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Case Report

Adaptation study of Garlic (*Allium sativum* L.) Varieties in the Highland Areas of Guji Zone, Southern Oromi, Ethiopia

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Abstract

Garlic (Allium sativum L.) is the second most widely used Allium next to onion with a wide area of adaptation and cultivation throughout the world including Ethiopia. In despite of this, the production and Productivity of the crop is low in the study area with the lack of improved varieties. This study was conducted to evaluate the growth and yield performance of garlic varieties at two farmers' fields in Abayi Kuture and Raya Boda. The goal was to identify high-yielding, disease-resistant/tolerant garlic varieties for the highland Guji Zone. Four improved Garlic varieties Holetalocal, Chefe, Tsedey, and Kuriftu and one Local check were evaluated. The treatments were arranged in randomized completed block design (RCBD) with three replications. Combined Analysis of variance indicated highly significant differences (P≤ 0.01) among studied varieties for Days to Maturity, Plant height, BW, Number of Cloves bulb^{-1}, Marketable and Total Yield and Significant difference (P≤ 0.05) for Leave Length and Clove Weight while non-significant (P>0.05) for Leave number and Unmarketable yield. The highest marketable yield (3918kgha^{-1}) was recorded from Local check followed by Chefe Variety (1263.7kgha^{-1}) but the lowest yield (1144.6kgha^{-1}) from Holeta Local Variety. GGE biplot analysis showed that PC1 and PC2 explained 99.10% and 0.90% of the GGE variance with *Local check best stability. So, the collection, evaluation and characterization of landrace accessions will be necessary in the study area.*

Keywords: *Adaptation; Garlic; Improved variety; Spice; Stability*

Introduction

Garlic is a small underground bulb crop. Botanically it is known as *Allium sativum and* is a member of *Alliaceae* or *Liliaceae family* [21]. Garlic (*Allium sativum* L., 2n=16) belongs to the family *Alliaceae* and is the second most widely used Allium next to onion [17]. Garlic has a wide area of adaptation and cultivation throughout the world [7]. Garlic is an ancient crop originated in Central Asia and is distributed widely throughout the temperate, warm temperate and boreal zones of the northern hemisphere. The species has been already grown and consumed in ancient Egypt and Rome. And China is by far the largest producer of garlic, with around 20 million tons grown annually accounting for over 81% of world outputs. India (4.6%) and South Korea (1.4%) follow, with Egypt (1.2%) on fourth place. Ethiopia is the seventh producer in the World by producing 222,548 tons annually [25].

Allium crops are planted in many parts of Ethiopia, including East and West Gojam Zones of the Amhara Regional State and it has been used long ago as vegetable and spice for flavoring a variety of Ethiopian local dishes. And it is used as traditional medicine for relief from any painful condition occurring inside the body. Today, the importance of garlic is well known all over the world, especially in pharmaceutical industries as well as botanicals against some plant diseases and insect pests [27].

Garlic is one of the most popular spices in the world. In the First World War, garlic was widely used as an antiseptic to prevent gangrene and today people use garlic to help prevent atherosclerosis and improve high blood pressure [9]. It is reported that in ancient Egypt, the workers who had to build the great pyramids were fed garlic daily, and the Bible mentions that the Hebrews enjoyed their food with garlic. It provides protection against various types of cancers. Garlic is a wonder remedy for treating fever, coughs, headache, stomach ache, hemorrhoids, asthma and bronchitis, low as well as high blood sugar and snakebites. Thus, garlic is a rich source of bioactive compounds, which meets the basic nutritional needs of an individual in day-to-day life [21].Garlic is widely cultivated throughout the world including Ethiopia. According to Tewodros *et al.*, 2014 the total area under cultivation in the world was 1,199,929 ha with a production of 17,674,893 tones where as in Ethiopia, CSA 2018/19 states that area under production reaches 21,754.49ha and the

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production is estimated to be production 1,957,400.45 [4]. During cropping season the total area under production reaches 15,979.54ha and the production is estimated to be 1,149,446.97 quintals (EAA, 2021).

In Ethiopia, Garlic is adapted to cool climates as high as 3000 masl and large sized bulbs are produced in cool highlands of North Shewa, Arsi, North Gondor, Bale and sidama. Rain falls about 600 to 700mm and optimum temperature 12°c to 24°c are required during growing period. Garlic withstands moderate frost and well-drained soils. Soils with high organic matter content are preferred due to their increased moisture and nutrient holding capacity, and less to prone to crusting and compaction. Suitable soil pH for garlic production ranges between 6.0 to7.5 [2].

Genetic diversity is required for populations to adapt to environmental changes. Large populations of naturally out breeding species usually have extensive genetic diversity, but it is usually reduced in populations and species of conservation concern [1]. Climate can have a significant impact on garlic flower stalk formation as well as garlic taste [21]. Characterization is of fundamental importance in diversity studies in a variety of different ways. For evaluation of species diversity, it is essential that individuals can be classified accurately. The identification of taxonomic units and endangered species, whose genetic constitution is distinct from their more abundant relatives, is important in the development of appropriate conservation strategies. In the population studies, molecular tools like molecular markers or genetic markers are being used to identify whether the two individuals are from the same species or are from the specific parents and estimating the degree of relatedness among individuals [1].

Even though, Garlic is one of the main Alliums vegetable crops known worldwide with respect to its production and economic value, and it is used as a seasoning in many foods worldwide and without garlic; many of our popular dishes would lack the flavor and character that make them favorites [8], the production and Productivity of the crop low in the study area. The lack of improved varieties and proper garlic production in highland area of Guji Zone is also other constraints. By considering these problems of garlic production and Productivity in the study area, and Suitable agro-ecology in highland area of Guji Zone, there is lack of research activity conducted to evaluate the adaptability of garlic varieties. In order to increase its production and productivity and to increase income of farmers, it is important to conduct adaptability of improved garlic varieties to highland area of Guji Zone. Therefore, this study was conducted with objective of to evaluate, and select the best performing, high yielding and disease resistant/tolerant garlic varieties for the study areas of Guji Zone.

Materials and Methods

Description of the Experimental Site

The field experiment was carried out during the 2021 and 2022 cropping season at Abayi Kuture and Raya boda on- farm. The first experimental site was located at Bore district (Abayi Kuture) kebele. The second experimental site was located at Anna sora district, (Raya Boda) kebele at the distance of about 30 km east of the town of Bore in Raya Boda '*Kebele*' just on the side of the main road to Addis Ababa via Adola town.

Treatments and experimental Design

The experiment was consisted four improved Garlic varieties; Holeta local, Chefe, Tsedey and Kuriftu which brought from Ethiopian Agriculture Research Institute, Debre Zeit Agricultural research Center and one local check. The treatments were arranged in Randomized Completed Block Design (RCBD) with three replications. A plot size of 2 m x 1.5 m and spacing of 30cm and 20cm between rows and plants respectively as well as five rows per plot and 50 cloves per plot were used. The three middle rows used for data collection whereas disease data collected from the whole plot. Fertilizer rates of 200 kg ha^{-1} NPSB and 150 $kgha^{-1}$ Urea was applied. Urea was applied in split. All relevant management practices were carried out following the recommendation of the crop.

Data Collected

The following data were collected and analyzed over year and location. phenology: Days to physiological maturity, Growth: Plant height PH (cm), Leaf length (LL) (cm), Number of leaves per plant (LN), Yield and yield component: Average bulb weight (g), Number of cloves per bulb, Clove weight per bulb (g), Marketable yield (kg/ha), Unmarketable yield (kg/ha), Total yield (kg/ha) and Garlic rust disease scored using 0-5 scoring scales should be pre transformed to percentage value described as 1(0%), 2(15%), 3(50%), 4(85%) and 5(100%) and then percentage values should be transformed and Arc Sine before statistical analysis.

Data Analysis

The collected data were analyzed by using Gen stat 18th edition software and mean separation by using LSD test at 5% level of significant.

Result and Discussion

Days Maturity

Similar to Yebirzaf *et al*. (2017) research, in the study there was a highly significant difference among varieties (P≤ 0.01) for days to maturity over a year and location, while it was non-

Table 1: The overall locations and year Analysis of Variance for different phenology, Growth, Yield and yield components of Garlic varieties in 2021/22 cropping season.

SV	Parameters									
	DM	PH	LL	NL	BW	NCB	CW	Mydkgha	Unmydkgha	Tydkgha
Var	29.85**	59.02**	45.48*	3.34ns	21.63*	337.79*	0.63**	1761.24*	22.78ns	1839.08*
Rep	4.01ns	11.38ns	17.61ns	0.61ns	22.89ns	55.59ns	0.32ns	40.40ns	22.75ns	100.37ns
Loc	232.06**	172.55*	109.35*	1.35ns	742.64*	165.66*	2.41**	923.70*	1.90ns	1009.42*
Year	1881.60**	1253.55**	0.00ns	0.00ns	775.22*	441.18*	0.02ns	783.51*	204.72**	187.26ns
Var*Loc	24.35*	26.53ns	10.08ns	1.65ns	30.90ns	25.39ns	0.16ns	17.19ns	22.23ns	54.47ns
Var*Yr	7.39ns	134.35**	0.00ns	0.00ns	90.08*	62.38*	0.12ns	207.38ns	76.01*	317.01*
Var*Loc*Yr	6.16ns	70.21ns	0.00ns	0.00ns	56.68ns	27.45ns	0.25ns	201.38ns	53.49ns	83.98ns

Where, = significant at (P≤0.05), and **= significant at (P≤ 0.01), DM = number of days from emergence to physiological maturity, PH= Plant Height, NL= Number of Leaf, LL= Leaf length, BW= Bulb Weight, NCB= Number of Clove per Bulb, CW= Clove Weight, Mydkgha = Marketable Yield in Kilogramper hectare, Unmykgha = Unmarketable Yield in Kilogramper hectare, Tydkgha=Total Yield in kilogram per hectare*

Table 2: The overall locations and year (AbayiKuture and Raya Boda) mean values of phenology, Growth, Yield and yield components of Garlic varieties in 2021/22 cropping season**.**

Varieties	Parameters										
	DM	PH	LL	NL	BW	NCB	CW	Mydkgha	Unmydkg/ha	Tydkg/ha	DS%
Kuriftu	134.42a	55.21ab	39.63ab	6.79a	16.62b	19.85c	1.71ab	1232b	466	1697b	19.44
Local	131.5b	56.19a	38.08bc	5.63b	28.99a	29.05a	1.81a	3918a	536	4455a	31.20
Chefe	131.5b	50.83b	36.67c	6.33ab	17.81b	16.92c	1.71ab	1264b	704	1967b	43.77
Holeta Local	133.42ab	52.27ab	41.42a	6.00ab	17.3b	16.38c	1.43bc	1145b	321	1466b	8.79
Tsedey	134.83a	54.73ab	37.13c	5.5b	18.27b	23.96b	1.26c	1205b	526	1731b	19.44
Means	133.13	53.85	38.58	6.05	19.80	21.23	1.59	1753	511	2263	24.50
LSD (5%)	3.00	6.42	3.49	1.39	6.39	5.62	0.49	1122	556	1308	25.9
CV	1.9	10.10	7.7	19.6	27.6	22.6	26.40	547	931	494	12.78

Where, = significant at (P≤0.05), and **= significant at (P≤ 0.01), CV = coefficient of variation, DM = number of days from emergence to physiological maturity, PH= Plant Height, NL= Number of Leaf, LL= Leaf length, BW= Bulb Weight, NCB= Number of Clove per Bulb, CW= Clove Weight, Mydqtha = Marketable Yield in kilogram per hectare, Unmyqktha = Unmarketable Yield in kilogram per hectare, Tydqtha=Total Yield in kilogram per hectare DS= Disease Severity. Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Duncan Multiple range test at 5% level of significance; CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at5% probability.*

significant for their interaction (Table 1). The highest mean (134.83) days to maturity recorded from Tsedey followed Kuriftu varieties, while the lowest (131.5) came from local check and chefe varieties (Table 2).

Plant Height

The experiment showed a highly significant difference (P≤ 0.01) for plant height for varieties, year, and variety-to-year interaction, a significant difference (P≤ 0.05) for location, and a non-significant difference for variety-to-location to year interaction (Table 1). Similar findings were also reported by Asfand *et al*. (2019), as there was a significant difference between his treatments regarding plant height throughout their life cycle. The highest mean (56.19) was recorded from the local check, followed by Kuriftu (55.21) and Tsedey (54.73), while the lowest (50.83) was from the chefe varieties (Table 2).

Leaf Length

Analyzed data from the experiment showed a significant difference for leaf length (P≤ 0.05) for both location and year, while non-significant for other sources of variation (Table 1). The highest mean values for leaf length were recorded from Holeta Local (41.42) followed by Kuriftu (39.63) varieties, while the lowest leaf length was 36.67 from Chefe Variety (Table 2).

Leave Number

Analyzed data also showed that there was no significant difference in leaf number per plant between treatments. On the other hand, Weldemariam *et al*. (2017) reported that there was a significant difference between his treatments. Even though the result was statistically non-significant, there was numerical significance (Table 1). The highest result was recorded from Kuriftu (6.79), followed by Chefe (6.33), while the lowest result was recorded from Tsedey Variety (Table 2).

Bulb Weight

The analyzed data revealed a highly significant difference for bulb weight (P≤ 0.01) for varieties, year, and location and a significant difference at (P≤ 0.05) for the interaction of variety - location, while showing a non-significant difference for other source variation (Table 1). Sandhu *et al. (*2015) also reported a similar result from their studies, as bulb weight per plant is the most important yield-contributing component, and it showed much variability in garlic genotypes. The highest mean value for this trait was recorded from the local check (28.99), followed by the Tsedey variety (18.27) (Table 2).

Number of Clove per Bulb

The analyzed data also showed a highly significant difference (P≤ 0.01) for variety and year and a significant difference (P≤ 0.05) for location and variety-to-year interaction, while being non-significant for other sources of variation studied under this experiment (Table 1). Similar findings were reported by Muhammad *et al*. (2018), as there was a clear and significant variation in the number of cloves per bulb of different varieties. The highest mean values for this trait were recorded from the local check (29.05), followed by the Tsedey variety (23.96) (Table 2).

Cloves Weight

Analyzed data showed significant differences (P≤ 0.05) for clove weight between treatments while non-significant differences for other sources of variation (Table 1). Similar results were also reported by Fikru and Fikreyohannes (2019), but Tewodros *et al*. (2014), reported in contrast to this result in his findings. The highest mean values for clove weight were recorded from the local check (1.81), followed by Kuriftu and chefe variety (1.71) (Table 2).

Marketable Yield

Combined analysis of variance result showed highly significant differences (P≤ 0.01) for marketable yield per hectare and non-significant differences for other sources of variation (Table 1). The overall analyzed data indicated that the local check was superior over theimproved varieties in terms of marketable yield per hectare. The highest marketable yield (3918.3kgha-1) was recorded from the local check, while the lowest marketable yield (1144.6kgha-1) was recorded from Holeta local varieties. Chefe (1263.7kgha^{-1}) and Kuriftu (1231.6kgha^{-1}) varieties were ranked second and third by their marketable yield per hectare, respectively (Table 2). Similar result was reported by Sandhu *et al.* (2015), as the observed variation in the characters studied among all the genotypes were due to effect of genotypes and environment. The range of mean values based on phenotype expression could represent an approximate estimate of the variation or magnitude of divergence present among different genotypes.

Unmarketable Yield

Analyzed data showed non-significant differences between treatments while significant differences (P≤ 0.05) for year and interaction of variety with year (Table 1). Even though there was no statistically significant difference between the evaluated treatments, there was a numerical variation. The highest unmarketable yield (703.6 kgha^{-1}) was recorded from Chefe, while

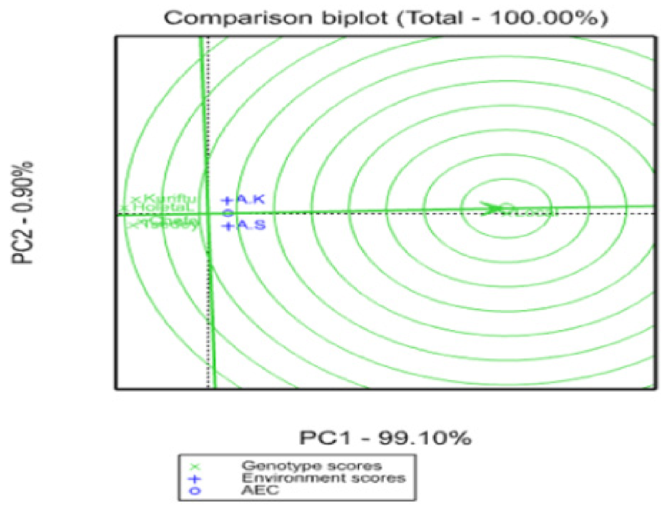

Figure 1: GGE biplot analysis for Stability study.

the lowest unmarketable yield (3.21 qtha^{-1}) was from Holeta local varieties (Table 2).

Disease Reaction

The highest disease severity mean percentage (43.77%) was scored from chefe variety while lowest (8.79%) from Holeta local variety (Table 3).

Stability

The GGE biplot analysis showed that PC1 and PC2 explained 99.10% and 0.90% of the GGE variance, respectively (Figures 1). Figure 1 helps visualize the marketable yield performance and stability of improved Garlic varieties and Local check. Accordingly, the GGE biplot showed that the Local check was in the first concentric circle, closer to the horizontal line, whereas others away from the mean vertical line, which indicates this Local check was stable and had a high yielder among tested varieties. The important feature of the GGE biplot is the Average Environment Coordinates (AEC) view of varieties to identify desirable varieties in an ideal environment. Varieties proximal to the arrow at the center of the concentric circles (ideal varieties) are assumed to be suitable. The important factor was that GGE biplot was the best way to visualize the interaction patterns between genotypes and environments (Yan and Kang, 2003).

Conclusion and Recommendation

The combined analysis of variance showed significant differences among varieties for all studied parameters, unless for the number of leaves and unmarketable yield parameters. The observed variation in the characters studied among all the Varieties were due to effect of genotype and environment. The local check was superior to all improved varieties in terms of Plant Height and Yield and Yield components and also showed best stable in tested environment to tested varieties. Even though the highest recorded marketable yield was not satisfied, based on the recorded data, the trial was completed by giving the following future research outlook: The superiority of the local check to improved varieties shows that there might be a high yield of landrace accessions in the study area. So, the collection and characterization of landrace accessions will be necessary in the study area.

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