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Effect of Spacing in Incidence and Severity of Garlic Rust (*Puccinia Allii* (Rudolphi.) and Bulb Yield and Related Traits of Garlic at Eastern Ethiopia

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Abstract

Garlic rust is caused by Puccinia allii (Rudolphi) extremely hinder the productivity of Alliaceae species, especially garlic *(*Allium sativum*)*. The disease has been found wherever garlics are cultivated and at present no system of control has been found that fully prevents the occurrence of the disease. A field experiment was conducted to determine the optimum planting density for abating garlic rust in order to maximize yield of garlic. The experiment was laid out in RCBD with three replications, garlic local cultivar (Chiro) and three levels of intra-row spacing (10 cm, 15 cm and 20 cm) were included in the study. Disease incidence and severity, plant height, Bulb yield, bulb diameter, Days to maturity, Plant height, Total yield (t/ha), Bulb weight (gm), Bulb diameter, Number of cloves per bulb and Clove weight were analyzed using SAS software. The result of the study revealed that the spacing was varied significantly in disease incidence and severity and in aforementioned agronomic data. The maximum yield was observed from plot planted with 10 cm intra row spacing where was the minimum value of yield was recorded at plot planted with 20 intra row spacing. The results explained that increasing intra-row spacings from 10 to 20 cm decreased significantly ($P \leq 0.05$) in disease incidence and severity simultaneously increased yield of garlic. Based on the results obtained, it could be concluded that spacing 10cmx30cm is optimal for better production of garlic under disease conditions.

Keywords: *Allium sativum*; Bulb yield; *Puccinia allii*; Spacing

Introduction

Garlic (*Allium sativum* L.), belongs to the family Alliaceae and is the second most widely used Allium next to onion [1]. In Ethiopia, the Alliums group (onion, garlic, and shallot) are important bulb crops produced for home consumption, spices, medicinal plant and as a source of income to many peasant farmers in many parts of the country as described by [2]. Garlic is one of the most important bulb vegetables, which is used as spice and flavoring agent for foods. It adds to taste of foods as well as it helps to make them digestible. Garlic contains different essential minerals, vitamins and many other substances used for health of human beings. It is rich in sugar, protein, fat, calcium, potassium, phosphorous, sulfur, iodine fiber and silicon in addition to vitamins. It possesses high nutritive value. Furthermore, garlic has miracle pharmaceutical effects and used to cure an enormous disease including blood pressure and cholesterol, cancer, hepatoprotective, antihelmentics, antiinflammatory, antioxidant, antifungal and wound healing, asthma, arthritis, sciatica, lumbago, backache, bronchitis, chronic fever, tuberculosis, rhinitis, malaria, obstinate skin disease including leprosy, leucoderma, discoloration of the skin and itches, indigestion, colic pain, enlargement of spleen, piles, fistula, fracture of bone, gout, urinary diseases, diabetes, kidney stone, anemia, jaundice, epilepsy, cataract and night blindness as mentioned by (Azene and Mengesha) [3].

Despite its importance, the productivity of garlic across the globe especially in Ethiopia is generally low due to numerous and prominent production problems which encompass lack of proper planting material, inappropriate agronomic practices, absence of proper pest and disease management practices and marketing facilities, abiotic and biotic factors. Pinto, et al. [4] elucidated that Insects and fungi are the major pests of the plant across the globe among the fungal diseases, garlic rust is the most serious disease that prevalent worldwide and cause severe economic losses in onion and garlic crops as explicated by Perez et al. [5]. Similarly, Pinto, et al. [4] reported that garlic rust attacks the crop throughout its developmental stages since the developmental process is important in the progression of diseases. It is assumed that densely populated plants are ideal habitats for fungal development and transmission to the nearby plant since moisture is retained within the leaves, and it prevents direct sunshine as explained by [6]. Limited options are available due to wind dispersal nature of these pathogens.

Garlic rust is the serious disease of garlic in almost all garlic producing regions of Ethiopia and it decline the productivity of crop for the last many years as described by Tesfaye and Habtu [7].

A number of studies in various parts of the world have shown that garlic production can be improved through proper spacing. It has been reported by Mohammad et al. that plant spacing significantly increase number of cloves per bulb, bulb size, bulb weight and yield. Naruka and Dhaka [8] and Alam, et al. [9] indicated that garlic bulb yields increased significantly with increasing intra-row spacings. It is better to evaluate the effects of different plant spacing in the disease incidence and severity, and bulb yield and related traits of garlic. The most common garlic spacing in Ethiopia is 30 cm between rows and 10 cm between plants (EARODRCV, 2004). In Eastern Ethiopia, garlic rust occurs and distributed naturally. It extremely hinders the productivity of such nutraceutical plant. However, no research work has been done

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to determine the optimum spacing that minimizes disease incidence and severity in order to utilize the crop with its full potential.

Determining the relationship between yield losses and disease severity is an ideal method to identify effective and economical management methods to minimize garlic rust. Determine the optimal plant spacing is the best, easy and accuracy way to minimize such garlic rust simultaneously maximize yield of garlic especially in developing country and also this method enables community to utilize the plant with its full potential. Mohibullah [10] justified that by decreasing the plant population from 2 to 0.5 million ha^{-1}, 10% decrease in rust severity and simultaneously increase garlic yield by 28%. In a different spacing experiment conducted on onion, 75% decrease in plant population caused 20% reduction in downy mildew severity and 23% increase in onion yield. Therefore, the main focus of the present research was to determine the optimum planting density to control garlic rust in order to maximize garlic yield.

Materials and Methods

The study was conducted under rainfed conditions during the year 2012/13 main cropping season at Raree, Eastern Ethiopia. The experimental site is located within Haramaya University at 42°3'E longitude, 9°26'N latitude and at an altitude of 1980 m.a.s.l. The mean annual rainfall is 760 mm. The mean maximum and minimum annual temperatures are 23.4 and 8.25°C, respectively.

The experiment was conducted using one garlic local variety (Chiro), three types of planting densities (0.33, 0.23 and 0.16 million/ha plants). Uniform sized cloves of garlic were used as seed (planting material). There were a total of 3 treatments comprising one garlic variety X three spacings treatments. Each plot consists of five rows of 2 m length with a distance of 0.3 m between rows. The space between plots and blocks was 1 and 1.5 m, respectively. The treatments were arranged in a randomized complete block design (RCBD) with three replications.

Disease assessment

Disease incidence percentage (plants showing symptoms divided by total observation) was assessed from 10 randomly selected plants on the onset of the first symptom appearance and the assessment was carried out on weekly basis.

Disease severity was recorded and estimated in percentage of the leaf surface covered with lesions. It was assessed from all leaves of a plant and the average was recorded for the respective plant. Average severity of the 8 plants per plot was used for statistical analysis.

Agronomic data recorded

Data of yield and yield components and other agronomic parameters, were collected as follows.

1. Days to maturity: number of days taken from emergence to 75% leaf fall.
2. Plant height (cm): average height of 10 plants of each plot measured from ground level to the tip of the pseudo stem at maturity.
3. Total yield (t/ha): yield estimated from the middle three rows of each plot after curing and transformed to tons per hectare.
4. Bulb weight (gm): average weight of 10 bulbs taken from each plot after curing.
5. Bulb diameter (mm): average diameter of 10 bulbs from each plot after curing using digital caliper.
6. Number of cloves per bulb: average number of cloves of 10 bulbs from each plot.
7. Clove weight (g): bulb weight divided by number of cloves per bulb.

Data analysis

Data on garlic rust severity from each assessment date, yield and yield components, and agronomic data were subjected to analysis of variance by using SAS computer software. Least significant difference (LSD) values at (α=0.05) were used to separate differences among treatment means.

Results and Discussion

Garlic rust onset and intensity

Garlic rust was first observed at 91 days after planting (DAP) and garlic rust assessment was started at 93 DAP. The disease first appeared on all plots simultaneously. The different types of spacing were significantly ($p \leq 0.05$) different in terms of their respective reaction to the disease incidence. The highest average severity level of garlic rust was recorded from plot planted with 10 cm intra row spacing while, the lowest average disease severity level of garlic rust was observed from plot planted with 20 intra row spacing cm spacing (Table 1).

Disease severity

The different types of spacing create a significantly different ($p \leq 0.05$) in their effects on disease severity (Table 1). Intra row spacing responded differently to garlic rust and high variation were existed between spacing (Figure 1).The maximum amount of disease severity (53.33%) was observed at plot planted with 10 cm spacing, while the lowest amount of disease severity (26.67%) was observed at plot planted with 20 cm spacing (Table 1). The result showed that increment of intra row spacing result in decrement of disease severity. This finding is in line with the findings of Darabi and Dehghani [11] who reported that disease severity increased when intra-row and inter-row spacing decreased from 13 × 40 cm to 7 × 10 cm. This might be due to that as

Spacing	Garlic rust severities at different days after planting						Garlic rust incidences at different DAP		
(Cm)	93 DAP	100 DAP	107 DAP	114 DAP	121 DAP	128 DAP	93 DAP	100 DAP	107 DAP
10	5.42	17.83	28.07	33.72	40.80	53.33	34.90	67.50	100.00
15	4.36	15.75	25.012	31.99	39.66	50.76	33.17	65.83	100 .00
20	2.94	13.43	21.63	30.88	36.18	48.47	26.67	59.50	87.50
CV (%)	15.63	21.20	17.86	8.13	6.68	5.72	19.80	13.88	2.10
SE (±)	0.21	1.24	2.03	1.06	1.20	2.04	1.35	3.39	1.02
LSD (5%)	0.49	2.48	3.33	1.96	1.94	2.18	4.68	6.67	1.39

Table 1: Garlic rust severity and incidence on garlic under different spacing.

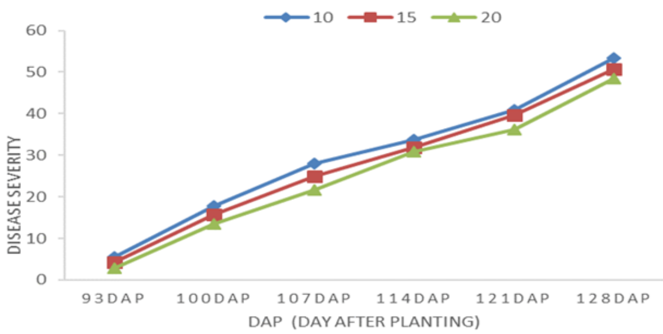

Figure 1: Disease progress under different spacing.

the plant population increases the transmission of the rust to the next plant also increases.

Effects of spacing on yield and related traits of garlic

Total bulb yield: There was significant ($p<0.05$) difference in total bulb yield of garlic plots planted with different intra row spacing. The maximum bulb yield (7.8 t/ha) was obtained from plots planted with 10 cm intra row spacing whereas, the lowest value of average total bulb yield (4.85 t/ha) were achieved from plots planted with 20 cm intra row spacing (Table 2). The result explained that total bulb yield of the garlic was deceased as increment of intra row spacing. The result was in accordance with research results of [12] who reported that total bulb yield deceased due to increase of intra row spacing. Similarly, Darabi and Dehghani [11] total bulb yield deceased due to increase in the distance between rows and plants, but the mean weight of bulb and clove increased. Therefore, the highest total bulb yield and the lowest mean weight of bulb and clove were produced with spacing of 20 × 7 cm (714,285.71 plants ha^{-1}). The plant densities which are considered as the most favorable for high bulb yields in garlic production range from 450,000 to 880,000 plants ha^{-1} as illustrated by Karaye and Yakubu [13]; Abubakar et al [14] and Kilgori [12]. The increment of bulb yield at closer spacing might be ascribed to the increase in plant population per unit land area, while the decrease in bulb yield at wider intra-row spacing could be associated with decreased plant population per unit land area. It can thus be explained that the bulb yield per plant area depended not only on the performance of individual plants but also on the number of plants per unit area as confirmed in this study.

Bulb weight: There was significant ($p<0.05$) difference in bulb weight of garlic plots planted with different intra row spacing. The maximum bulb weight (31.52 g) was obtained from plots planted with 20 cm in intra row spacing and the lowest values of bulb weight was recorded from plots planted with 10 cm intra row spacing (27.44 g) from 10 cm spacing between plants. The bulb weight (28.21 g) obtained from 15 cm spacing was not significantly different from bulb weight of plot planted with 10 cm intra row spacing (Table 2). The result justified that increment of intra row spacing increase bulb weight of the plant. This research finding is in line with the findings of Darabi and Dehghani [11] increasing the distance between rows and plants decreased the total bulb yield but increased the mean bulb and clove weights. Therefore, the highest total bulb yield and the lowest mean weights of bulb and clove were produced with spacing of 20 × 7 cm. On the contrary, Karaye and Yakubu [13] reported that decreasing the plant to plant distance from 20 to 10 cm decreased the yield from 9176.7 to 5263.3 kg/ha. This might be due to in the lowest spacing there might be nutrient competition as well as high disease severity.

Bulb diameter: There was significant ($p<0.05$) difference in bulb diameter of garlic plots planted with different intra row spacing. Intra row spacing created significant different on bulb diameter. The longest bulb diameter (34.59 mm) was obtained from plots planted with 20 cm intra row spacing while, the shortest bulb diameter (30.44 mm) of garlic was recorded from plot planted with 10 cm intra row spacing (Table 2). Bulb diameters obtained from plot planted with 10 and 15 cm intra row spacing did not show significant difference. Similar research results were reported by Jorind [6] there was no significant difference on bulb diameter with increment of intra-row spacing from 15 to 20 cm intra row spacing in 2011 dry season. This might be due to the lowest spacing that might intensified the nutrient competition and might resulted in high disease severity and, therefore, prominent to higher bulb diameter observed from 20 intra row spacing than both 15 and 10 cm.

Clove weight and number of cloves per bulb: There was significant ($p<0.05$) difference in clove weight and number of clove of garlic plots planted with different intra row spacing (Table 2). The maximum clove weight (1.74 g) was obtained from plot planted with 20 cm intra row spacing whereas, the minimum value of clove weight (1.53 g) observed in plot planted with 10 cm intra row spacing (Table 2). The findings of this study indicated that bulb weight of garlic was significantly affected by spacing and Increasing of intra-row spacing from 10 to 20 cm significantly increased bulb weight. This finding is full agreement with research findings of Darabi and Dehghani [11]; Adejpe et al. [15] and Abubakar et al [14] who reported that increasing intra row spacing decreased the total bulb yield but increased the mean weights of bulbs and cloves. The reason for this might be due to the lowest spacing might increase nutrient competition as well as increase disease severity.

Days to maturity: There was no a significant statistical variation ($p>0.05$) in days to maturity between the different spacings (Table 2). Hence this parameter is not affected by spacing.

Plant height: There was no a significant statistical variation ($p>0.05$) in plat height between the different spacings (Table 2). Hence this parameter is not affected by spacing.

Correlation among disease incidence, disease severity and yield and related traits of garlic

Correlation analysis revealed that some of agronomic data of garlic significantly ($p \leq 0.05$) negatively correlate to weekly levels of garlic rust severities and total yield and yield related traits except with the number of cloves per bulb. Based on the coefficients of correlation (r) computed for the relationships between the disease and yield parameters, the garlic rust severity was strongly ($p \leq 0.05$) and negatively correlated with the total yield, bulb weight, bulb diameter and clove weight. Plant height had a non-significant negative relationship (Table 3). There was no significant ($p \leq 0.05$) correlation between number of cloves per bulb and plant height and garlic rust severities (Table 2). Yonas

Spacing (cm)	TY (t/ha)	BW (g)	BD (mm)	CW (g)	DM (Days)
10	7.87	27.44	30.44	1.53	145.33
15	6.38	28.21	32.00	1.62	145.27
20	4.85	31.52	34.59	1.74	145.67
CV (%)	12.16	13.35	10.70	12.38	3.163
SE(±)	0.3	1.37	1.26	0.08	0.678
LSD (5%)	0.73	3.75	3.34	0.19	3.44

Table 2: Means of yield and yield related parameters on different garlic plant spacing.

	PH	TY	BW	BD	CW	CN	DM
idap93	-0.06879ns	0.12109ns	-0.12428ns	-0.10164ns	-0.07255ns	-0.30327*	-0.05767ns
idap100	-0.22843ns	-0.44630**	-0.74102**	-0.62780**	-0.76378**	0.04709ns	-0.43629**
idap107	-0.07210ns	-0.43404**	-0.77284**	-0.56559**	-0.74595**	-0.00622ns	-0.43587**
sdap93	-0.04381ns	0.14759ns	-0.53825 **	-0.60727**	-0.51529 **	0.03283ns	-0.33436 *
sap100	-0.06086ns	-0.26987ns	-0.56614**	-0.53795**	-0.63767**	-0.03677ns	-0.18751ns
sdap107	0.00649ns	-0.40286**	-0.69556 **	-0.67953**	-0.76781**	0.03875ns	-0.27528ns
sdap114	-0.10723ns	-0.50125**	-0.81680**	-0.66477**	-0.82069**	0.05649ns	-0.46398**
sdap121	-0.07776ns	-0.58145**	-0.86251**	-0.77602**	-0.87099 **	0.11265ns	-0.49687**
sdap128	-0.00926ns	-0.60776**	-0.88892**	-0.81815**	-0.90913**	0.18498ns	-0.50846**

**Highly significant at p<0.01, *significant at p<0.05, ns=non-significant at p=0.05, PH=plant height, TY=total yield,BW=bulb weight,BD=bulb diameter,CW=clove weight,CN=clove number,DM=days to maturity,idap=disease insidense days after planting,sdap=disease severity days after planting.

Table 3: Coefficients of correlation (r) between garlic rust severity and yield and related traits of garlic.

[16] reported similar results with correlations in this disease and plant parameters. Similarly, Dill-Macky [17] reported that grain yields of some barley and winter wheat varieties were most affected by terminal stem rust severity.

Conclusion

Field experiment was conducted to study the effects of spacing on intensity and severity of garlic rust *(Puccinia allii)* on yield and yield components of garlic at research field of haramaya university, Ethiopia. The experiments were conducted using one garlic variety and three intra row spacing. The three intra row spacing created significantly different disease severity levels. Among intra row spacing, the lowest disease severity level was recorded on plots planted with 10 intra row spacing. Different types of intra row spacing could significantly affect bulb yield and related traits of garlic. The maximum value of yield (7.87t/ha) was obtained from plot planted with 10 cm intra row spacing while, the minimize value of yield was achieved by plot planted with 20 intra row spacing. This might be due to effective use of the land resource in the populated spacing and the tolerance ability of the variety (chiro). It can thus be explained that the bulb yield per unit area depended not only on the performance of individual plants and severity of disease but also on the number of plants per unit area and also tolerance ability of a variety as confirmed in this study.

The present study revealed that, garlic rust can cause more than 51% yield loss on the crop. Hence, application of control measures to minimize the loss is justifiable in areas where it is prevalent. Optimal spacing can be used ideal methods to control the disease and to maximize bulb yield of garlic. Since this research is done in one location in a single cropping season, research works should be carried out for confirmation in similar environmental conditions in different seasons in the future.

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