetic advance;*

## 1. Introduction

Garlic (*Allium sativum* L.) is the second most widely cultivated (next to onion) (Brewster, 1994). It's used long ago as vegetable and spice for flavoring a variety of Ethiopian local dishes among different ethnic groups (Alemu, 1998). Besides it's used as traditional medicine for relief from any painful conditions happened inside our 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). Garlic as a spice is utilized in both fresh and dehydrated form in the food industry. In Ethiopia, garlic is used in preparing foods, particularly some kinds of stew and in making dried foods for storage (Edwards *et al.*, 1997). The world average yield of garlic is about 10 - 19 tons per hectare (FAO, 2001). In Ethiopia, the total area under garlic production in 2006/07 reached 9,266 hectares and the production is estimated to be over 683,000 quintals annually (MoARD, 2007). Because of its diverse economic and dietary importance, improving its yield need to be given top priority in the breeding work. Hence, considering garlic as one of the potential vegetable crop for consumption as well as for market, it is imperative to increase its productivity along with desirable attributes through genetic manipulation. In great efforts have been made in the selection and breeding of locally adapted cultivars and the development of cultural techniques (Rabinowitch and Brewster, 1990).

The basic pre-requisite for yield improvement is the presence of genetic variability in genetic stock and knowledge of inheritance and inter-relationship of the yield components, along with their relative influence on each other (Sharma and Saini**,** 2010). Information on the variability and correlation between agronomic characters of different accessions with their yield are important for supporting breeding program of the plant (Hakim, 2008). In addition, knowledge of the nature of association of bulb yield with yield contributing characters is necessary for yield improvement through selection of better varieties (Haydar *et al.,* 2007).

Variability is a touch-stone to the breeders to evolve high yielding varieties through selection, either from the existing genotypes or from the segregates of a cross. Hence, the genetic information on yield and yield contributing characters of the crop species need to be properly assessed for its improvement (Alam *et al*., 2010**)**.

Production and productivity does not depend only on area and cultural practices but also on the genotypes of the crop and environmental conditions (Lawande *et al.,* 2009). Research to improve the productivity of garlic has been underway through development of varieties using germplasm collected from major garlic producing areas of Amhara region of the country. The collected germplasms has not been characterized and evaluated. This study was conducted to investigate the genetic variability in the collected germplasms thereby estimating the different genetic parameters of quantitative characters in garlic.

## 2. MATERIALS AND METHODS

**Experimental Site** - The experiment was conducted at Debre Markos University, Ethiopia during 2015. Debre Markos University is geographically located at about $10^0 21^1$ latitude North and $37^0 43^1$ longitude East; its elevation is estimated to be 2509 meter above sea level. The annual average temperature is $18.5^0$C while the maximum and minimum recorded temperature being $24^0$c and $4^0$c respectively. Annual average rainfall is 1380mm. the general climatic condition of Debre Markos is humid, characterized by Woyna Dega weather condition (Planning and Economic Development of East Gojjam, 2004 cited in Yeshiwas, 2017).

**Experimental Materials -** The material for the present study consisted of 36 garlic genotypes that include two standard checks were used for study. The germplasms were collected from different major garlic producing parts of the region (Table 1).

Table 1. Garlic germplasms used for the study and their site of collection

| No | Germplasm Name | Kebele | Woreda | No | Germplasm Name | Kebele | Woreda |
|---|---|---|---|---|---|---|---|
| 1 | G/1/05 | Abeb Micael | Machacle | 19 | G/28/05 | Fendika | Gozamen |
| 2 | G/5/05 | Sensen Gebriel | Dembecha | 20 | G/29/05 | Gedamawit | Senan |
| 3 | G/6/05 | Lejat | Dembecha | 21 | G/33/05 | Taychibi | Sinan |
| 4 | G/10/05 | Kebesa | Bure | 22 | G/34/05 | Seybeygn | Sinan |
| 5 | G/11/05 | Tirch jeva | Dejen | 23 | G/36/05 | Kuancha | Guagusa shikudad |
| 6 | G/13/05 | Gibgib | Dejen | 24 | G/37/05 | Bata | Banja |
| 7 | G/14/05 | Koncher | Dejen | 25 | G/38/05 | Satma | Kosober |
| 8 | G/15/05 | Borebor | Dejen | 26 | G/39/05 | Akena | Banja |
| 9 | G/16/05 | Abkesit | Awebel | 27 | G/42/05 | Wunbiry | Tilili |
| 10 | G/17/05 | Denguma | Awebel | 28 | G/43/05 | Washtakidanemihret | Tilili |
| 11 | G/18/05 | Yazera Giorgis | Awebel | 29 | G/45/0 | Lijima | Sekela |
| 12 | G/20/05 | Yejube | Baso Liben | 30 | G/46/05 | Lijima | Sekela |
| 13 | G/21/05 | Simachew dily | Baso Liben | 31 | G/47/05 | Achayta | Sekela |
| 14 | G/22/05 | Dogm | Baso Liben | 32 | G/48/05 | Yedem Mariyam | Sekela |
| 15 | G/23/05 | Yelemelem | Baso Liben | 33 | G/49/05 | Achayta | Sekela |
| 16 | G/24/05 | Debre Zeit | Sinan | 34 | G/50/05 | Menbeta | Sekela |
| 17 | G/25/05 | Kebi | Gozamen | 35 | Bishoftu | Standard Check | Debrezeit |
| 18 | G/27/05 | Balara | Gozamen | 36 | Kuriftu | Standard Check | Debrezeit |

**Experimental Design -** The experiment was carried out in a 6x6 simple lattice design with two replications. Healthy and clean cloves of each germplasm were selected and planted on well prepared plots At planting time, cloves were separated from the bulbs and sorted and graded according to their size category large (2.0-2.5 g), medium (1.5-1.9 g) and small (1.0-1.49 g). The cloves were spaced 10 cm between plants and 30 cm between rows. The space between block and between plots was 1 m and 0.5 m respectively. There were four rows per plot and 10 plants per row with a total of 40 plants per plot. The middle two rows were used for data collection. Agronomic practices were applied per recommended (Getachew *et al*., 2009).

**Data collected -** The data were recorded on the middle twelve plants and the plot averages were used for analysis by adapting IPGRI, 2001). The following parameters were considered for data collection: Plant height (cm): Leaf length (cm): Leaf number per plant: Average bulb weight (g), Number of cloves per bulb: Clove weight (g) and Total bulb yield (q/ha).

**Statistical Analyses -** Data collected for quantitative characters were subjected to analysis of variance (ANOVA) for simple lattice design using proc lattice and proc GLM procedures of SAS version 9.2 (SAS Institute Inc, 2008).The difference between treatments means was compared using LSD at 5% probability levels The genetic parameters, including the 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 (1989) and Johnson *et al.* (1955).

Table 2. Analysis of Variance Table for Simple Lattice Design

| Source of variation | Df | MS | SS |
|---|---|---|---|
| **Replication** | (r-1) | | SSr |
| **Tratment(adj.)** | (t-1) | | SSt |
| **Blocks (adj.)** | r(q-1) | Eb | SSb |
| **Intra block Error** | (q-1)(rq-a-1) | Ee | SSe |
| **Total** | Rq-1 | | Total SS |

**Source: (**Mandefro, 2005).

*SS r = Sum of squares due to replication SS t = Sum of squares due to treatments* ; *SS b = Sum of squares due to blocks SSe = Error sum of squares*

**Estimation of genetic parameters -** The phenotypic and genotypic variances and coefficients of variation were estimated Jim et al (2003) as follows:

***Genotypic variance ($б^2g$)***

$б^2g= [б^2t- б^2e] /r$

Where $б^2t$= mean square of treatment

$б^2e$= error mean square

r= number of replications

***Environmental Variance***

б$^2$e=Error maen square (б$^2$e)

***Phenotypic variance (б$^2$p)***

б$^2$p= б$^2$g + б$^2$e

Where б$^2$p= Phenotypic variance

б$^2$g =Genotypic variance

б$^2$e= error mean square

The ***phenotypic coefficients of variation*** (PCV) were computed as:

$$PCV = \sqrt{\frac{б^2 p}{\bar{x}}} \text{x } 100$$

Where, б$^2$p = phenotypic variance

$\bar{X}$ = mean of the character

The ***genotypic coefficient of variation*** (GC V) was computed as:

$$GCV = \sqrt{\frac{б^2 g}{\bar{x}}} )\text{x } 100$$

Where, б$^2$g = genotypic variance

$\bar{x}$ = grand mean of the character

**Heritability (H):**

Heritability in broad sense for all characters will be computed using the formula by Falconer (1989).

$$\text{Heritability (H)} = \frac{б^2 g}{б^2 p} \text{x } 100\%$$

Where: H= heritability in broad sense

$б^2 p$ = Phenotypic variance

б$^2$g = Genotypic variance

**Estimation of genetic advance (GA)**:

Expected genetic advance for each character at 5% selection intensity will be computed using the methodology described by Johnson *et al.,* (1955)

GA= K. $_{p}$.H

Where GA=expected genetic advance

K = constant (selection differential where K=2.056 at 5% selection intensity

$_{p}$ = phenotypic standard deviation on mean basis

H = heritability in broad sense

Genetic advance as percent of mean will be calculated to compare the extent of predicted advance of different traits under selection, using the following formula.

$$GAM = \frac{GA}{\bar{X}} \text{x } 100\%$$

Where: GAM= genetic advance as percent mean

GA=genetic advance under selection

$\bar{X}$ = Mean of the population in which selection was employed

## 3. RESULTS AND DISCUSSION

**Analysis of variance –** The analysis of variance for all studied characters, except number leafs per plant which is non-significant (*p>0.01*), showed highly significant (p<0.01) differences among the garlic genotypes (Table 3). This indicates to the existence of large variability among genotypes. Generally, the present result indicates the existence of sufficient genetic variability. In line with the present study, Haydar *et al* (2007) reported significant difference in bulb fresh weight and days to harvest in onion which is highly significant differences were reported by Stavelikova (2008) in skin color, bulb cross section (bulb diameter), weight of cloves, and number of bulbils, bulbil weight, plant vigor, leaf diameter (leaf width) and leaf number in garlic. Similar results were also attained by of Abdlkafer-Halmy *et al.* (2011), Jenderek and Yayeh (2005) that significant variations exist within and among families of garlic for bulb and clove weight, number of cloves per bulb, flower stack height, number of cloves per bulb, plant height and days to maturity. Awel *et al.*, 2011 reported the existence of genetic diversity within shallot produced in Ethiopia which is in agreement with present findings. In addition Abebech, 2011 found variability in garlic for tested characters which supports the present result.

 

Table 3. Analysis of variance for seven characters tested by using simple lattice design

| Source of variation | DF | Mean square of characters | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | PH | LL | LN | CW | CN | BW | TBY |
| **Replication** | 1 | 483.38 | 34.725 | 0.482 | 0.013 | 33.120 | 0.023 | 1.06 |
| **Treatment(Adj.)** | 36 | 82.68** | 25.31** | 1.13ns | 0.029** | 171.16** | 17.56** | 780.44** |
| **Block with in reps (adj)** | 10 | 150.44 | 22.02 | 0.8126 | 0.019 | 101.677 | 7.646 | 339.92 |
| **Error** | 24 | 43.066 | 9.88 | 0.7139 | 0.0097 | 59.51 | 4.5055 | 200.43 |

**Mean performance of germplasms -** Table 4 indicate the mean values of growth and yield parameters for garlic (plant height, leaf length, leaf number, clove number, clove weight, bulb weight and total bulb yield ) of 36 garlic germplasms collected from various different areas. From the present study, estimates of plant height, clove weight and total bulb yield exhibited wide range of variation among the germplasms. Germplasm-11(68.33cm), G-23(64.83 cm), G-24(64.5 cm), G-25(62 cm) and G- 38(63.66cm) had the highest plant height and germplasm -18(45.5 cm), bishoftu (44cm) and kuriftu (41.5cm) recorded the shortest plant height among all germplasms. In line with the present study Awale *et al*., (2009) reported that plant height and bulb weight varied significantly among onion accessions.

Germplasm-24 (37.66cm) and G-21 (37.66cm) had the longest leaf length. Similarly, average clove weight per plant, also exhibited wide variations. Germplasm -5, G-11and G13 had largest clove weight (0,58g, 0.63g and 0.57g/plant) respectively. While G-27 had the smallest clove weight (0.15g/plant. the highest bulb weight was also obtained from G- 5 (17.6g/plant) and G-11( 16.13g/plant)while the lowest bulb weight was recorded form G-20 which is 20.319g/plant. Germplasm5, 11 and 13 had the largest bulb yield per hectare (117.35q/ha, 107.53q/ha and 102.65q/ha) respectively. The lowest yield per hectare was recorded from germplasm 20(21.27q/ha) Table3). Germplasms with the highest clove weight and bulb weight had the highest bulb yield.

The results of the present study are in agreement with that of Volk and Stern (2009) and Jenderek and Zewdie (2005) that reported significant variations among the sexually derived families for bulb and clove weight, number of cloves per bulb, bulb shape, flower stalk, height, number of leaves per plant, and days to maturity within and among families of garlic.

Table 4. Mean performance of 36 garlic germplasms for seven quantitative characters.

| No | Germplasm Name | PH | LL | LN | CN | CW | BW | TBY |
|---|---|---|---|---|---|---|---|---|
| 1 | G/1/05 | 54.16 | 32.83 | 8 | 35 | 0.18 | 5.78 | 38.55 |
| 2 | G/5/05 | 52.00 | 28.83 | 8.5 | 26.5 | 0.58 | 17.6 | 117.35 |
| 3 | G/6/05 | 57.33 | 35.66 | 8.83 | 37.25 | 0.29 | 8.32 | 55.45 |
| 4 | G/10/05 | 42.33 | 33.5 | 8.16 | 29.5 | 0.35 | 8.77 | 58.48 |
| 5 | G/11/05 | 68.33 | 28.3 | 8.16 | 30.25 | 0.63 | 16.13 | 107.53 |
| 6 | G/13/05 | 55.5 | 26.5 | 6.16 | 24.5 | 0.57 | 15.4 | 102.65 |
| 7 | G/14/05 | 49.67 | 28.66 | 7.83 | 16.25 | 0.38 | 6.32 | 42.17 |
| 8 | G/15/05 | 47.66 | 26.5 | 8.16 | 23.75 | 0.33 | 7.45 | 49.66 |
| 9 | G/16/05 | 52.5 | 34.16 | 6.16 | 22 | 0.48 | 10.41 | 69.4 |
| 10 | G/17/05 | 54.5 | 31.66 | 7.16 | 21.75 | 0.35 | 7.5 | 50.01 |
| 11 | G/18/05 | 45.5 | 25.16 | 8 | 20.25 | 0.46 | 11.13 | 74.17 |
| 12 | G/20/05 | 55.66 | 32.83 | 7.83 | 27 | 0.21 | 3.19 | 21.27 |
| 13 | G/21/05 | 56.16 | 37.66 | 8.5 | 30.75 | 0.21 | 6.64 | 44.27 |
| 14 | G/22/05 | 53.67 | 36.33 | 8.33 | 37.25 | 0.16 | 6.6 | 43.96 |
| 15 | G/23/05 | 64.83 | 36.16 | 7.83 | 40.75 | 0.22 | 7.09 | 47.25 |
| 16 | G/24/05 | 64.5 | 41.16 | 8 | 25.25 | 0.49 | 8.08 | 53.88 |
| 17 | G/25/05 | 62 | 35.66 | 9.5 | 31.5 | 0.29 | 10.91 | 72.75 |
| 18 | G/27/05 | 57 | 32 | 7.33 | 49 | 0.14 | 10.87 | 72.43 |
| 19 | G/28/05 | 56.5 | 34 | 8.83 | 32.25 | 0.33 | 9.47 | 63.13 |
| 20 | G/29/05 | 57.17 | 33 | 7.66 | 29.5 | 0.23 | 7.55 | 50.35 |
| 21 | G/33/05 | 44.67 | 33.66 | 7.83 | 34.25 | 0.24 | 7.45 | 49.66 |
| 22 | G/34/05 | 59.33 | 33 | 8.33 | 28.5 | 0.24 | 7.56 | 50.36 |
| 23 | G/36/05 | 51.67 | 33.16 | 7.5 | 32.5 | 0.36 | 8.46 | 56.38 |
| 24 | G/37/05 | 61.17 | 34.33 | 7.5 | 44.5 | 0.21 | 6.8 | 45.33 |
| 25 | G/38/05 | 63.66 | 29.5 | 7.5 | 19.25 | 0.38 | 9.06 | 60.4 |
| 26 | G/39/05 | 53.33 | 36.67 | 8.83 | 25 | 0.26 | 5.96 | 39.73 |
| 27 | G/42/05 | 56.67 | 36.67 | 8.5 | 40.5 | 0.21 | 7.22 | 48.17 |
| 28 | G/43/05 | 64.5 | 35.67 | 8.5 | 48.25 | 0.15 | 9.33 | 62.22 |
| 29 | G/45/05 | 54 | 35.16 | 8 | 28 | 0.31 | 7.13 | 47.53 |
| 30 | G/46/05 | 57 | 32.83 | 7.66 | 50.75 | 0.2 | 9.96 | 66.36 |

| No | Germplasm Name | PH | LL | LN | CN | CW | BW | TBY |
|---|---|---|---|---|---|---|---|---|
| 31 | G/47/05 | 60.66 | 35.67 | 9.83 | 63.5 | 0.26 | 14.93 | 99.52 |
| 32 | G/48/05 | 60.16 | 31.5 | 7.83 | 31 | 0.33 | 8.34 | 55.92 |
| 33 | G/49/05 | 58.16 | 35 | 8.16 | 33 | 0.23 | 8.65 | 57.66 |
| 34 | G/50/05 | 60.33 | 33.33 | 9.33 | 43.5 | 0.28 | 10.91 | 72.75 |
| 35 | Bishoftu | 44 | 25.33 | 7.33 | 22.25 | 0.28 | 5.16 | 42.97 |
| 36 | Kuriftu | 41.5 | 28.66 | 7.66 | 28.75 | 0.24 | 6.45 | 34.43 |
| | Mean | 55.51 | 32.8 | 8.03 | 0.31 | 32.34 | 8.85 | 58.99 |
| | CV | 11.82 | 9.58 | 10.51 | 23.84 | 31.82 | 23.97 | 23.66 |

PH= plant height, LL= Leaf length, LN= Leaf number, BW= Bulb Weight, CN= Clove number, CW= Clove weight, TY= Total bulb yield, CV= Coefficient of Variation,

**Genotypic and Phenotypic Variances -** Genetic variability is a measure of the tendency of individual accessions in a population to vary from one another. Variability is different from genetic diversity, which is the amount of variation seen in a particular population. The variability of a trait describes how much that trait tends to vary in response to environmental and genetic influences. Genetic variability in a population is important for biodiversity, because without variability, it becomes difficult for a population to adapt to environmental changes and therefore makes it more prone to extinction. Variability is an important factor in evolution as it affects an individual's response to environmental stress and thus can lead to differential survival of organisms within a population due to natural selection of the fit variants (Burt and Austin, 2000).

Furthermore, phenotypic variability is the total variability, which is observable and consist both genotype and environmental variation. Such variation is measured in terms of phenotypic variation (Singh, 2000). Garlic has phenotypic variation including clove arrangement, maturation date, and number of cloves, clove weight, clove skin tightness, in diverse location within and between cultivar (Baghalin *et al*, 2006).

The result indicated that phenotypic variance ranging in between 0.019and 490.4 for different characters (Table 4). The higher phenotypic variance 490.4 was obtained from total bulb yield and clove number 115.3. Also Plant height (**19.81**), Clove number (**55.83**), and Total bulb yield (**290**) had larger genotypic variance. Therefore, the larger proportion of phenotypic variance observed on these traits was contributed from the genotypic variance than the environment variance and hence, it can be exploited in breeding program. For those traits for which the genetic variance is large relative to the environmental variance, accessions may be evaluated adequately by testing in few replicates, location and years (Miller *et al.,* 1957). Baghalin., (1997) reported that genetic variation of morphological traits viz. Yield, bulb weight, clove weight, clove number, plant height, leaf number ,leaf width and absence or presence of scape. After evaluation of 24 garlic ecotypes collected from main cultivation of Iran Banerjee *et al*. (2002) reported that breeding status of garlic influences bulb to bulb variation

Studies on the genetic variability, heritability and genetic advance in 48 diverse exotic and indigenous collections of ginger showed that a large portion of phenotypic variability was genetic and highly heritable in most of the cases (Mayur and Deshmukh, 2003).

**Estimates of Phenotypic and Genotypic Coefficient of Variability -** The results revealed a wide range of variability among 36 garlic genotypes for quantitative traits (Table 5). The phenotypic variance ($\sigma^2$P) of all traits was higher than the genotypic variance ($\sigma^2$g); similarly, the phenotypic coefficient of variation (PCV) was also higher than genotypic coefficient of variation (GCV).

High genotypic coefficient of variation (31.69%) was recorded from clove weight, clove number (23.1%), bulb weight (28.86%) and total bulb yield (28.87%). The lowest GCV was recorded from leaf number (5.71%). The estimated phenotypic coefficient of variation was ranged from 11.97 % for leaf number to 44.87% for clove weight. High phenotypic variations were high genetic variability for different traits and less influence of environment. Therefore, selection on the basis of phenotype alone can be effective for the improvement of these traits. Kassahuin 2006 reported that high GCV and PCV estimates for bulb weight and bulb yield of garlic. Awel *et al.*, 2011 also reported similar result in shallot that phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV).

**Table. 5** Estimation of mean, range, 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

| Characters | Mean | Range | SE | $^2$g | $^2$e | $^2$p | GCV% | PCV% | H% | GA | GAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 55.514 | 47 | 1.093 | 19.81 | 43.07 | 62.87 | 8.017 | 14.28 | 31.5 | 513.58 | 925 |
| LL | 32.800 | 20 | 0.533 | 7.715 | 9.88 | 17.6 | 8.468 | 12.79 | 43.85 | 378.15 | 1153 |
| LN | 8.036 | 5 | 0.118 | 0.211 | 0.714 | 0.925 | 5.717 | 11.97 | 22.82 | 45.118 | 561 |
| CW | 0.310 | 1 | 0.017 | 0.01 | 0.01 | 0.019 | 31.69 | 44.87 | 49.87 | 14.263 | 4601 |
| CN | 32.347 | 56 | 1.379 | 55.83 | 59.51 | 115.3 | 23.1 | 33.2 | 48.4 | 1068.8 | 3304 |
| BW | 8.852 | 18 | 0.414 | 6.527 | 4.506 | 11.03 | 28.86 | 37.52 | 59.16 | 404.03 | 4564 |
| TY | 58.996 | 118 | 2.759 | 290 | 200.4 | 490.4 | 28.87 | 37.54 | 59.13 | 2692.4 | 4564 |

PH= plant height, LL= Leaf length, LN= Leaf number, BW= Bulb Weight, CN= Clove number, CW= Clove weight, TY= Total bulb yield, CV= Coefficient of Variation

**Estimates of Heritability ($H^2$) in Broad Sense -** A broad-sense heritability estimate provides information on the relative magnitude of genetic and environmental variation in the population. Heritability is classified as low (below 30%), medium (30-60%) and high (above 60%). The characters studied in the present investigation expressed low to medium heritability estimates ranging from 22.82% to 59.16 %. Among the yield characters, broad sense medium heritability was recorded by Plant height( 31.5%), leaf length (43.85%), Clove weight(49.87%) clove number( 48.4%), Bulb weight ( 59.16) and Total bulb yield (59.13). this characters may respond effectively for selection. High to medium heritability values indicate that the characters under study are less influenced by environment in their expression. Whereas, the lowest heritability was obtained from leaf number per plant (22.82%) indicating that limiting scope of improvement of the character through selection. In line with the present finding Madhukar *et al,* 2015 reported that moderate to high heritability estimates for tomato fruit yield. Awel *et al*., 2011 also reported moderate heritability estimate for plant height and leaf number of Shallot. 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 Expected Genetic Advance (GA) -** Heritability in conjunction with genetic advance would give a more reliable index of selection value (Johnson *et al*., 1955). Genetic advance is classified as low (<20%), moderate (10-20%) and high (>20%). Genetic advance was high expressed as percentage of mean for all characters except clove weight

**Correlation Study -** Correlations among traits influence effectiveness of selection (Das *et al*., 2010). The present study showed that, the existence of significant and positive correlation of yield and yield related parameters. Plant height was positively and significantly correlated with leaf length (r=0.43*), leaf number (r=0.29*), clove weight (r=0.32*), and total yield per hectare (r=0.23*). Clove number was negatively correlated with clove weight (r=-0.47***). Positive and significant correlated with bulb weight (r=0.54 ***) and total bulb yield (r=0.54 ***) Table 6.

Table 6. Correlation among different traits in garlic

| | PH | LL | LN | CN | CW | BW | TY |
|---|---|---|---|---|---|---|---|
| PH | 1 | 0.43 *** | 0.29 * | 0.32 * | 0.32 * | 0.01 ns | 0.23 * |
| LL | | 1 | 0.35 ** | 0.33 ** | -0.24 ns | -0.52 ** | -0.15 ns |
| LN | | | 1 | 0.39 *** | -0.19 ns | 0.2 Ns | 0.14 ns |
| CN | | | | 1 | -0.47 *** | 0.2 * | 0.2 * |
| CW | | | | | 1 | 0.54 *** | 0.54 *** |
| BW | | | | | | 1 | 1 *** |
| TY | | | | | | | 1 |

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