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Intra Row Spacing Effect on Growth and Yield Performance of Garlic (*Allium sativum* L.) at Wolkite University, Gurage Zone, Central Ethiopia

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Abstract: Garlic (*Allium sativum* L.) is one of the most important vegetable crops produced in Ethiopia including Gurage zone. Use of appropriate plant spacing's is a major agronomic practice to improve the productivity and quality of garlic. However, farmers are producing the crop without appropriate plant spacing; due to this the productivity of the crop in the zone is far below its potential including other factors. Cognizant of this, the present experiment was initiated and conducted with the objective of determining the ideal intra row spacing for growth and yield component of garlic, a field experiment was carried out at the experimental site of Wolkite University, located at Cheha district, Gurage zone of South Nation and Nationality of People Region, throughout the entire 2019 growing season using supplemental irrigation. The experiment used a randomized complete block design (RCBD) with four treatments of 6cm, 8cm, 10cm, and 12cm between plants, and three replications. Garlic plant height, leaf length, leaf width, leaf number, and fresh and dry biomass yield were all examined attributes, and the analysis of variance revealed that intra row spacing significantly affected all of the tested parameters. Maximum plant height (48.91cm) and leaf length (43.75cm) were recorded from 30cm by 6cm plant spacing, while maximum leaf width (10.6cm), leaf number per plant (10.53), fresh yield biomass (166.74g), and dry biomass (38.59g) were obtained from 30cm by 12cm plant spacing. The wider the plant spacing the higher were the leaf number, leaf width, and fresh and dry biomass yield but plant height and leaf length were decreased. Therefore, based on these results mostly bulb a yield of garlic was positively correlated with the better performance of the parameters were the plant spacing became increased, hence it can suggest bulb yield of garlic increased were the spacing between plants were increased. The results of this experiment should be confirmed by a similar investigation that includes yield components in the study area.

Keywords: Garlic, Growth Performance, Intra Row Spacing, Yield Component

1. Introduction

Garlic (*Allium sativum* L.) is the second most frequently grown Allium crop after onions and first cultivated in Central Asia [18]. It is created for the fresh market, dehydrated as a food processing ingredient, and generated as food supplements, such as dehydrated powder, essential oil, oil macerate, powder, and aged garlic extract [9, 16]. Additionally, it has a lot of calcium, phosphorus, and potassium. Additionally, the leaves have protein, vitamin A, and antibiotics like allistatin and garlicin [13].

The Alliums, which include onions, garlic, and shallots, are significant bulb crops grown in Ethiopia for domestic consumption as a spice, a medicinal herb, and as a means of revenue for farmers [6]. It primarily grows in the country's mid-altitudes and highlands, but it may thrive in a broad variety of climatic and soil conditions. As a cash crop, it can be exported to Europe, Middle East, Africa, and USA to generate foreign currency [11]. Garlic bulb yield in Ethiopia increased from 11,845.53ha in 2015/16 to 15,381ha in 2016/17, totaling about 107,743.5 and 138,664.3 tons of bulbs with respective productivity levels of 9.10 and 9.02 t ha^{-1} [3].

Garlic produced an average yield of 9.34 t ha^{-1} in Ethiopia, which is significantly less than the global average of 23.53 t ha^{-1}. Among the main causes of the nation's low productivity

are lack of improved and high-yielding varieties, inadequate use of plant spacing, a lack of high-quality seeds, low soil fertility, improper agronomic practices, a lack of proper pest and disease management, and a lack of improved postharvest technologies [7, 15]. The best level for any agronomic technique, like plant population density, depends on the environment, the crop's intended use, and the variety.

Due to the absence or unavailability of standard production practices, most farmers in the study area cultivate alliums according to their personal preferences, which hastened the crop's low yield. The nationally prescribed intra row spacing is not ideal for all crop or varietal characteristics or growing situations. Therefore, the overall goal of the study is to determine the ideal intra row spacing for the best production of garlic in the study area by evaluating how growth and yield respond to various intra row spacing's.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted in Gurage Zone at Wolkite University, College of agriculture and Natural Resource Demonstration site in during the off season of 2019 with supplemental irrigation. Wolkite University is geographically located 170 km from Addis Ababa to South West direction. The latitude is about 8°11'60.0''N (8.20°) and 37°-47'60.0" (37.8°) E longitude. Its elevation is ranging from 1300 meters above sea level. The annual rain fall of the area is 1294mm and the annual average temperature is 20.5°C. While the maximum and minimum recorded temperature being 24°C and 14°C, respectively. The soil type of the area heavy vertisol is around 80%, which is rich in organic matter, while there is less capability to drain water. The rain fall of Wolkite is bimodal in which 80% of rain falls in the winter period of June to August whereas 20% in the *belg* period of February to May [8].

2.2. Experimental Material

Local variety of garlic cloves used as a plant material, and NPS and urea were used as a source of fertilizer for the study.

2.3. Treatments and Experimental Design

The experiment was consisted four levels of intra row spacing/treatments (6cm, 8cm, 10cm and 12cm) and arranged in Randomized Complete Block Design (RCBD) with three replications. The width and length of each experimental plot was 1.5m x 1.5m ($2.25m^2$) and had a distance of 0.5m, 0.3m and 1m between plots, rows and blocks respectively. Each plot accommodated five rows with 25, 19, 15 and 12 plants per row of 6cm, 8cm, 10cm and 12cm intra row spacing, respectively. Plants in the middle three rows were used for data collection, leaving aside those at the border rows as well as those at both ends of each row.

2.4. Management of Experimental Plots

The land was cleared, ploughed (disked), leveled; large clods were broken down. After large clods were broken down to a fine tilth, and then a total of 12 plots, each with a size of 1.5m x1.5 m, were prepared, with four plots in each replication. After preparing the plots at 20cm height of bed and randomized there chance, planted the garlic cloves at 3cm depth with the plant spacing of 6cm, 8cm, 10cm and 12cm on March 2019, by taking the row spacing constant 30cm.

Fertilizers applied according to national recommendation at the rate of 200kg/ha DAP and 150kg/ha urea, were applied as a source of nitrogen and phosphorus respectively, where DAP fertilizers were applied at planting and urea fertilizer was side dressed in a split in two applications; with half was applied two weeks after emergence and the remaining half five weeks after emergence [12]. The planted garlic cloves were taken under irrigation every day as the rain is available (if there is enough amount of rain no need of irrigation) and all other management practices were carried out uniformly in all experimental plots.

2.5. Methods of Data Collection

Plant height (cm): was measured from the soil surface to the tip of matured leaf using a ruler in centimeters at the time of maturity.

Leaf number per plant: was measured the mean number of leaves produced by sampled plants and were measured calculated by dividing the total number of leaves counted from the sampled plants to the number of sampled plants to get mean leaf number per plant.

Leaf length (cm): The length of three leaves per plant (from upper, medium and lower) was measured at maturity by using ruler and the average leaf length was taken.

Fresh biomass yield/plant (g): Plants were removed from soil and washed off any loose soil, and they were blotted gently with soft paper to remove any free surface moisture and weighed immediately by using a sensitive balance.

Dry biomass yield/plant (g): Plants were removed from the soil and washed off any loose soil, and they were blotted to remove any free surface moisture. The plants were dried in an oven set to low heat (70°C) for 72 hours and then cooled in a dried environment, and weighed using sensitive balance.

2.6. Data Analysis

All variables were subjected to the analysis of variance using SAS (version 9.3) software. Significant treatment means were separated using least significance difference (LSD) at 5%.

3. Results and Discussion

Analysis of variance showed that intra row spacing had a significant ($P \leq 0.05$) effect on all tested growth and yield parameters.

3.1. Growth Parameters

Plant height: The smallest plant height (40.91cm) was

obtained at 12cm intra-row spacing, which was statistically equal to a height of (43.93cm) at 8cm and that of (42.08cm plant height) at 10cm intra row spacing. The largest plant height (48.91cm) was produced from the narrow intra-row spacing of 6cm (Table 1). Garlic plants with the smallest plant spacing had the tallest plants, which may be a result of competing for light under conditions of high plant population density. Plants were not impacted by plant density when they were spaced farther apart since there was less competition for light and other resources. These findings concur with those made for onions [10, 2].

Leaf length: The plants grown with 6cm intra row spacing produced the longest leaves measured 43.75cm, while the shortest leaves measured 35.35cm, were grown with 12cm intra row spacing, which was statistically equivalent to leaf lengths of 37.65cm at a 10cm intra spacing and 38.66cm from 8cm between plants (Table 1). The outcome revealed that increasing intra-row spacing from 6cm to 12cm reduced garlic leaf length from 43.75 to 35.35cm, which is consistent with the maximum leaf length was recorded on the narrow plant spacing [5], but different who claimed that the highest leaf length of garlic was obtained at wider intra row spacing and the shortest at the narrow intra row spacing [14].

Leaf width: The narrow leaf width (5.51cm) was recorded at a row spacing of 6cm, while the widest leaf (10.60cm) was measured where plants grown at a row spacing of 12cm (Table 1). The leaf width of garlic increased linearly from 5.51cm to 10.6cm with an increase in intra-row spacing from 6cm to 12cm. The lowest plant densities can give wider leaf width of garlic, which may be attributed because wider plant spacing showed less competition for resources, and as a result, leaves developed to a larger size, which also agrees with who reported that the highest leaf width of garlic was found in their study [14, 17].

Leaf number per plant: The lowest leaf number (8.53) was recorded at a row spacing of 6 cm, while the highest leaf number (10.56) was obtained at a row spacing of 12cm (Table 1). This claim is consistent with research found that garlic plants' number of leaves decreased as plant density increased [1, 14]. This might be because plants that are spaced widely develop more axillary branching than those that are spaced closely, which led to fewer leaves. It could also be because to increased competition among the plants for resources such as water, soil nutrients, space, light, etc., which results in poor photosynthetic efficiency. However, in the current investigation, the quantity of leaves produced by garlic plants was not significantly impacted by the interaction effects of intra row space and variety. Similar to this, the widest row spacing produced the most leaves per plant [20].

Table 1. *Effect of intra row spacing on plant height, leaf length, leaf width and leaf number/plant.*

Plant spacing (cm)	Growth parameters			
	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Leaf number/plant
T1=6cm	48.91^{a}	43.75^{a}	5.51^{c}	8.53^{d}
T2=8cm	43.93^{b}	38.66^{ac}	8.10^{b}	9.53^{c}
T3=10cm	42.08^{b}	37.65^{c}	9.47^{ab}	9.75^{ab}
T4=12cm	40.91^{b}	35.35^{c}	10.60^{a}	10.53^{a}
Mean	43.96	38.85	8.42	9.58
LSD (0.05)	4.70	5.55	1.62	0.182
CV (%)	0.05	7.15	9.64	0.023

CV=Coefficient of Variation, LSD=Least Significance Difference

3.2. Yield Parameters

Fresh biomass yield: The highest fresh yield biomass (166.74g) was recorded at a row spacing of 12cm and was significantly similar with biomass yield obtained from plants grown from 10cm, while the lowest fresh yield biomass (92.58g) was found at a row spacing of 6cm (Table 2). The outcome demonstrated that when plant spacing increased, biomass yield likewise increased. Wider plant spacing, which demonstrated reduced competition for water, sunlight, space, and necessary nutrients, may be responsible for this outcome. The plant grows larger and produces more bio-mass as a result. Accordingly, shallot bulbs planted at 20cm intra-row spacing develop more aggressively and provide greater biological yield per plant than shallot bulbs planted at 10cm spacing [4]. The findings of this study corroborate their findings.

Dry biomass yield: Dry biomass yield increased from 10.02g to 38.59g as intra-row spacing increased from 6cm to 12cm (Table 2). However, plants grown from intra row spacing's of 10cm and 12cm, their dry biomass yield no varied statistically. It was discovered that as plant spacing was increased, plant competition decreased, ensuring the highest possible vegetative growth and dry weight per plant. The result was consistent with who noted that while onion dry yield biomass weight increased with increasing intra-row separation, total bulb yield increased less rapidly with tighter spacing [14].

Table 2. *Effect of intra row spacing on fresh and dry biomass yield.*

Plant spacing (cm)	Fresh biomass yield/plant (g)	Dry biomass yield/plant (g)
T1=6cm	92.58^{d}	10.02^{d}
T2=8cm	101.15^{c}	18.18^{c}
T3=10cm	122.02^{ab}	31.08^{ab}
T4=12cm	166.74^{a}	38.59^{a}
Mean	120.62	24.47
LSD (0.05)	47.85	5.84
CV (%)	23.53	1.2

CV=Coefficient of Variation, LSD=Least Significance Difference

4. Conclusion and Recommendation

In the present study, intra row spacing had its effect on growth and yield parameters of garlic including plant height, leaf length, leaf width, leaf number, fresh and dry biomass yield. Accordingly, plant height and leaf length were decreased as the spacing between plants increased, whereas leaf width, leaf number per plant, fresh and dry biomass yield became increased as the intra row spacing increased. Hence, these results indicated that positively correlation between bulb yield of garlic and the parameters that increased when the intra row spacing increased i e leaf number, leaf width, and fresh and dry biomass yield increased also bulb yield of garlic became increased. Generally, planting garlic crops at wider space can increase its production without competition for light, space and resources. Therefore, based on these results can suggest planting garlic crops with an intra-row spacing of 10cm and above for improve productivity of garlic crop in the study area. A similar experiment should be also carried out to verify the positive relationship between growth parameters and yield and to confirm the findings of the current investigation.

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