Cross Current International Journal of Agriculture and Veterinary Sciences
Abbreviated Key Title: Cross Current Int J Agri Vet Sci
ISSN: 2663-2454 (Print) & Open Access
DOI: https://doi.org/10.36344/ccijavs.2025.v07i01.001

Volume-7 | Issue-1| Jan-Feb, 2025 |

Original Research Article

Assessing Genetic Variability and Heritability in Garlic (*Allium sativum* L.) Genotypes for Bulb Yield and Related Traits

Nimona Fufa[1*], Dasta Tsagaye[1], Awoke Ali[2], Gizaw Wegayehu[1], Demis Fikre[1]

[1]Ethiopian Institute of Agricultural Research, Kulumsa Agricultural Research Center, Asella, Ethiopia
[2]Fogera National Rice Research and Training Center, Wereta, Ethiopia

***Corresponding author:** Nimona Fufa

| **Received:** 26.11.2024 | **Accepted:** 01.01.2025 | **Published:** 03.01.2025 |

Abstract: One of the fundamental goals of plant breeding is to evaluate genetic diversity in crop species, which aids in the development of breeding approaches. Therefore, this field experiment was conducted to assess mean performance, the genetic variability in garlic genotypes on bulb yield and related traits. The field evaluation of thirteen garlic genotypes and one released variety Holetta local (HL) was conducted at Kulumsa Agricultural Research Center using a randomized complete block design with three replications during the main growing seasons of 2020 and 2021. The analysis of variance indicated there were significant differences among the genotypes for all traits except days to physiological maturity in 2020 season, while only some growth and yield traits are significant in 2021 production season. Some of the genotypes GOG-065/18, GOG-057/18, GOG-047/18, GOG-064/18, GOG-068/18, GOG-045/18, and GOG-018/18 had mean performances higher than the standard check variety Holetta local (HL). Highest phenotypic (PCV) and genotypic (GCV) coefficients of variation recorded for total bulb yield tons per hectare and number of cloves per bulb, while the days to physiological maturity had the lowest heritability (h^2b) in broad sense and genetic advance as a percent of mean (GAM), 67% and 33.89% (total bulb yield per hectare) and 1.13% to 0.08% (day to physiological maturity) respectively. High phenotypic and genotypic coefficients of variation coupled with high heritability and genetic advance as percent of mean were observed for total bulb yield tons per hectare number of cloves per bulb and clove weight. Therefore, selection for these characters would be effective for selecting genotypes for future garlic breeding programs.

Keywords: Bulb yield, Genetic variability, GCV, PCV, Mean Performance.

1. INTRODUCTION

Garlic (*Allium sativum L.*) is a bulbous perennial crop cultivated in different temperate and subtropical climates all over the world (Elsharkawy *et al.*, 2021). It belongs to the genus Allium, which includes almost 1008 species distributed in 15 subgenera and more than 70 sections (Friesen *et al.*, 2020, Parreno *et al.*, 2023). After the onion it is the second most widely used cultivated bulb crops in the World (Benke *et al.*, 2021). It is widely grown in Ethiopia's central and highlands, both under irrigation and rain-fed conditions (Martha & Marie, 2019). But, the productivity is low primarily due to a lack of suitable plant material, cultivar with low yield potential, and their sensitivity to various environmental stresses (Dejen *et al.*, 2021; Tesfaye *et al.*, 2021). Garlic has a wide range of genetic diversity; depending on soil type, humidity, latitude, altitude, and cultural practices of its cultivation, even a single garlic accession would have a lot of phenotypic variabilities (Volk *et al.*, 2004; Tesfaye *et al.*, 2021). Natural variations in plant parts, for example, have economic significance and suggest the possibility of garlic improvement (Hoogerheide *et al.*, 2017). In addition, a great number of cultivars have resulted through natural and human selection for adaptation in growing areas (Viana *et al.*, 2015).

The degree of genetic variability in a population (Dejen *et al.*, 2021), which is a universal feature of all species in nature (Hoogerheide *et al.*, 2017), is a key factor in genetic improvement. When selecting genotypes/accessions for yield and related traits, the variability of the genotypes is the most essential component of breeding (Hoogerheide *et al.*, 2017; Tesfaye, 2021). Due to garlic's mode of cultivation, which is usually by clonal propagation, which is an important breeding method and little work has been done on the association between different traits which are

Citation: Nimona Fufa, Dasta Tsagaye, Awoke Ali, Gizaw Wegayehu, Demis Fikre (2025). Assessing Genetic Variability and Heritability in Garlic (*Allium sativum* L.) Genotypes for Bulb Yield and Related Traits. *Cross Current Int J Agri Vet Sci*, *7*(1), 1-8.

prerequisites for executive a selection programme (Singh *et al.*, 2012). 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). The degree of variability is a base for a successful breeding programme. Thus, the information on the native and magnitude of genetic variability present in the genetic stocks, heritability and genetic advance among various traits are of considerable use in selecting the suitable genotypes to include in future breeding programs (khadi *et al.*, 2022)

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). An effective improvement programme in garlic, often based on clonal selection, depends on the availability of sufficient genetic variability in a collection (Gurpree *et al.*, 2013; Kumar *et al.*, 2017). In Ethiopia, various diversity studies involving germplasm collection, characterization, and evaluation have resulted in the release of different improved varieties (EAA, 2021). However, the shortage of high yielding and stable varieties remains a major constraint for the low productivity and production of garlic in the country (Belay *et al.*, 2020). Production and productivity do not depend only on area and cultural practices but also on the genotypes of the crop and environmental conditions (Lawande *et al.*, 2009). Garlic yield is the integration of many variables that affect plant growth during the growing period. 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. Thus, the aim of the study was to assess the extent of genetic variability for bulb yield and yield-related traits of garlic and estimate heritability in a broad sense and expected genetic advance due to selection in garlic genotypes.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The field experiment was conducted at Kulumsa Agricultural Research Center, Southeastern Ethiopia during the rain growing season in 2020 and 2021. KARC is located between latitude and longitude of 8°' to 8° 2' N and 39° 07' to 39° 10' E coordinates. The altitude of KARC is 2200 meters above sea level and the annual minimum and maximum temperature of 10.5 and 22.8 ^{0}C respectively with annual rain fall 832 mm. The rainy season over the sites extends from May through October with soil type classified as clay loam soil with a pH of 6 (Abayneh *et al*., 2003).

2.2 Experimental Materials and Design

A total of 20 garlic accessions/genotypes collected from different major garlic producing parts of Ethiopia, and maintained at Debre Zeit Agricultural Research Centre, including one released variety as standard check were used for the experiment (Table 1). The experiment was laid out as a Randomized Complete Block Design (RCBD) where each genotype was replicated three times. Healthy and normal cloves of each accession were selected and planted on prepared plots of 2 m × 2.4m. Each plot consisted of four rows, with 20 plants per row, and a total of 80 plants per plot with pacing of 20 cm within a plant and 10 cm between plants. The recommended rate of 242 kg NPS ha^{-1} was applied at planting as source of phosphorous and 75 kg N ha^{-1} in the form of Urea in two splits, half rate after full emergence and half rate at the initiation of bulb. Field agronomic practices used were as recommended for the garlic crop (Getachew *et al.*, 2009)

Table 1: List of experimental materials included in the study

Accession code	Accession code	Accession code
GOG-065/18	GOG-075/18	GOG-001/18
GOG-067/18	GOG-018/18	GOG-055/18
GOG-069/18	GOG-068/18	GOG-057/18
GOG-072/18	GOG-059/18	GOG-011/18
GOG-073/18	GOG-061/18	GOG-045/18
GOG-074/18	GOG-047/18	HL*
GOG-058/18	GOG-064/18	

***Sources*: DzARC- DebreZeit Agricultural Research Center, *= a released variety**

2.3 Data Collection

Data collection included determination of days physiological to maturity, plant height, leaf length (cm), leaf width (cm), number of clove per bulb, clove weight (g), clove height (cm), bulb polar diameter (cm), bulb equatorial diameter (cm), total bulb yield (tons per hectare). These were recorded from eight randomly sampled plants in the two central rows of each plot (IPGRI, 2001).

Statistical Analysis

Data collected for quantitative characters were subjected to analysis of variance (ANOVA) using R Statistical software version 4.2.2. (R Core Team 2021). Mean separation was carried out using Duncan's

Multiple Range Test (DMRT) at 5% and 1% level of significance.

Phenotypic and Genotypic Variability

The variability present in the population was estimated by simple measures viz., range, mean, standard error, phenotypic and genotypic variances and coefficient of variations. The phenotypic and genotypic variances and coefficient of variations were estimated according to the following methods suggested by Burton and De vane (1953).

$$\delta_p^2 = \delta_g^2 + \delta_e^2 \quad \delta_g^2 = \delta_t^2 - \delta_e^2/r$$

Where δ_p^2 = Phenotypic variance, δ_g^2 = genotypic variance and δ_e^2 = environmental variance (error mean square); δ_t^2 = mean square of treatment and r = number of replications;

Genotypic coefficient of variation (GCV %) = $\frac{\sqrt{\sigma 2_g}}{\bar{x}}$ *100

Phenotypic coefficient of variation (PCV %) = $\frac{\sqrt{\sigma 2_p}}{\bar{x}}$ *100

Where, V_g = Genotypic variance, V_p = Phenotypic variance, $\bar{x}$ = Grand mean of the character. PCV and GCV were categorized as following: 0-10%: low, 10-20%: moderate, 20% and above high (Sivasubramanian and Menon, 1973).

Heritability in the Broad Sense:

Heritability on plot basis was calculated for each character based on the formula developed by Allard (1960) as: H= $\frac{\delta_g^2}{\delta_p^2} * 100$

Estimated heritability values was classified according to (Singh, 2001) that heritability values greater than 80% were very high, values from 60–79% were moderately high, values from 40–59% were medium and values less than 40% were low.

Genetic Advance:

The Genetic Advance (broad sense) expected under selection assuming the selection intensity of 5% was calculated by the formula suggested by Johnson *et al*., (1955) and Allard (1960):

Gs= (K) (δA) (H)

Where, Gs = expected genetic advance, and K = the selection differential (K=2.06 at 5% selection intensity), δA= phenotypic standard deviation, H = heritability.

Genetic Advance as Percent of Means (GAM):

Genetic advance as percent of mean was estimated (*IPGRIE*, 2001) as follows:

GAM = $\frac{GA}{\bar{x}} * 100$

Where, GA = Genetic advance, $\bar{x}$ =Grand mean; Genetic advance as percent of mean was categorized as 0-10% = Low, 10-20% = Moderate, >20% = High

4. RESULTS AND DISCUSSION

4.1. Analysis of Variance

A homogeneity test was conducted since the experiment was multi-seasonal that needs to be analyzed with combined ANOVA. Homogeneity of error variances assured that the data of both seasons were not similar so that separate data analysis were preferred rather than combined analysis over years. The combined analysis of variance (ANOVA) showed that there was a highly significant difference in garlic bulb yield in almost all traits. Thus, the mean squares from the analysis of variance for all traits of fourteen garlic accessions are presented in Table 2. There was a highly significant difference (P<0.01) among tested accessions for some traits as: plant vigor, pseudo stem length, leaf width, leaf length, clove diameter, and significant difference (P<0.05) for plant height, number of cloves per bulb, clove weight, clove height, bulb equatorial diameter, and total bulb yield, while days to physiological maturity and bulb polar diameter, which had no significant effect in 2020 season. In 2021season plant vigor, plant height, neck thickness and leaf length highly significant difference (P<0.01) and significant difference (P<0.05) for leaf width and bulb equatorial diameter, other treats are non-significant. The highly significant differences indicate the existence of large genetic variability for the characters studied, which shows ample scope for the selection of promising genotypes from the present gene pool for increasing bulb yield. There were less coefficients of variation in most of the characters, indicating good precision in the experiment. These results indicate the presence of variability among the genotypes used for effective selection or vegetable improvement. In line with this study, Abebech *et al.*, (2021), Getaneh *et al.*, (2024), Dixit *et al*., (2021) found variability in garlic genotypes for some characters, which supports the present result.

Table 2: Mean squares from analysis of variance for agronomic and yield traits of twenty Garlic genotypes tested for two years at Kulumsa

Source of variation	Year 2020														
	DF	**V**	**MD**	**PH**	**Nth**	**SHL**	**LW**	**LL**	**NCPB**	**WtC**	**CH**	**CD**	**BPD**	**BED**	**Twt**
Replications	2	0.8	25.87	15.16	0.1	16.2	0.001	0.15	2.4	1.94	0.03	0.08	0.06	0.1	7.69
Genotypes	19	1.37^{**}	35.94^{ns}	23.65^{*}	0.02^{*}	7.77^{**}	0.07^{**}	12.74^{**}	18.66^{*}	0.48^{*}	0.08^{*}	0.03^{**}	0.15	0.19^{*}	6.13^{*}
Error	38	0.44	23.56	10.84	0.01	2.82	0.02	4.18	8.52	0.23	0.04	0.01	0.1	0.1	0.85
Mean		4.60	142.72	68.59	0.96	26.01	1.47	44.48	17.75	1.92	2.42	0.97	3.75	4.18	6.61
CV5 %		14.72	3,41	4.85	14.29	7.18	9.84	4.48	16.15	29.40	8.44	12.71	8.48	7.59	16.55
	Year 2021														
Replications	2	0.61	0.42	128.59	0.09	97.25	1.22	120.95	35.83	0.36	0.01	0.01	2.67	5.26	3.5
Genotypes	19	1.41^{**}	0.82^{ns}	35.46^{**}	0.05^{**}	8.93^{ns}	0.07^{*}	24.25^{**}	123.25^{ns}	0.59^{ns}	0.07^{ns}	0.02^{ns}	0.15	0.19^{*}	7.41^{*}
Error	38	0.4	0.67	10.8	0.02	6.63	0.03	6.51	106.09	0.39	0.05	0.01	0.1	0.1	6.38
Mean		2.97	129.12	59.43	0.88	21.15	1.39	40.98	17.18	1.57	2.13	0.94	3.94	4.27	4.68
CV5 %		21.31	0.64	5.53	14.81	12.18	13.20	6.22	5.99	3.97	11.11	12.13	8.16	7.43	5.38

*and **, significant at $p<0.05$ and $p<0.01$, respectively. ns= non-significant difference, CV (%) = coefficient of variation in percent, DF = degree of freedom, V= Vigorisity, MD=Days to maturity, PH = Plant height (cm), Nth is neck thickness , SHL is pseudostem length, LW is leaf width(cm), LL is leaf length (cm), NCPB is Number of clove per bulb, WtC is clove weight (g), CH is clove height (cm), CD clove diameter (cm), BPD is bulb polar diameter (cm), BED is bulb diameter (equatorial) (cm), TBY is total bulb yield (tons per hectare).

4.2. Estimation of Phenotypic and genotypic coefficient of variation

The phenotypic and genotypic variances have been estimated to determine the extent to which genetic and environmental factors influenced the observed variations. There was a great variation observed for every character that was being studied. Total variability, or phenotypic variability, is observable and is made up of environmental and genotype variation. The results revealed a wide range of variability among twenty garlic genotypes for quantitative traits. The phenotypic variance (δ^2p) of all traits was higher than the genotypic variance (δ^2g). Number of cloves per bulb (111.81) and plant height (8.22) had the highest phenotypic and genotypic coefficients of variation, respectively, whereas the days to clove diameter (0.01) and (0.001) had the lowest phenotypic and genotypic coefficients of variation respectively (Table 3). For each traits, the phenotypic coefficient of variation was higher than the genotypic coefficient in both season. Thus, the higher genotypic and phenotypic coefficients of variation were found for total bulb yield tons per hectare (20.06% & 24.45%), cloves weight (29.37% for PCV respectively, while the lowest GCV and PCV values observed on days to physiological maturity (1.43% & 3.68%) respectively in 2020 season(Table 3).. Number of cloves per bulb (61.54%) and plant vigor (19.44%) had the highest GCV and PCV respectively in second 2021season. High GCV and PCV estimates for garlic bulb weight and bulb yield were reported by Kassahun (2006). The phenotypic coefficient of variation (PCV) was greater than the genotypic coefficient of variation (GCV), which is consistent with findings published by Awel *et al*., (2011). High estimates of genotypic and phenotypic coefficients of variation indicate that certain traits are highly likely to improve through selection, whereas other traits are difficult or nearly impossible to improve through selection. Consequently, the larger proportion of phenotypic variance observed on these traits was contributed by the genotypic variance than the environmental variance, indicating that it can be used for breeding programs (Yebirzaf and Belete, 2017).

4.3. Estimates of Heritability and Genetic Advance

The proportion of genetic and environmental variation in the population can be determined using a broad-sense heritability estimate. The amount of genetic advance that can be expected as a result of phenotypic selection may be precisely estimated using genetic advance and a heritability estimate. Among the characters studied, high heritability estimates was found for total bulb yield (67%), While moderate for plant vigor (42% & 45%), leaf length (41% & 47%), pseudo stem length (37%), leaf width (41%), and plant height (43%), neck thickness (39%) in 2020 and 2021 season respectively. High heritability for the above characters clarified that they were least affected by environmental fluctuations, and selection based on phenotypic performance would be reliable for these traits. This caused by additive gene action, thereby, reflecting the efficiency of selection for the improvement of these traits. The results align with the observations of Singh *et al.*, (2012) and Tsega *et al.*, (2010), high heritability was observed for bulb yield of garlic to moderates for some traits. In general, heritability in the broadest sense suggests that, depending on the phenotypic expression, selection might be successful. The genetic advance varied from 1.13 to 33.89 % as a percentage of the mean in first season and 0.08 to 26.99 % in second season. The total bulb yield (33.89 %) and plant vigor (26.99 %) showed the highest genetic advance as a percentage of the mean, while leaf width (10.97%), weight of cloves (16.15%), number of cloves per bulb (11.37%) and neck thickness (15.32%) showed the moderate. In comparison, traits like days to physiological maturity, plant height, pseudo stem length, leaf length, weight of clove, clove height, clove diameter, bulb polar diameter, and bulb equatorial diameter showed low genetic advance as percentages of the mean. For selecting the best individual, heritability estimates combined with genetic advancement are more helpful than the heritability value alone. For both the total bulb yield per hectare and the number of cloves per bulb, high heritability and high genetic advance were observed. The results of this study align with Haydar *et al*., (2007), Dhal and Brar (2013), Abebech (2013), Bhat *et al.*, (2017), and Bayisa (2021) they reported high heritability and high genetic gain for number of leaves per plant, bulb yield per hectare and clove weight per bulb.

Table 3: Estimate of variability components for twenty garlic genotypes evaluated at Kulumsa for two seasons 2020 & 2021

	Year 2020										
Traits	**Range**		**Mean**	δ_g^2	δ_p^2	s_e^2	**PCV**	**GCV**	H^2	**GA**	**GAM**
	Max	**Min**									
vigor	6.00	3.00	4.60	0.31	0.75	0.44	18.84	12.11	0.42	0.74	16.05
Days to maturity	150.0	114	142.72	4.12	27.69	23.57	3.68	1.43	0.15	1.61	1.13
Plant Height (cm)	76.0	60.8	68.59	4.27	15.12	10.84	5.67	3.01	0.28	2.26	3.29
Neck thickness (cm)	1.38	0.68	0.96	0.002	0.02	0.01	13.43	4.91	0.13	0.04	3.68
Pseudostem length(cm)	31.00	20.00	26.01	1.65	4.47	2.82	8.13	4.94	0.37	1.62	6.19
Leaf width(cm) (cm)	1.86	1.08	1.47	0.02	0.04	0.02	13.08	8.35	0.41	0.16	10.97
Leaf Length(cm)	50.40	38.20	44.48	2.85	7.04	4.18	5.96	3.79	0.41	2.22	4.98
Number of cloves per bulb	27.60	9.00	17.75	3.38	11.9	8.52	19.44	10.36	0.28	2.02	11.37
Weight of cloves (g)	4.40	1.00	1.92	0.08	0.32	0.23	29.37	15.17	0.27	0.31	16.15
Clove height (cm)	2.9	1.94	2.42	0.02	0.06	0.04	9.89	4.99	0.26	0.13	5.21
Cloves diameter(cm)	1.34	0.70	0.97	0.01	0.02	0.02	13.59	7.78	0.33	0.09	9.17
Bulb Polar diameter (cm)	4.36	3.16	3.75	0.02	0.12	0.11	9.24	3.43	0.14	0.09	2.62
Bulb equatorial diameter(cm)	5.16	3.50	4.18	0.03	0.13	0.10	8.66	4.17	0.23	0.17	4.15
Total bulb weight (t ha^{-1})	11.37	3.23	6.61	1.76	2.61	0.85	24.45	20.06	0.67	2.24	33.89
	2021										
vigor	4.00	1.00	2.97	0.33	0.74	0.40	28.85	19.44	0.45	0.80	26.99
Days to maturity	131.0	127.0	129.12	0.05	0.73	0.68	0.66	0.16	0.06	0.11	0.08
Plant Height (cm)	68.60	44.8	59.43	8.22	19.03	10.8	7.34	4.83	0.43	3.88	6.53
Neck thickness (cm)	1.30	0.44	0.88	0.01	0.03	0.02	18.96	11.87	0.39	0.14	15.32
Pseudostem length(cm)	28.2	14.2	21.15	0.77	7.39	6.63	12.86	4.14	0.10	0.58	2.75
Leaf width(cm) (cm)	1.92	0.56	1.39	0.01	0.05	0.03	15.27	7.68	0.25	0.11	7.97
Leaf Length(cm)	50.0	30.0	40.98	5.91	12.42	6.51	8.59	5.93	0.47	3.45	8.43
Number of cloves per bulb	93.2	6.6	17.18	5.72	111.81	106.09	61.54	13.92	0.05	1.11	6.48
Weight of cloves (g)	5.88	0.77	1.57	0.06	0.46	0.39	42.96	16.42	0.15	0.20	12.93
Clove height (cm)	2.78	1.68	2.13	0.01	0.06	0.05	11.79	3.95	0.11	0.06	2.72
Cloves diameter(cm)	1.24	0.68	0.94	0.001	0.01	0.01	12.83	3.35	0.07	0.02	2.00
Bulb Polar diameter (cm)	4.79	2.88	3.94	0.02	0.12	0.10	8.78	3.26	0.14	0.09	2.48
Bulb equatorial diameter(cm)	5.46	3.04	4.27	0.03	0.13	0.10	8.48	4.09	0.23	0.17	4.07
Total bulb weight (t ha^{-1})	21.86	0.78	4.68	0.34	6.72	6.38	55.31	12.51	0.05	0.27	5.83

Where: $\delta^2 p$ =Phenotypic variance, $\delta^2 g$ =Genotypic variance, PCV = phenotypic coefficient of variance, GCV = Genotypic coefficient of variation, H^2= Heritability in broad sense, GA (5%) = genetic advance at 5% selection intensity, GAM (%) = genetic advance as percent mean.

4.4. Mean Performance of Genotypes

The mean performance values for all traits showed a wide range of variation among the twenty garlic genotypes. The study of variance revealed that there was a highly and significant variation among the genotypes in most of traits such as plant vigor, plant height, pseudo-stem length, leaf width, leaf length, bulb equatorial diameter, clove diameter, clove weight, clove height and total bulb yield (Table 4). The genotype GOG-047/18 and GOG-067/18 were had the highest vegetative performance in plant height, leaf length and leaf width among all the others which was non-significant with standard check HL, despite the fact that the minimum mean performance of plant height was recorded in GOG-070/18. Due to the different genetic components of each genotype, there was variation in the vegetative performance, this could be the result of physiological processes that have been triggered by stimulants that have an effect on the plant's growth and metabolism. The outcomes agree with the research conducted by Sandhu *et al*., (2015), Singh *et al*., (2015), and Bhat *et al*., (2017), which revealed there a significant variation in the mean performance of genotypes varied significantly in terms of leaf width and length in garlic. Also, there was a significant variation in clove weight and height among genotypes GOG-067/18, had a significant and maximum clove weight, clove height and clove diameter which results a genotypes to performed better in bulb yield. Highest significant difference in number of clove per bulb was given by genotype GOG-075/18 (24.53), while genotype GOG-069/18 had the lowest mean (14.6) (Table 3). These findings are closely in line with findings of Vatsyayan *et al.*, (2013), Singh *et al.*, (2015), Bayisa (2021, and Kumar *et al.*, (2017), who reported the significant differences was observed between the genotypes on clove length average weight of clove, number of clove per bulb and clove diameter.

The bulb equatorial diameter showed significant differences between the genotypes. Out of all the genotypes, genotype GOG-047/18 had the highest mean bulb equatorial diameter 43.72cm), while genotype G-009/19 had the lowest mean (3.73cm). There was a high significant difference in bulb yield per hectare between the genotypes; G-067/18 had the highest bulb yield (9.63 t ha^{-1}) and GOG-061/18 the lowest mean bulb yield (3.91 t ha^{-1}) in 2020 season, while GOG-057/18 had the highest (9.90 t ha^{-1}) with list mean bulb yield of 1.26 t ha^{-1} was recorded from genotype GOG-064/18 in 2021 season. These results are consistent with the reported significant variation among the genotypes for this character in garlic by Tsega *et al.*, (2011), Vatsyayan *et al.*, (2013), Khar *et al.*, (2015) and Bayisa (2021) are closely aligned with the results obtained.

Table 4: Mean performances of twenty genotypes for bulb yield and other traits evaluated at Kulumsa for two seasons 2020 & 2021

Genotypes	Year 2020													
	DM	V	PH	Nth	ShL	LW	LL	NCPB	WtC	CH	CD	BPD	BED	Twt
GOG-065/18	139.33	4.67	70.87	0.97	27.47	1.39	44.60	16.13	2.20	2.39	1.08	3.73	4.01	7.31
GOG-067/18	142.33	5.33	73.47	1.06	26.6	1.46	47.13	16.27	3.07	2.75	1.14	3.93	4.57	9.63
GOG-069/18	143.33	4.00	66.33	0.98	27.07	1.32	44.27	14.60	2.13	2.43	1.09	3.72	3.99	6.25
GOG-072/18	144.33	4.17	67.03	1.01	25.27	1.56	45.40	19.47	2.20	2.42	0.98	4.01	4.38	6.15
GOG-073/18	145.00	4.00	66.33	1.00	26.13	1.41	43.27	16.80	1.60	2.35	0.95	3.57	3.90	5.22
GOG-074/18	142.67	4.67	71.13	1.03	24.53	1.63	45.47	18.00	2.47	2.55	1.08	3.96	4.49	6.61
GOG-058/18	139.67	4.17	64.06	0.83	24.00	1.25	40.33	14.93	1.67	2.38	1.01	3.51	4.04	5.16
GOG-075/18	147.67	4.33	66.93	1.11	23.93	1.55	44.47	24.53	1.87	2.36	0.88	3.85	4.34	6.81
GOG-018/18	144.67	4.33	69.40	0.95	26.47	1.43	46.00	16.27	1.80	2.37	1.06	3.73	4.24	5.99
GOG-001/18	139.00	4.33	66.93	0.83	25.73	1.29	42.87	17.80	1.47	2.36	0.97	3.68	3.98	6.27
GOG-055/18	144.67	3.67	68.40	0.84	24.73	1.46	43.53	20.27	1.53	2.14	0.86	3.48	3.94	5.21
GOG-057/18	132.33	5.33	66.93	0.98	26.80	1.57	42.00	16.73	2.07	2.44	0.96	3.90	4.24	7.42
GOG-011/18	146.00	4.17	68.73	0.91	25.53	1.35	44.33	20.33	1.67	2.25	0.79	3.55	3.97	5.52
GOG-045/18	143.67	4.33	65.53	0.88	24.73	1.35	43.17	20.47	1.53	2.21	0.87	3.50	4.06	6.23
GOG-059/18	140.00	4.33	67.80	0.87	24.80	1.43	42.40	14.67	1.93	2.41	1.04	3.60	4.09	5.84
GOG-061/18	142.00	4.00	65.73	0.93	23.60	1.31	42.33	18.53	1.27	2.16	0.78	3.38	3.73	3.91
GOG-047/18	142.00	6.00	73.53	0.95	28.20	1.79	46.47	15.47	2.07	2.74	0.98	3.95	4.72	8.96
GOG-064/18	145.67	5.5	69.93	0.95	27.2	1.60	47.07	16.80	2.13	2.65	0.95	4.05	4.35	8.73
GOG-068/18	143.33	4.67	73.87	0.95	27.53	1.56	46.00	16.93	1.87	2.57	0.91	3.66	4.31	8.17
HL(St. Check)	146.67	6.00	68.93	1.11	29.80	1.75	48.67	20.00	1.87	2.43	1.00	4.23	4.34	6.86
LSD (5%)	ns	1.12	5.48	0.23	3.08	0.24	3.29	4.73	0.93	0.34	0.20	ns	0.52	1.81
CV (5%)	3.41	14.72	4.85	14.29	7.18	9.84	4.48	16.15	29.40	8.44	12.71	8.48	7.59	16.55
	Year 2021													
GOG-065/18	129.30	3.33	61.87	0.94	21.60	1.50	41.87	15.20	1.77	2.15	0.95	3.92	4.10	5.44
GOG-067/18	129.30	2.67	55.93	0.79	17.33	1.11	37.33	14.93	1.54	2.11	0.91	4.13	4.66	3.73
GOG-069/18	129.00	2.33	57.87	0.93	19.40	1.10	40.07	15.20	1.44	2.12	0.86	3.91	4.08	3.87
GOG-072/18	128.67	3.67	62.33	0.95	20.93	1.33	41.40	15.73	1.62	2.29	0.94	4.20	4.47	4.56
GOG-073/18	130.00	2.50	59.60	0.82	20.60	1.48	41.73	14.67	1.44	1.96	1.05	3.77	3.98	3.56
GOG-074/18	129.67	2.67	62.00	0.77	20.33	1.45	42.80	42.60	1.42	2.01	0.87	4.15	4.58	4.10
GOG-058/18	129.33	3.00	60.60	0.76	21.93	1.30	41.20	13.67	1.35	2.04	0.86	3.71	4.13	4.40
GOG-075/18	128.67	3.33	57.87	0.85	19.00	1.58	41.67	20.27	1.17	2.08	0.79	4.05	4.43	4.90
GOG-018/18	128.33	3.33	65.80	1.15	22.87	1.53	45.47	15.80	3.16	2.23	0.93	3.93	4.33	5.95
GOG-001/18	128.67	3.00	60.27	0.85	22.33	1.52	41.20	15.27	1.52	2.22	0.99	3.87	4.01	4.48
GOG-055/18	128.67	2.67	57.53	0.83	19.00	1.40	37.80	18.67	1.09	1.89	0.91	3.68	4.03	4.39
GOG-057/18	128.00	2.67	58.07	0.91	20.13	1.37	39.80	13.67	1.65	2.06	0.95	4.09	4.33	9.90
GOG-011/18	129.67	3.00	58.67	1.04	21.40	1.46	41.20	17.13	1.31	1.99	0.91	3.74	4.06	4.26
GOG-045/18	129.33	4.00	60.67	0.92	21.87	1.51	41.73	16.87	1.49	2.19	1.03	3.69	4.15	5.24
GOG-059/18	129.33	2.33	60.20	0.90	23.60	1.51	42.00	14.93	1.37	2.19	1.06	3.79	4.18	3.85
GOG-061/18	129.67	3.00	57.73	0.91	22.20	1.32	39.67	15.73	1.54	2.18	0.90	3.57	3.81	4.87
GOG-047/18	129.33	3.33	59.93	0.95	24.53	1.53	43.93	15.60	1.64	2.47	1.01	4.14	4.81	4.97
GOG-064/18	129.00	1.00	48.60	0.49	20.13	1.07	32.13	9.80	1.77	2.06	1.03	4.25	4.44	5.26
GOG-068/18	129.67	4.00	59.67	0.94	22.67	1.45	42.80	18.47	2.09	2.50	0.96	3.85	4.40	5.68
HL (St. Check)	128.67	3.67	63.33	0.87	21.07	1.40	43.93	19.47	1.08	1.92	0.85	4.42	4.43	4.37
LSD (5%)	1.36	ns	5.43	0.22	ns	0.30	4.22	ns	ns	ns	ns	ns	0.53	3.17
CV (5%)	0.64	21.31	5.53	14.81	12.18	13.20	6.22	5.99	3.97	11.11	12.13	8.16	7.43	5.38

Note: ns= non-significant difference, CV (%) = coefficient of variation in percent, V= Vigorisity, MD=Days to maturity, PH = Plant height (cm), Nth is neck thickness, SHL is pseudostem length, LW is leaf width(cm), LL is leaf length (cm), NCPB is Number of clove per bulb, WtC is clove weight (g), CH is clove height (cm), CD clove diameter (cm), BPD is bulb polar diameter (cm), BED is bulb diameter (equatorial) (cm), Twt is total bulb yield (tons per hectare).

5. CONCLUSION

The analysis of variance in the current experimental study showed that there were highly significant differences in each character's genotype. Total bulb yield showed highly significant variability among the genotypes, ranging from 4.78 to 12.72 t ha^{-1}, with a mean of 7.97 t ha^{-1}. In terms of total bulb yield, the genotypes GOG-065/18, GOG-057/18, GOG-

047/18, GOG-064/18, GOG-068/18, GOG-045/18, and GOG-018/18 had mean performances higher than the mean of the standard check variety (HL), whereas the genotype GOG-073/18 produced lower yields. For every character under present investigation, phenotypic coefficients of variation were generally greater than genotypic coefficients of variation, suggesting that environmental factors in addition to genetic factors influence how characters are expressed. The highest phenotypic coefficient of variation was found for cloves per bulb, clove weight, and bulb yield per hectare. Leaf weight was found to have a moderate PCV; on the other hand, days to maturity, plant height, number of leaves, leaf length, clove height, bulb polarity, and equatorial diameter were found to have low PCV. Both the total bulb yield per hectare and the number of cloves per bulb showed high GCV as a percentage of the mean, along with high heritability and high genetic advance. Additive genes control these characteristics, and improving them will be helpful for selection. This study suggests that selection would be beneficial in bringing out the greatest attributes in garlic due to its high PCV, GCV, heritability, and genetic gain. Since these traits additionally showed sufficient genetic variability, emphasis should be given to them when choosing genotypes during the yield improvement program as good selection criteria to improve bulb yield in garlic through breeding or selection.

REFERENCES

- Abayneh, E., Sahlemedhin, S., & Demeke, T. (2003). Soils of Kulumsa Agricultural Research Center, Soil Survey and Land Evaluation Section, *Technical Paper*, 76.
- Abebech, T. (2013). Genetic variability and character association among bulb yield and yield related traits in garlic (Allium sativum L.) M. Sc. Thesis. *Haramaya, Ethiopia*.
- Allard, R.W. (1960). Principles of Plant Breeding. John Willey and Sons, Inc, New York, 227- 228.
- Awale Degewione, A. D., Sentayehu Alamerew, S. A., & Getachew Tabor, G. T. (2011). Genetic variability and association of bulb yield and related traits in shallot (Allium cepa var. aggregatum Don.) in Ethiopia.
- Batth, G. S., Kumar, H., Gupta, V., & Brar, P. S. (2013). GGE biplot analysis for characterization of garlic (Allium sativum L.) germplasm based on agro-morphological traits. *International Journal of Plant Breeding*, *7*(2), 106-110.
- Bayisa, K. (2021). Genetic Variability and Associations among Bulb Yield and Yield Related Traits of Garlic (Allium sativum L.) Genotypes at Bishoftu Agricultural Research Center, Ethiopia. M.Sc. Thesis, School of Graduate Studies of Haremaya University.
- Bekis, D., Mohammed, H., & Belay, B. (2021). Genetic divergence and cluster analysis for yield and yield contributing traits in lowland rice (Oryza sativa L.) genotypes at Fogera, Northwestern Ethiopia. *International Journal of Advanced Research in Biological Sciences*, *8*(5), 1-11.
- Belay, F., Tekle, G., & Chernet, S. (2020). Evaluation of genotype environment interaction effect on performance of garlic (Allium sativum L.) genotypes in Tigray region, Northern Ethiopia using AMMI and GGE biplot analysis. *African Journal of Agricultural Research*, *16*(5), 691-701.
- Benke, A. P., Krishna, R., Mahajan, V., Ansari, W. A., Gupta, A. J., Khar, A., ... & Manjunathagowda, D. C. (2021). Genetic diversity of Indian garlic core germplasm using agro-biochemical traits and SRAP markers. *Saudi journal of biological sciences*, *28*(8), 4833-4844.
- Burton, G. W., & De Vane, D. E. (1953). Estimating heritability in tall fescue (Festuca arundinacea) from replicated clonal material.
- Dhall, R. K., & Brar, P. S. (2013). Genetic variability, correlation and path coefficient studies in garlic (Allium Sativum L.). *Vegetable Science*, *40*(1), 102-104.
- Dixit, S., Dubey, A. K., Shukla, I. N., Singh, L., & Lal, B. (2021). Genetic Variability, Heritability and Genetic Advance for Bulb Yield and Yield Developmental Traits in Garlic (Allium sativum L.).
- EAA- Ethiopian Agriculture Authority. (2021). Plant variety release, protection and seed quality control directorate report, crop variety register, Addis Ababa, Ethiopia.
- Elsharkawy, G. A., Hegazi, H. H., Azab, E., Gobouri, A. A., & Sayed, S. A. (2021). Assessment of genetic diversity among Egyptian garlic landraces based on morphological characteristics and ISSR markers. *Eur. J. Hortic. Sci*, *86*, 579-589.
- Friesen, N., Smirnov, S. V., Shmakov, A. I., Herden, T., Oyuntsetseg, B., & Hurka, H. (2020). Allium species of section Rhizomatosa, early members of the Central Asian steppe vegetation. *Flora*, *263*, 151536.
- Getachew, T., Eshetu, D., & Tebikew, D. (2009). Guidelines for shallot and garlic production. *Debre-Ziet Agricultural Research Center, Debre-Ziet, Ethiopia*, *6*, 51-67.
- Hakim, L. (2008). Variability and correlation of agronomic characters of mungbean germplasm and their utilization for variety improvement program lukman hakim. *Indonesian Journal of Agricultural Science*, *9*(1), 24-28.
- Haydar, A., Sharker, N., Ahmed, M. B., Hannan, M. M., Razvy, M. A., Hossain, M., ... & Karim, R. (2007). Genetic variability and interrelationship in onion (Allium cepa L.). *Middle-East Journal of Scientific Research*, *2*(3-4), 132-134.
- Hoogerheide, E. S. S., Azevedo Filho, J. A., Vencovsky, R., Zucchi, M. I., Zago, B. W., & Pinheiro, B. J. (2017). Genetic variability of garlic accessions as revealed by agro-morphological traits evaluated under different environments.

- IPGI, E. C. P., & Gr, A. (2001). Descriptors for Allium *(Allium spp.)*. International Plant Genetic Resources Institute.
- Johnson, H. W., Robinson, H. F., & Comstock, R. E. (1955). Estimates of genetic and environmental variability in soybeans.
- Kassahun Tsega, K. T., Akhilesh Tiwari, A. T., & Kebede Woldetsadik, K. W. (2011). Genetic variability among bulb yield and yield related traits in Ethiopian garlic (Allium sativum L.) germ plasm.
- Kassahun, T. (2006). Variability and association among bulb yield and related traits in garlic (Allium sativum L.). M.Sc. Thesis, School of Graduate Studies of Alemaya University.
- Khadi, P., & Hejjegar, S. H. I. (2022). Genetic variability, heritability and genetic advance in garlic (Allium sativum L.) genotypes.
- Khar, S., Kumar, S., Samnotra, R. K., Kumar, M., Chopra, S., Kumar, M., & Gupta, S. (2015). Variability and correlation studies in garlic (Allium sativum L.) germplasm collected from different parts of Jammu. *Indian Journal of Plant Genetic Resources*, *28*(02), 229-236.
- Kumar, K., Ram, C. N., Yadav, G. C., Gautum, D. P, Kumar, P., & Kumar, R. (2017). Studies on variability, heritability and genetic advance analysis for yield and yield attributes of garlic (Allium sativum L.) *International Journal of Current Research in Bioscience and Plant Biology*, *4*, 123-129.
- Lawande, K. E., Khar, A., Mahajan, V., Srinivas, P. S., Sankar, V., & Singh, R. P. (2009). Onion and garlic research in India. *Journal of Horticultural Sciences*, *4*(2), 91-119.
- Mebratu, M., & Mulie, M. (2019). Intra Row Spacing Effect on Growth Performance of Garlic (Allium Sativum (L.)) at Wolaita Sodo Southern Ethiopia. *J Nat Sci Res*, *9*(19), 47-53.
- Melesse, M. G., & Asfaw, A. A. (2024). Trait Correlation and Path Study for Quantitative Traits in Garlic (Allium sativum L.) Genotypes.
- Parreño, R., Rodríguez-Alcocer, E., Martínez-Guardiola, C., Carrasco, L., Castillo, P., Arbona, V., ... & Candela, H. (2023). Turning garlic into a modern crop: State of the art and perspectives. *Plants*, *12*(6), 1212.
- R Core Team. R: A language and environment for statistical computing. Vienna: R Core Team; 2021.
- Sandhu, S. S., Brar, P. S., & Dhall, R. K. (2015). Variability of agronomic and quality characteristics of garlic (Allium sativum L.) ecotypes.
- Sharma, L. K., & Saini, D. P. (2010). Variability and Association Studies for Seed Yield and Yield Components in Chickpea (Cicer arietinum L.). *Research Journal of Agricultural Sciences*, *1*(3), 209-211.
- Shivasubramanian, S., & Menon, M. (1973). Heterosis and inbreeding depression in rice. *Madras Agric.J. 60*, 1139.
- Singh, G., Mishra, D. P., Vimlesh, K., Pandey, D. P., & Singh, S. (2015). Genetic diversity in genotypes of garlic (Allium sativum L.) for growth, yield and its attributing traits. *Biosc. Biot. Res. Comm*, *8*(2), 149-152.
- Singh, R. K., Dubey, B. K., & Gupta, R. P. (2012). Studies on variability and genetic divergence in elite lines of garlic (Allium sativum L.).
- Singh, R. K., Dubey, B. K., Bhonde, S. R., & Gupta, R. P. (2011). Correlation and path coefficient studies in garlic (Allium sativum L.). *Journal of Spices and Aromatic Crops*, *20*, 83-85.
- Sivasubramania, S., & Menon, M. (1973). Heterosis and inbreeding depression in the rice. *Madras Agric. J.*, *60*, 11-39.
- Tesfaye, A. (2021). Genetic variability, heritability, and genetic advance estimates in garlic (*Allium sativum*) from the Gamo Highlands of Southern Ethiopia. *International Journal of Agronomy*, 3171642. https://doi.org/10.1155/2021/3171642
- Tesfaye, A., Mijena, D. F., Zeleke, H., & Tabor, G. (2021). Genetic variability and character association for bulb yield and yield related traits in garlic in Ethiopia. *African Crop Science Journal*, *29*(2), 293-308.
- Tesfaye, A., Mijena, D. F., Zeleke, H., & Tabor, G. 2021. Genetic variability and character association for bulb yield and yield-related traits in garlic in Ethiopia. *African Crop Science Journal*, 29(2), 293–308. https://doi.org/10.4314/acsj.v29i2.8
- Tsega, K., Tiwari, A., & Kebede, W. (2010). Genetic variability, correlation and path coefficients among bulb yield and yield traits in Ethiopian garlic germplasm. *Indian J. Hort*, *67*(4), 489-499.
- Viana, J. P. G., Pires, C. D. E. J., Pinheiro, J. B., Valente, S. E. D. S., Lopes, Â. C. D. E. A., & Gomes, R. L. F. (2015). Divergência genética em germoplasma de alho. *Ciência Rural*, 46, 203–209. https://doi.org/10.1590/0103-8478cr20130988
- Volk, G. M., Henk, A. D., & Richards, C. M. (2004). Genetic diversity among US garlic clones as detected using AFLP methods. *Journal of the American Society for Horticultural Science*, 129(4), 559–569. https://doi.org/10.21273/JASHS.129.4.0559
- Yebirzaf, Y., & Belete, N. (2017). Genetic Variability, Heritability and Genetic advance of Growth and Yield Components of Garlic (Allium sativm L.) Germplasms. *Journal of Biology, Agriculture and Healthcare*, *7*(21), 84-91.