Research Article

Impact of Plant Spacing on Garlic Rust (*Puccinia allii*), Bulb Yield and Yield Component of Garlic (*Allium sativum*)

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Abstract | Garlic rust is caused by pathogen (*Puccinia allii)* that severely hinders the productivity of Alliaceae family. Experiment was conducted to determine the optimum plant spacing in order to abate garlic rust and maximize garlic crop yield. The experiment was carried out in RCB design with three replications; garlic cultivar (china) and three levels of intra-row spacing (10, 15 and 20 cm) were included in the study. Data regarding disease occurrence, disease severity, plant height (cm), bulb weight (g), bulb diameter (mm), clove weight (g), number of cloves bulb^{-1} and yield (t ha^{-1}) was measured. The result of the study reveals that plant spacing had significant impact on the occurrence of rust disease and its severity, yield and yield components. Plants with 10 cm spacing had more disease incidence and severity (79 and 55.66% respectively). Plants with 20 cm spacing had more Bulb weight (99.33 g), Bulb diameter (67.33 mm), clove weight (11.65g) and no of cloves per bulb (12.5); whereas taller plants (54 cm) and maximum bulb yield of 12.85 t ha^{-1} was recorded in those plots planted with 10 cm spacings. While the highest unite price of Rs. 300 kg^{-1} (Rs. 3.315 m ha^{-1}) was received from those garlic which were obtained from 20 cm spacing as against the lowest market price of Rs. 225 kg^{-1} (Rs. 2.891 m ha^{-1}) received from those garlic obtained from10 spacing. To achieve high market price, good quality garlic production and free from rust disease it is suggested to plant garlic crop in 20 row spacing.

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Introduction

Garlic (*Allium sativum*) is popular condiment crop and is second most widely grown winter crop after onion of Alliaceae family (Rochecouste, 1984). It is native to arid and semi-arid regions central Asia and domesticated there since 3000 B.C. (Etoh and Simon, 2002). Mostly garlic is used for home consumption in various forms for cooking purpose either as spices or condiments. Moreover, it has great importance because of its medicinal value and is used for curing of various cardiovascular diseases, stomach diseases, sore eyes, earache, as it contains considerable amount of minerals and Vitamins (Kumar et al., 2010; Mengesha and Azene, 2015). Garlic bulb is normally enclosed by thin membrane which contains at least 16 blublets called cloves. Worldwide garlic is grown on an area of 2.5 million acres with total production of 25 million tones. China is among the leading garlic producing country which contributes 80 percent of the total world production (FAO, 2014). In Pakistan it is cultivated on an area of 172.4 thousand hectares with total production of 1698.1 thousand tones annually and with an average yield of 9 tones per hectares (GoP, 2012). The production of garlic in Pakistan per acre is generally low as compared to other growing countries. Several factors i.e. unavailability of appropriate disease free seeds (Cloves), inappropriate agronomic practices i.e. sowing time, seed rate, irrigation and fertilizer requirement along with poor pest and disease management are responsible for low productivity of garlic (Javed et al., 2008; Mengesha and Azene, 2015). One the major problem of garlic crop is fungal disease and insects, which badly affect the crop yield and over all bulb quality throughout the world (Pinto et al., 2000). Among the fungal diseases, rust has been reported to be the most destructive diseases of garlic and onion which causes critical economic losses to farmers community (Tesfaye and Habtu, 1986; Perez et al., 1994). Garlic rust can attack the plant during bulb formation stage as reported to be the vital stage for the progression of disease (Pinto et al., 2000; Mengesha and Azene, 2015). Closed plantation of garlic crop is more susceptible to rust disease as more moisture is retained within the leaves as close canopy of plants also prevents the entrance of direct sunshine (Jorind, 2012). Previous research studies reveal that optimum plant spacing can significantly improve the garlic bulb quality i.e. bulb weight, bulb size, number of cloves per bulb and yield, minimize disease severity and incidence (Naruka and Dhaka, 2001; Alam et al., 2010). The most recommended plant spacing for garlic crop is 10 cm between plants and 30 cm between the rows (Alam et al., 2010). The optimum plant spacing is an accurate, best and easy way to minimize the incidence and severity of garlic rust and simultaneously enhance crop productivity (Mengesha and Azene, 2015). Higher plant population for garlic crop can increases the bulb yield but it had adverse affect on bulb uniformity and diseases incidence and severity (Liasas and Fernandaez, 1984). Results revealed that in thinner plant population the bulbs become more lavish (Karaye and Yakubu, 2006). Mohibullah (1991) reported that decreasing garlic plant population range from 2.0 to 0.5 million ha^{-1}, decrease the rust severity up-to 10% and simultaneously increase crop yield up-to 28%. There is limited information about the effect of plant spacing on the garlic rust, its incidence, severity and its effect on bulb quality and yield traits. So the present research work was carried out with the objectives to determine the effect of different plants spacings on the incidence and severity of rust and bulb yield and quality of garlic crop.

Materials and Methods

The experiment “Impact of plant spacings on garlic rust, bulb yield and yield components of garlic” was conducted at National Tea and High Value Crops Research Institute (NTHRI) Shinkiari, Mansehra Khyber Pakhtunkhwa Pakistan during the year 2016-17, at an altitude of 1000 meter above the sea level. Garlic variety (china) of uniform bulb size and free from diseases and any defects was planted with three different plant spacings i.e. 10, 15 and 20 cm with 30 cm spacings between the rows, replicated three times in randomized complete block design (RCBD). Nitrogen at the rate of 200 kg and phosphorus at the rate of 160 kg ha^{-1} as urea and single super phosphate were applied at the time of sowing.

Disease assessments

For the assessment of percent disease incidence on weekly basis 10 plants were randomly selected on the commencement of first disease symptom that appeared on selected plants. The percent disease incidence (% DI) was calculated by the following formula.

$$\%\ DI = \frac{No.\ of\ plants\ infected\ X\ 100}{Total\ number\ of\ selected\ plants}$$

Disease severity percentage was assessed by measuring the percent leaf surface covered with rust lesions in all selected plants. Average disease severity of the 10 plant per plot was used for statistical analysis.

Agronomic Data: Data of yield and yield traits were recorded as follow.

Plant Height (cm): Average height of 10 plants per plot was measured from ground level to the tip of pseudo-stem at maturity.

Total Yield (t ha^{-1}): Yield was estimated from the middle three rows of each plot after curing and was converted to tons ha^{-1}.

Bulb weight (g): Average weight of bulb was calculated by weighing 10 randomly select bulbs from each plot after curing.

Bulb diameter (mm): Average diameter of bulb was calculated with the help digital vernier calliper

Table 1: *Garlic rust severity in different days after planting (DAP) using different plants spacing.*

Spacing (cm)	DAP 83	DAP 90	DAP 97	DAP 104	DAP 111	DAP 118
10	12.5 a	18.83 a	30.06 a	34.16 a	42.16 a	55.66 a
15	8.80 b	17.10 ab	26.50 b	31.00 b	36.33 b	48.66 b
20	2.86 c	13.94 b	21.00 c	28.33 c	34.00 b	45.33 b
Grand Mean	8.05	16.62	25.85	31.16	37.5	49.88
CV (%)	1.31	10.19	5.95	3.70	2.88	3.13
SE(±)	0.08	1.38	1.25	0.94	0.88	1.27
LSD (5%)	0.23	3.84	3.48	2.61	2.44	3.54
P value =	0.0000	0.0563	0.0050	0.0089	0.0018	0.0031

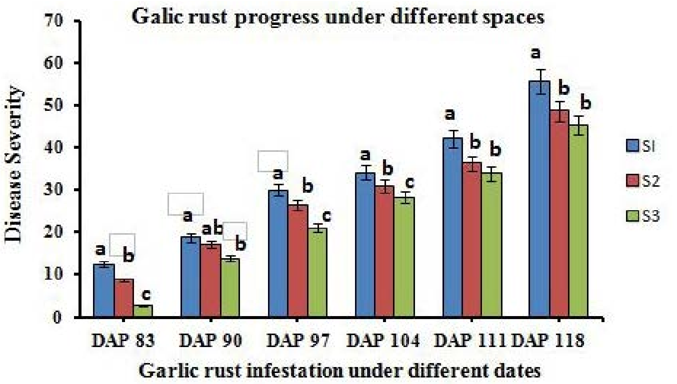

Figure 1: *Garlic rust severity in different days after planting (DAP) using different plants spacing.*

Table 2: *Diseases incidence at different days after sowing.*

Spacing (cm)	DAP 83	DAP 90	DAP 97
10	39.80 a	61.00 a	79.00 a
15	35.83 b	55.33 ab	72.00 b
20	27.22 c	47.66 b	67.00 b
Grand Mean	34.28	54.66	72.66
CV (%)	3.85	6.55	3.60
SE (±)	1.07	2.92	2.13
LSD (5%)	2.99	8.12	5.92
P value =	0.0008	0.0257	0.0124

by measuring the diameter of 10 randomly selected bulbs from each plot after curing.

Number of cloves bulb^{-1}: Average number of cloves per bulb was calculated from 10 randomly selected bulbs from each plot.

Clove weight (g): Average clove weight was measured by dividing the bulb weight by the number of clove bulb^{-1}.

Data analysis

Data regarding garlic rust incidence and severity from each assessment date, yield and yield traits were subjected to ANOVA using statistix 8.1 computer software. Least significant difference (LSD) value at (a=0.05) were used to separate differences among treatments means.

Results and Discussion

Garlic rust onset and intensity

The earliest garlic rust symptoms on plants were observed 81 days after planting (DAP) and the diseases assessment was started on 83rd day after planting. The occurrence of rust disease appeared on all respective plots simultaneously.

Disease incidence and severity (percentage)

Garlic planted at different spacing had significantly differences regarding disease severity (Figure 1). The maximums level of disease severity (55.66%) was observed in plots planted with 10 cm spacing while the lowest level of disease severity (45.33%) was noted in plot planted with 20 cm spacing (Table 1).The different plants spacing showed significant results in term of their respective response to disease incidence and severity. Minimum disease incidence (67%) was recorded in plot with plants at spacing of 20 cm; whereas maximum disease incidence (79%) was recorded in plots with plant spacing @ 10 cm (Table 2). The results revealed that increasing plant spacing can significantly decreases disease incidence and severity level of garlic rust. This might be due to proper aeration resulting in decreased humidity level suitable for fungus growth and decreasing plant population also limits the transmission of rust pathogen to the next plant (Azene and Worku, 2015).

Plant height (cm)

All the treatments had significant effect on plant height. The result showed that plant height decreases with increasing plant spacing (Table 3). The plant

Table 3: *Yield and yield Traits of garlic under different plant spacing sown at different dates.*

Spacing (cm)	BW (g)	BD (mm)	CW (g)	NCB-1	PH (cm)	TY (t h-1)
10	74.66 C	60.66 C	09.84 C	9.633 C	54.00 A	12.85 A
15	86.33 B	63.66 B	10.66 B	11.48 B	47.00 B	11.73 B
20	99.33 A	67.33 A	11.65 A	12.51 A	40.66 C	11.05 C
Grand mean	86.77	63.88	10.71	11.21	47.22	11.88
CV (%)	1.54	0.52	2.78	0.54	3.42	1.89
SE(±)	1.08	0.27	0.24	0.04	1.31	0.18
LSD	3.02	0.75	0.67	0.13	3.66	0.51
P-Value	0.0001	0.0000	0.0045	0.0000	0.0014	0.0016

BW: *Bulb weight;* **BD:** *Bulb diameter;* **CW:** *Clove weight;* **NCB:** *No. of clove per bulb;* **PH:** *Plant height;* **TY:** *Total yield.*

height ranges from 40 to 54 cm. The maximum plant height (54 cm) was recorded from plot planted with 10 cm spacing, whereas minimum plant height (40 cm) was observed in plots planted with 20 cm spacing. This might be due to competition for light at high plant population density. At wider spacing due to less competition for light and other resources, plant remain unaffected by plant density. These results are in agreement with result obtained by Jones Mann (1963), Brewster (1994) on garlic.

Bulb weight (g)

Different plant spacing had significant effect on bulb weight. The results show that bulb weight increases with increase in row spicing (Table 3). The bulb weight ranges from 74.66 to 99.33 gram. Greater bulb weight was noted in plot planted with 20 cm plant spacing and less bulb weight was recorded in plot planted with 10 cm plant spicing. (f-9)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 (2004), who reported that 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 10 cm. On the contrary, Karaye and Yakubu 2005, 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 the fact that in the lowest spacing there might be nutrient competition as well as high disease severity.

Bulb diameter (mm)

Analysis of the data indicates that spacing have significant effect on bulb diameter (mm). The result indicates that bulb diameter increase with increase in spacing (Table 3). Bulb diameter ranges from 60.66 to 67.33 mm. Maximum bulb diameter (67.33mm) was observed in plot planted with 20 cm spacing, whereas minimum bulb diameter (60.66 mm) was noted in plot planted with 10 cm spacing. The probable reason for minimum bulb diameter in closer row spacing might be due to competition of plants for nutrients, moisture and sunshine. Results also testify that wider plant spacing had significantly increased the bulb diameter (Azene and Worku, 2015).

Clove weight (g) and No of clove bulb^{-1}

Significant differences regarding clove weight was observed for all the plant spacing. As maximum clove weight (11.65 g) was noted in plot planted with 20 cm plant spacing, whereas minimum clove weight (09.84 g) was observed in plot planted with 10 cm row spacing. Number of Clove bulb^{-1} was in the range of 9.63 to 12.51 (Table 3). The highest number of Clove bulb^{-1} (12.51) was observed with 20 cm plant spacing as compared to minimum of 9.63 Clove bulb^{-1} in a plot planted with 10 cm plant spacing (Table 3). The results of this study revealed that bulb weight and clove weight significantly increased with wider row spacing as supported by the findings of Darabi and Dehghani, 2004; Abubakar et al., 2008 and Adekpe et al., 2007 who stated that mean bulb weight in number of clove per plant in wider row spacing might be due to vigorous plants that produces larger bulb and more number of clove per plant.

Bulb yield (tons ha^{-1})

Perusal of the data indicated different plant spacing had significant effect on bulb yield (Table 3). The highest bulb yield (12.85 t ha^{-1}) was recorded in plot planted with 10 cm spacing where lowest bulb yield (11.05 t ha^{-1}) was observed in plot planted with 20 cm spacing. The result explained that total bulb yield of the garlic was decreased with wider spacing as compared to closer plantation. The probable reason for higher yield in closed plantation was due to more plants in closer plants. The results are supported by the findings of Darabi and Dehghani, 2004; Karaya and Yakubu, 2005 who illustrated that increasing plant density are more favorable for getting higher yield.

Conclusions

Study on the impact of different plant spacing on disease incidence, severity and yield of garlic revealed that plant spacing had significant effect on disease incidence, severity and phenotypic characteristics and bulb yield tons ha^{-1} of garlic crop. The data showed that although the bulb yield ha^{-1} was higher in 10 cm spacing, but garlic plantation with wider spacing (20 cm) had more efficiency to produce garlic crop with low diseases and higher bulb quality with high market price compared to closer plantation (10 cm). Based on this finding, it is suggested to plant garlic crop at 20 cm spacing to achieve good quality garlic bulbs free from disease with high market price.

Author's Contributions

Imtiaz Ahmed, Muhammad Abbas Khan and Noorullah Khan conceived and designed the experiment, collected and analyzed the data and wrote the paper. Naveed Ahmed, Abdul Waheed, Sajjad Khan, Fazal Yazdan Saleem and Sohail Aslam provided technical assistance at every stage of the experiment and critical reviewed and revised the article.

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