

# Effects of Garlic Rust (*Puccinia allii*) on Yield and Yield Components of Garlic in Bale Highlands, South Eastern Ethiopia

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## Abstract

Garlic (*Allium sativum* L.) is one of the most important crops grown in Bale highlands. Garlic rust caused by *Puccinia allii* is the major disease of garlic in almost all garlic producing regions of Ethiopia. To determine the effects of this disease on yield and yield components of garlic, field experiment was conducted using two garlic varieties, namely the improved variety MM-98 and a local variety at Sinana Agricultural Research Center (SARC), Ethiopia. Five different spray intervals of a systemic fungicide, Tebuconazole (Folicur), were used to create different levels of rust severity. The plots were arranged in Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. There was severe garlic rust development on the plots. The spray intervals created significantly different rust severity levels. The disease inflicted total yield losses as high as 58.75%. The results from this study confirmed that garlic rust can cause considerable losses on the crop in areas where it is prevalent. Hence, application of control measures to minimize the loss is justifiable. Fungicide can be used to effective control of the disease. Its application should be started at very low level of severity and frequent application should be used if the prevailing weather condition seems very conducive for development of the disease. But, the frequency of application should be based on economic analysis with consideration of the costs of fungicide application and return from yield recovery.

**Keywords:** *Puccinia allii*; Garlic; *Allium sativum*

## Introduction

Next to onion, garlic (*Allium sativum* L.) is the second most widely cultivated *Allium* species in Ethiopia. The annual 'meher' season garlic production of this country is estimated at 70,470.73 tons [1]. Ambo, Debre-Work, Adet, Sinana and many other areas of the Ethiopian highlands produce the bulk of garlic under the small-scale farmers sector [2]. In the highlands of Bale, south eastern Ethiopia, farmers produce garlic under rain fed condition during both 'Bona' (August - December) and 'Gena' (March - July) cropping seasons for commercial purpose.

Garlic production is constrained by multiple biotic and abiotic factors in Ethiopia. Garlic rust, which is caused by *Puccinia allii*, is the major disease problem in almost all garlic producing regions of Ethiopia [3]. This disease is the most common, probably the only disease of the crop in Bale highlands. During 'Gena' cropping season of 2005, the level of severity of this disease reached 83.7% on almost all garlic experiments of Sinana Agricultural Research Center on-station, Bale. There was no variability in the level of severity of this disease between improved and local varieties [4].

*Puccinia allii* infects garlic at bulb formation stage [5]. The earliest symptom of garlic rust is small, circular to elongate white flecks that occur on both sides of leaves. As the disease progresses, these small spots expand, and the leaf tissue covering the lesions ruptures and masses of orange, powdery spores (uredospores) then become visible as pustules. Severely infected leaves are almost entirely covered with pustules, resulting in extensive yellowing, wilting and premature drying of leaves. Teliospores, a second type of spores formed by garlic rust fungus, later develop on the same leaves, resulting in black pustules [6].

Studying the effect of a given disease on a specific crop helps to decide on the control measures. Although this rust is the common disease of garlic, its effect on yield and yield components of the crop is not yet studied in Ethiopia in general, and in the highlands of Bale in particular. Hence, this experiment was initiated with the objective of determining the effects of rust on yield and yield components of garlic in the highlands of Bale.

## Materials and Methods

The experiment was conducted using two garlic varieties; improved ('MM-98', released by Debre Brhan Agricultural Research Center, Ethiopia) and local. Uniform sized cloves were used as seeds (planting material). Planting was done on August 18, 2009.

Natural multiple levels of garlic rust severities were created in the experimental plots through application of tebuconazole (Folicur), which is systemic fungicide recommended for the control of the disease in different countries [6,7]. The fungicide was applied at a rate of 1 L-ha<sup>-1</sup> in four different spray schedules viz., every 7, 14, 21 and 28 days. The seven-days spray treatment started on the first date of disease appearance, i.e. on October 29, 2009 (72 days after planting / DAP). The 14, 21 and 28-days intervals spray treatments started two, three and four weeks after the onset of the disease, respectively. Spraying continued at the specified intervals until the crop attained its physiological maturity. Unsprayed plots were included for each variety to allow maximum garlic rust development. During fungicide sprays, plastic sheet was used to separate the plot being sprayed from the adjacent plots to prevent inter-plot interference due to spray drift.

There were a total of 10 treatments comprising two garlic varieties X five fungicide spray treatments (including unsprayed check). Each plot consisted of five rows of 2 m length with a distance of 0.3 m and 0.1 m between rows and plants, respectively. The treatments were arranged in a Randomized Complete Block Design (RCBD) with a factorial layout

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in three replications. The plots were fertilized with DAP and UREA at the rate of 200 and 150 kg per hectare, respectively.

### Diseases assessment

Garlic rust severity was assessed on weekly bases from 21 plants which were randomly pre-tagged with red linen ropes in the middle three rows of each plot (seven plants per row). The assessment started on November 05, 2009 i.e. 79 DAP.

Disease severity was estimated in percentage of the leaf surface covered with lesions. It was assessed from all leaves of a plant and the average was taken (recorded) for the respective plant. Average severity of the 21 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 from planting to 85% of plants of each plot became brown/pale yellow (mature).
2. Plant height (cm): average height of 20 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 (60 plants) of each plot after curing and transformed to tones per hectare.
4. Bulb weight (g): average weight of 10 bulbs 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 IRRISTAT computer soft ware. Least significant difference (LSD) values were used to separate differences among treatment means.

### Yield loss estimation

The relative losses in total yield and yield components were determined as a percentage of the protected plots (weekly fungicide sprayed plots). Losses were calculated separately for each of the treatment with different levels of disease severity using the following formula.

$$RL = \frac{YP - YLT_x}{YP} \times 100$$

Where, RL- relative loss (reduction of the parameters; total yield or yield component); YP- mean of the specific parameter from the maximum protected plots (spray at 7-days intervals) and YLT is

respective parameter from lower treatment plots (sprays at 14, 21 or 28 day intervals or unsprayed control).

## Results and Discussion

### Garlic rust severity

Garlic rust was first observed on October 29, 2009; 72 days after planting (DAP). However, garlic rust assessment was started on November 05, 2009 (79 DAP).

The two varieties, improved (*MM-98*) and local, were not significantly ( $p < 0.05$ ) different in terms of their respective reaction to the disease i.e. both the improved and local varieties were equally susceptible to the rust. The interaction between variety and spray intervals was also non-significant ( $p < 0.05$ ) (Appendix table 1).

Significantly different levels of garlic rust severity were created by the different schedules of fungicide application. The plots showed significantly ( $p < 0.05$ ) different levels of garlic rust severity starting from the first date of disease assessment (79 DAP). During each disease assessment, the lowest average severity level of garlic rust was recorded on weekly fungicide sprayed plots. The maximum level of severity on these plots, 0.25%, was recorded on the first date of disease assessment. There was no significant ( $p < 0.05$ ) garlic rust severity difference between plots treated with fungicide at interval of both every 14- as well as 21-days and the rest two spray intervals (28-days interval and no spray) until the fourth date of disease assessment. The difference between the levels of disease severity on plots treated with fungicide at interval of 14- and 21-days remained statistically ( $p < 0.05$ ) non-significant until the fifth date of disease assessment. Plot sprayed at 28-days interval showed significantly lower disease severity than the unsprayed plot after a week when it was first treated with the fungicide. The unsprayed plot had the maximum disease severity levels consistently for the last five assessment dates. On the final date of disease assessment i.e. on the 135<sup>th</sup> DAP, the mean severity level of the disease on unsprayed plot was 82.77% where as on plots on which fungicide was sprayed at intervals of 14-, 21- and 28-days were 45.58, 57.25 and 70.17%, respectively (Table 1).

### Relative losses in yield and yield components and variation in agronomic parameters

**Losses in total yield:** The data from this experiment showed that, similar to the disease severity, there was not significant ( $p < 0.05$ ) total yield difference between the improved, *MM-98*, and local varieties (Appendix table 2). And also, the interaction between the varieties and the spray intervals could not result significant total yield difference among the plots. The different spray intervals and the consequent difference in disease severity resulted difference in total yield among the experimental plots. The highest total yield was obtained from plots in which garlic rust was completely controlled with 7-days fungicide spray interval (Table 2).

All fungicide-treated plots gave higher total yield than the unsprayed check plots. However, the plots treated with the fungicide at 28-days interval could not give significantly ( $P < 0.05$  %) higher yield than the unsprayed plots. Controlling garlic rust by spraying the fungicide every 14- or 21-day intervals gave significantly higher yield than the 28-days interval and the unsprayed plot treatments. However, the plots sprayed every 14 days could not give significantly higher yield than the 21 days interval treatment. At this location, the highest relative yield loss obtained from unsprayed plots was 58.75 % (Table 2). This yield loss is higher than the loss caused by the same disease on garlic in the USA where the loss was estimated about 50 % [6]. However, it is less

Spray intervals (days)	Garlic rust severity assessed at different days after planting (%)								
	79DAP	86DAP	93DAP	100DAP	107DAP	114DAP	121DAP	128DAP	135DAP
7	0.25	0.08	0.02	0.03	0.03	0.00	0.00	0.00	0.00
14	11.42	22.25	25.67	31.58	34.54	38.92	40.58	43.08	45.58
21	10.50	20.50	29.75	34.33	41.42	47.25	49.96	53.08	57.25
28	10.50	20.25	29.42	41.83	46.42	54.75	58.92	64.33	70.17
No spray	9.75	20.00	28.92	40.58	52.67	64.75	72.25	77.42	82.77
CV (%)	17.8	13.5	19.3	11.6	6.7	7.3	8.5	7.9	5.2
SE	0.62	0.92	1.79	1.40	0.95	1.23	1.53	1.53	1.08
LSD (0.05)	1.83	2.72	5.33	4.16	2.84	3.64	4.55	4.56	3.20

Table 1: Garlic rust severities at different days after planting under different fungicide spray intervals in 2009/10 'Bona' cropping season.

Spray interval (days)	Total yield (t/ha)	RTYL (%)	Bulb weight (g)	RBWL (%)	Bulb diameter (mm)	RBDL (%)	Number of clove/bulb	RLNC/B (%)	Clove weight (g)	RCWL (%)
7	12.46	0.00	40.51	0.00	48.77	0.00	22.03	0.00	1.93	0.00
14	7.95	36.24	26.92	33.55	41.28	15.36	22.97	+4.24	1.21	37.26
21	7.10	43.01	24.31	39.98	36.64	24.88	20.19	8.36	1.30	32.45
28	6.01	51.82	20.54	49.28	34.64	28.98	15.10	31.47	1.40	27.66
No spray	5.14	58.75	18.18	55.12	30.06	38.37	19.02	13.69	0.99	48.86
CV (%)	9.8		8.90		9.70		23.70		23.80	
SE	0.31		0.95		1.51		1.92		0.13	
LSD (0.05)	0.92		2.81		4.48		NS		0.39	

NS – Non-significant at p = 0.05 level of significance

RTYL- Relative total yield loss, RBWL- Relative bulb weight loss, RBDL- Relative bulb diameter loss/reduction  
RLNC/B- Relative loss in number cloves per bulb, RCWL- Relative clove weight loss

Table 2: Yield and yield components of garlic and the corresponding relative losses due to garlic rust under different spray intervals in 2009/10 'Bona' cropping season.

than the loss (83%) reported by Ahmad and Iqbal [8] in Nepal.

**Losses in bulb weight:** Bulb weight was significantly ( $p < 0.05$ ) different among the spray intervals (Appendix table 3). Similar to the total yield, the highest bulb weight was obtained from weekly fungicide sprayed plots. The different disease severity levels created by different fungicide spray intervals caused different amount of losses in bulb weight.

All plots treated with the fungicide gave bulbs with higher average weight than the unsprayed plots. However, the average weight of bulbs harvested from the 28-days interval treatment plots were not statistically ( $p < 0.05$ ) heavier than that of the unsprayed plots. Bulbs obtained from plots in which the fungicide was sprayed every 14 and 21 days were significantly ( $p < 0.05$ ) higher in weight than bulbs from plots sprayed with the fungicide every 28 days as well as weights obtained from the unsprayed plots. There was no significant difference in weight of bulbs from plots in which the fungicide was sprayed every 14- and 21-day. The highest bulb weight loss from the unsprayed plots at Shallo was 55.12%. This value is in the range of the amount of loss in bulb weight due to the same disease which was estimated about 25-60% [6]. Bulb weight losses from plots treated with the fungicide at spray intervals of 14, 21 and 28 days were 33.55, 39.98 and 49.28%, respectively (Table 2).

**Reduction in bulb diameter:** Alike the above two yield parameters, bulb diameter was significantly ( $p < 0.05$ ) different among the spray intervals (Appendix table 4). This parameter was the least affected yield component by garlic rust as compared to bulb and clove weights.

All the fungicide-treated plots gave higher bulb diameter than the unsprayed plots. The highest bulb diameter (48.77 mm) was recorded on bulbs from weekly fungicide-sprayed plot while the smallest (30.06 mm) was from unsprayed plots. Unlike total yield and bulb weight, average diameter of bulbs harvested from plots under every 14 days

interval treatment was significantly longer than those harvested from plots in which garlic rust was controlled at 21 days interval. Spraying fungicide at 21-days interval however did not give significantly ( $p < 0.05$ ) larger bulb diameter than the bulbs harvested from plots treated at 28-days spray interval. The highest relative reduction (38.37%) in bulb diameter was obtained from the unsprayed plots (Table 2).

**Loss in number of cloves per bulb:** There was no significant ( $p < 0.05$ ) difference in the number of cloves per bulb among the different spray intervals (Appendix table 5).

**Losses in clove weight:** The clove weight was computed by dividing the bulb weight by the respective number of cloves. Hence, its value was determined by the number of cloves per bulb which was non-significant among all treatments. The highest clove weight was obtained from bulbs harvested from plots sprayed with fungicide at weekly interval (Appendix table 6).

Next to the weekly sprayed plots, cloves, with higher average weight (1.4 g) were obtained from plots chemically treated at interval of 28 days. The lowest clove weight (0.58 g) was recorded from the unsprayed plots. However, only plots sprayed with the fungicide every 7 and 28 days gave statistically ( $p < 0.05$ ) heavier cloves than those from the unsprayed plots. The highest clove weight loss (48.86%) was recorded from the unsprayed plots (Table 2).

**Difference in days to maturity:** There was significant ( $p < 0.05$ ) difference in days to maturity (DTM) of garlic plots sprayed with fungicide at different intervals. DTM of the every 7- and 14-days interval treatment plots was statistically ( $p < 0.05$ ) longer than the unsprayed plot. However, DTM of plots under the rest two spray intervals was not statistically different from the unsprayed ones (Table 3).

The reason why the days to maturity of completely protected plots

were longer as compared to the unsprayed ones is, garlic leaves that are heavily infected by rust dry prematurely [6,9].

**Difference in plant height:** There was no significant ( $p < 0.05$ ) height difference among plants from plots treated with different fungicide spray intervals (Table 3). Hence, this parameter was not affected by the disease.

## Summary and Conclusions

Field experiment was conducted to study the effects of garlic rust (*Puccinia allii*) on yield and yield components of garlic at research field of Sinana Agricultural Research Center (SARC) on station, Ethiopia. The experiments were conducted using two garlic varieties; improved ('MM-98') and local. Natural multiple levels of garlic rust severities were created in the experimental plots through application of tebuconazole (Folicur), which is systemic and effective fungicide against the disease, in four different spray schedules.

The four spray intervals created significantly different disease severity levels. The disease severity in all fungicide sprayed plots was significantly lower than the unsprayed ones. Among fungicide sprayed plots, the lowest disease severity level was recorded on plots in which the disease was controlled every week while the highest was on plots in which fungicide was applied at 28-days interval after the onset of the disease. These indicated that spraying fungicide on garlic fields infected with garlic rust at different schedule have different effect on garlic rust development. Generally, the disease was severe in all plots except the weekly sprayed ones. This indicated that, garlic rust progression is difficult to contain under favorable conditions once the plots are uniformly infected. Hence, early garlic rust detection and application of fungicide while the disease was less severe is very essential if effective control measure is intended.

Different levels of rust severities created by the different fungicide spray intervals could result different amount of losses in total yield and yield components of the crop. The highest severity level (82.77%), recorded in the unsprayed plots, could result relative total yield losses of 58.75%. This level of severity could also reduce the size of the bulbs (bulb weight as well as diameter and clove weight) which were positively correlated with total yield. The average weight of the bulbs was reduced by 55.12 while the bulb diameter was reduced by 38.37. The highest relative losses were recorded from the unsprayed plots. Among the less protected plots, the lowest total yield loss was recorded on plots in which rust was controlled every 14 days after the onset of the disease while the highest was from plots in which fungicide was sprayed between 28 days interval after the onset of the disease. Plants, on which rust was controlled every week, at both locations, remained green and disease free for long period of time as compared to the others and plants of the unsprayed plots matured early. This is

because, garlic leaves that are heavily infected by rust dry prematurely and plants remained green get longer time to develop or enlarge their bulbs. The results showed that, losses in garlic yield due to rust can be minimized by controlling the disease by spraying fungicide during early development of the disease as well as at short intervals. Unlike the total yield and yield components, the height of garlic plants was not affected by *Puccinia allii*.

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. Fungicide can be used to effective control of garlic rust. But, fungicide application should be started at very low level of garlic rust severity and frequent application should be used if the prevailing weather condition seems very conducive for development of the disease. But, the frequency of application should be based on economic analysis with consideration of the costs of fungicide application and return from yield recovery.

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Fungicide spray intervals (days)	DTM	PH (cm)
7	176.50	33.50
14	171.67	33.10
21	167.50	32.33
28	164.33	32.60
No spray	161.00	31.17
CV (%)	3.90	6.10
SE	2.68	0.81
LSD (0.05)	7.96	NS

NS- Non-significant difference at  $p = 0.05$ .

**Table 3:** Days to maturity and plant height of garlic under different fungicide spray intervals in 2009/10 'Bona' cropping season.