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RESEARCH ARTICLE

Performance Evaluation of Garlic (*Allium Sativum* L.) Varieties in West Arsi Zone, Ethiopia

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ABSTRACT

Garlic is grown worldwide in all temperate to subtropical and tropical hilly areas as an important spice and medicinal plant. Ethiopia, with its diversified agroecological conditions, is suitable for garlic production. However, its production and productivity are very low due to many biotic and abiotic factors. It was also indicated that a lack of improved varieties and garlic rust are the major contributing factors responsible for the low production and productivity of garlic in Ethiopia. It is, therefore, crucial to identify appropriate cultivars with high productivity and quality suiting to target study environments. The current study was therefore initiated with the intention of evaluating and selecting high-performing garlic varieties under the conditions of West Arsi Zone and other similar agroecologies. Three garlic varieties, namely, Holeta (HL), Kuriftu, and Tseday 92, were evaluated using a randomized complete block design with three replications at three locations for two consecutive cropping seasons under rainfed conditions. The analysis of variance of an individual environment revealed that the total bulb yield showed a significant difference ($P \leq 0.05$) at all test environments. The combined analysis of variance for the total bulb yield also showed a significant difference ($P \leq 0.05$) among the varieties and locations. The mean bulb yield values of the tested varieties averaged across the environments showed that the variety HL was found to have the highest mean bulb yield (6.99 ton/ha), followed by the variety Kuriftu with its mean bulb yield of 6.36 ton/ha. The varietal effect contributed more to varying the total bulb yield performance. However, the presence of blocking and/or replicating within the testing environment could not influence more to the total bulb yield of the tested garlic varieties. In general, the variety HL was found to be the most adaptable variety for the present ecology of study areas.

Key words: Garlic, high-yielding varieties, locations, total bulb yield

INTRODUCTION

Garlic (*Allium sativum* L.) is one of the main *Allium* vegetable crops known worldwide with respect to its production and economic value. It belongs to the family *Alliaceae*, genus *Allium*, and originated in Central Asia.[1] It is the second most widely cultivated *Allium* after onion and has been used throughout history for culinary and medicinal purposes.[2] Garlic has a higher nutritive value than other bulb crops.[3] Keeping in view of its medicinal value, especially the allicin of garlic, which has antibacterial properties[4,5]; garlic is widely used in all households throughout the year. It is used for seasoning in many foods as well as for medicinal purposes.[6]

Garlic is grown worldwide in all temperate to subtropical and tropical hilly areas as an important spice and medicinal plant.[2] It is widely cultivated throughout the world including Ethiopia. Ethiopia, with its diversified agroecological conditions, is suitable for garlic production. South Gondar zone in the Amhara region of Ethiopia is potentially endowed with favorable climatic and soil conditions for the cultivation of garlic both under rainfed and using irrigation.

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Garlic is a high-value crop. However, its production and productivity are very low due to many biotic and abiotic factors such as lack of high-yielding varieties, non-availability of quality seeds, imbalanced fertilizer use, lack of irrigation facilities, lack of proper disease and insect pest management and other agronomic practices, low storability, and lack of proper marketing facilities.[7,8]

Despite multifaceted uses, garlic suffers from several problems that cause low productivity and poor quality largely attributable to the use of unimproved local cultivars with poor productivity. It was also indicated that the lack of improved varieties and garlic rust are the major one among many contributing factors responsible for the low production and productivity of garlic in Ethiopia.[9] It is, therefore, crucial to identify appropriate cultivars with high productivity and quality suiting to target study environments.

Even though the diversified agroecological conditions of Ethiopia are suitable and potentially endowed with favorable climatic and soil conditions for the cultivation of garlic both under rainfed and irrigation, its distribution to these ecological zones was still limited. Therefore, the current study was initiated with the intention of evaluating and selecting different garlic varieties under the conditions of the West Arsi Zone and other similar agroecologies.

MATERIALS AND METHODS

Descriptions of the Study Area

The study was conducted at three locations Negelle Arsi (Keraru and Turge Gallo), and Kofele (districts of West Arsi Zone) during 2020/2021 and 2021/22 cropping seasons. All districts are found on the main road from Addis Ababa to Bale Robe through Shashemene town.

Experimental Materials, Design, and Management

Three garlic varieties were introduced by the Debre Zeit Agricultural Research Center. The varieties were planted at three locations in the Negelle Arsi and Kofele districts using a complete block design with three replications.

The plot size for each experimental unit was 2 m × 3 m, each of which was 3 m long. Then, the cloves (bulb splits) were planted with an 8 cm distance between plants. The total area of a plot will be 6 m^2. The plots and blocks were 50 cm and 100 cm, respectively. Planting was carried out in the 1st week of November 2021. All agronomic and other management practices were done as per requisition at all locations.

Data Collection

Data were collected from the middle two harvestable rows from a plot and 10 randomly selected plants from the central two rows in each plot were tagged. Bulb yield (ton ha^{-1}) was estimated from the weight of harvested bulbs from the two innermost rows in a plot and then converted into the hectare basis.

Number of leaves per plant, number of cloves per bulb, stem diameter, bulb diameter, plant height (cm), days to maturity (DM), single clove weight (g), single bulb weight (SBW) (g), and total bulb yield per hectare ($TBYHa^{-1}$) (ton ha^{-1}) were the data recorded during the study.

Data Analysis

All the collected data were subjected to analysis of variance following the standard procedure of statistical software to estimate the prevalent differences among the tested varieties. Accordingly, the analysis of variance for each location and combined analysis were computed using the Gen-Stat statistical software programs.

An initial analysis of variance was performed for each location to validate the existence of differences among the varieties. Subsequently, the homogeneity between residual variances was determined, and a combined analysis of variance was employed to test the varietal, environmental, and their interaction effects.

Cultivar superiority measure (P)

The cultivar superiority measure was considered to test the bulb yield performance and its stability over the test environments. It measures the mean bulb yield performance and its stability simultaneously.[10] Mathematically, the value of cultivar superiority was obtained using the following formula:

$$P_i = \frac{n\left(X_{i.} - M\right)^2 + {}_j\left(X_{ij} - X_{i}. - M_j + M\right)^2}{2n} \quad (I)$$

Where;

- P_i = Cultivar superiority values
- X_{ij} = the response of the i[th] genotype/variety in the j[th] environment/location
- $X_{i.}$ = the mean of genotype/variety "I" in overall environments/locations
- M_j = the genotype/variety with maximum response among all genotypes/varieties in the j[th] environment/location
- M = the mean of the genotypes/varieties with maximum response over all environments/locations, and
- "n" = the number of environments/locations.

Additive main effects and multiplicative interaction (AMMI) stability analysis

The AMMI was used to integrate the analysis of variance and principal component analysis into a unified approach.

RESULTS AND DISCUSSION

The analysis of variance for an individual environment revealed that the DM, number of cloves per bulb (NCB^{-1}), SBW, and $TBYHa^{-1}$ showed a highly significant difference ($P \leq 0.05$) at all test environments [Table 1]. The variation due to the varieties was found to be significant in all environments. This indicated that varieties could not express the same seed yield performance at the test environments or that different varieties had responded differently to the test environments.

The results of Bartlett's homogeneity test have shown that error variances for p DM, NCB^{-1}, SBW, and $TBYHa^{-1}$ were found to be homogenous. This in turn allowed for further pooled/combined analysis. Accordingly, the combined analysis of variance revealed that the varieties had shown a significant difference for their DM, NCB^{-1}, SBW, and $TBYHa^{-1}$. The locations showed a significant difference for DM, NCB^{-1}, SBW, and $TBYHa^{-1}$. On the other hand, DM showed a significant difference across the varieties, locations, years, and VLI [Table 2].

The combined analysis of variance for total bulb yield revealed the presence of a highly significant difference ($P \leq 0.05$) among the varieties and environments [Table 2]. This indicates that the varieties and environments contributed more to varying the total bulb yield performance. However, the presence of blocking and/or replicating within the testing environments and years could not influence the total bulb yield of the tested garlic varieties.

The mean bulb yield values of the tested varieties averaged across the environments showed that the variety Holeta (HL) was found to have the highest mean bulb yield (6.99 ton/ha) followed by the variety Kuriftu with its mean bulb yield of 6.36 ton/ha [Table 3].

The combined analysis of variance across the environments for bulb yield revealed that

Table 1: Mean value of days to maturity (DM), number of cloves per bulb (NCB^{-1}), single bulb weight (SBW), and total bulb yield per hectare ($TBYHa^{-1}$) of three garlic varieties tested at each location

Varieties	Test environments											
	Keraru				Turge Gallo				Kofele			
	DM	NCB^{-1}	SBW	TBY	DM	NCB^{-1}	SBW	TBY	DM	NCB^{-1}	SBW	TBY
Holeta (HL)	120.30[c]	13.00[b]	67.23[b]	7.27[b]	126.30[c]	11.67[b]	58.51[b]	6.61[b]	141.00[c]	12.17[c]	63.18[b]	7.09[b]
Kuriftu	110.50[a]	10.83[a]	50.35[a]	6.33[a]	121.30[b]	10.50[a]	45.27[a]	6.22[a]	133.5[a]	10.67[a]	51.77[a]	6.53[a]
Tseday 92	114.70[b]	11.67[a]	49.38[a]	6.42[a]	117.50[a]	10.00[a]	44.90[a]	6.17[a]	135.70[b]	11.33[b]	48.49[a]	6.33[a]
GM	115.17	11.83	55.65	6.67	121.72	10.72	49.56	6.33	136.72	11.39	54.48	6.65
MSE	0.80	0.70	14.30	0.05	0.72	0.72	15.31	0.04	1.42	0.12	7.99	0.03
SE (d)	0.73	0.68	3.09	0.19	0.69	0.69	3.19	0.15	0.97	0.29	2.31	0.14
LSD	1.63	1.52	6.88	0.41	1.55	1.55	7.12	0.34	2.17	0.64	5.14	0.32
CV	0.8	7.1	6.8	3.4	0.7	7.9	7.9	3.0	0.9	3.1	5.2	2.6

GM: Genotypic means, MSE: Mean square of error, SE (d): Standard error of difference, LSD: Least significant difference, and CV: Coefficient of variation. Values with the same letters in a column mean to "not statistically significantly different"

Table 2: Combined analysis of variance for days to maturity (DM), number of cloves per bulb (NCB^{-1}), single bulb weight (SBW), and total bulb yield per hectare ($TBYHa^{-1}$) of tested varieties across locations

Traits	Source of variations									
	Replications (2)	Varieties (2)	Locations (2)	Years (1)	VLI (4)	VYI (2)	LYI (2)	VLYI (4)	Residual (34)	Total (53)
Sum squares										
DM	1.37	696.04	4395.70	17.80	10.5	26.70	11.2	8.74	33.3	5201
NCB^{-1}	2.70	29.04	11.26	0.17	0.35	1.33	0.00	0.33	17.9	63.65
SBW	190	2584.2	376.12	7.40	59.9	88.00	3.84	34.5	404	3748
$TBYHa^{-1}$	0.29	5.23	1.3	0.000	0.58	0.139	0.10	0.06	1.58	9.28
Mean squares										
DM	0.7^{ns}	348**	2198**	17.8**	2.6^{ns}	13**	5.6^{ns}	2.2^{ns}	0.9^{ns}	
NCB^{-1}	1.4^{ns}	14.5**	5.6**	0.13^{ns}	0.2^{ns}	0.7^{ns}	0.0^{ns}	0.1^{ns}	0.5^{ns}	
SBW	95^{ns}	1292**	188.1**	7.40^{ns}	15^{ns}	44.0^{ns}	1.9^{ns}	8.6^{ns}	11^{ns}	
$TBYHa^{-1}$	0.2^{ns}	2.62**	0.65**	0.00^{ns}	0.2^{ns}	0.07^{ns}	0.1^{ns}	0.0^{ns}	0.01^{ns}	

"**" stands for highly significant differences at ($P \leq 0.05$); "ns" for non-significant difference; DF: Degree of freedom, VLI: Varieties by location interaction, VYI: Variety by year interaction, LYI: Location by year interaction, VLYI: Variety by location by year interaction and the numbers in the brackets stand for the respective degree of freedom

Table 3: The combined mean values for days to maturity (DM), single bulb weight (SBW), number of cloves per bulb (NCB^{-1}), and total bulb yield per hectare ($TBYHa^{-1}$) for the tested varieties over locations

Genotypes	Traits			
	DM	NCB^{-1}	SBW	$TBYHa^{-1}$
Holeta (HL)	129.20^{c}	12.28^{c}	62.97^{b}	6.99^{b}
Kuriftu	120.5^{a}	10.50^{a}	49.13^{a}	6.36^{a}
Tseday 92	123.9^{b}	11.17^{b}	47.59^{a}	6.31^{a}
GM	124.54	11.52	53.23	6.55
MSE	0.98	0.53	11.88	0.047
SE (d)	0.81	0.59	2.82	0.18
LSD	1.64	1.21	5.72	0.35
CV	0.8	6.4	6.5	3.3

GM: Grand means, MSE: Mean square of error, SE (d): Standard error of difference, LSD: Least significant difference, and CV: Coefficient of variation. Values with the same letters in a column mean to "not statistically significantly different"

Table 4: Percent contribution of varieties, locations, replications (blocks within environments), years, variety by location interaction (VLI), varieties by year interaction (VYI), location by year interaction (LYI), varieties by location by year interaction (VLYI), and residual effects on bulb yield over the locations

Source of variations	Sum square	Sum square (%)
Replications (2)	0.291	3.14
Varieties (2)	5.233	56.38
Locations (2)	1.300	14.01
Years (1)	0.001	0.01
VLI (4)	0.581	6.26
VYI (2)	0.139	1.50
LYI (2)	0.101	1.09
VLYI (4)	0.055	0.59
Residual (34)	1.581	17.03
Total	9.282	100

The numbers in the brackets stand for the degree of freedom

varieties, locations, replications (blocks within environments), year, variety by location interaction (VLI), variety by year interaction (VYI), location by year interaction (LYI), variety by location by year interaction (VLYI) and residual contributed about 56.38%, 14.01%, 3.14%, 0.01%, 6.26%, 1.50%, 1.09%, 0.59% and 17.03%, respectively [Table 4]. The largest percent contribution (56.38%) under the variety indicates that the varieties had influenced more than the total bulb yield variations over the locations.

CONCLUSION AND RECOMMENDATION

The analysis of variance for an individual environment discovered that the bulb yield showed a highly significant difference ($P \leq 0.05$) at all test environments. The combined analysis of the tested varieties across the environments has also shown a significant difference ($P \leq 0.05$) for the total bulb yield. Accordingly, the variety HL had the highest mean yield (6.99 ton/ha).

The observed highest variation to the total variations was attributed to the varietal effects. This in turn shows that the varieties had contributed more (56.38%), playing a leading role in varying the overall bulb yield performance. In general, in the present study, the variety HL was identified to be the most adaptable and recommended variety to the present ecology of the study as compared to the other tested varieties.

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