Management of Garlic Rust (Puccinia allii) Through Fungicide at Bale Highlands, South Eastern Ethiopia

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Abstract
Garlic (Allium sativum L.) is one of the most important crops in worldwide. Despite its importance, production and productivity of this particular crop is highly constrained by several biotic and abiotic factors among which fungal diseases are very devastating. Garlic rust which is caused by Puccinia allii is the most common and economically important fungal disease. *F*ield experiments were conducted with the objective to study the effects of natura spray at rates of 0.25, 0.5, and 0.75 L/ha and frequencies of application (at 7, 14, 21, 28- day and no spray) on the spatial epidemics of garlic rust. The experiments were conducted in the main cropping seasons (August–December) in 2017 at Madda Walabu University Research Site (MWURS) and Sinana Agricultural Research Center (SARC) in Bale highlands, Ethiopia. Percentage severity index (PSI), disease progress rate (DPR) and area under disease progress curve (AUDPC) were used to evaluate the effects of the treatments. The final levels of disease severity were about 89.9% at MWURS and 87.2% at SARC on unsprayed plots.The disease developed at a rate of -0.011 units per day at weekly interval when 0.75L/ha natura sprayed and 0.075 units per day under natural disease epidemics at MWURS. Marketable yield harvested from sprayed plots was consistently greater than the yield harvested from unsprayed plots. Since the study was conducted for one season at two locations, similar study need to be conducted at different locations with similar agro-ecologies and more number of seasons.
Keywords: Allium sativum; Disease progress rate; Fungicide; Puccinia allii; Bale highlands, AUDPC

1. INRODUCTION

Garlic (*Allium sativum* L.) belongs to Alliaceae family and the origin of garlic is thought to be in Central Asia and spread to other parts of the world through trade and colonization (Brewster, 1994). Garlic has been used in China and India for more than 5000 years, and Egypt since 2000 BC (Kamenetsky and Rabinowitch, 2001). Garlic is among the most important bulb vegetable crops used as a seasoning or condiment of foods because of its pungent flavor. It possesses high nutritive value. Furthermore, garlic has miracle pharmaceutical effects and used to cure an enormous disease including blood pressure, cholesterol, cancer, hepato protective, antihelmentics, anti-inflammatory, 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 (Mengesha *et al*., 2015). It is the second most widely cultivated Allium species next to onion in Ethiopia (Zewde *et al*., 2007). Garlic is produced mainly in the mid and highlands of Ethiopia such as Arsi, Bale, Shewa, Jimma, Wolaita, Haddiya and many other areas (Zewde *et al*., 2007; Kero, 2010; Worku and Dejene, 2012) and the bulk of garlic for domestic market is produced in homestead gardens of subsistence farmers.

Garlic production and productivity are very low due to many biotic and abiotic factors such as lack of high yielding varieties, non-availability of quality seeds, imbalanced fertilizer use, lack of irrigation facilities, lack of proper disease and insect management and other agronomic practices, low storability, and lack of proper marketing facilities (Getachew and Asfaw, 2000; Siyoum and Mohammed, 2013; Diriba, 2016). Among the fungal diseases, foliar disease, caused by the fungus are some of the most destructive plant diseases worldwide (Agrios, 2005). From foliar disease garlic rust caused by *Puccinia allii* is the major destructive disease problem in almost all garlic producing regions of Ethiopia (Tesfaye and Habtu, 2003; Mengesha *et al*., 2016); Worku, 2017). The disease does not attack the garlic bulb directly, but it damages on the leaves which indirect effect size and quality of bulbs at harvest thereby reduce its marketability (Koike *et al*., 2001, Tahir *et al*., 2006). Until recently, this fungus was considered to be of minor importance in garlic production. Heavily infected plants may be more susceptible to secondary infections and there can be direct bulb yield losses. Worldwide, garlic rust has caused significant losses to garlic, leek, and onion production. Yeshewas *et al*. (2018) screened 16 garlic germplasm for yield and diseases tolerance in east Gojam and reported none of the germplams showed high resistance to rust. Additionally use of resistant varieties is cheaper but such varieties are not available in Ethiopia (Worku, 2017).

There are different fungicides recommended for the control of garlic rust on different Allium crops in

different countries. So far in Ethiopia, fungicides such as mancozeb (Manzate, Mancofol, Dithane-M-45, Zineb+Maneb), triadimefon (Bayleton), triadimenol (Bayfidan), propiconazole (Tilt) and tebuconazole (Folicur) were tried to control garlic rust (Worku and Dejene, 2012; Meseret, 2013; Mengesha *et al*., 2016; Work, 2017), but still the disease is devastating. This might be resistance was developed against those fungicides or new virulent races were arrived. In spite of the importance of garlic rust and its frequent epidemics in the Bale highlands, no study has been conducted to study spatial development of this disease and natura fungicide as a component strategy to manage the disease. Therefore, there is a research need for evaluation of the fungicidal spray rates and frequencies for control of garlic rust. The objective of this study was to determine the effect of fungicide applications on rust development on garlic at Bale highlands.
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2. Materials and methods

2.1. Experimental Design and Treatments

Field experiments were conducted during 2017/2018 main cropping season over two locations at Madda Walabu University Research Site (MWURS) and Sinana Agricultural Research Center (SARC). Three different rates of natura (0.25L/ha, 0.5L/ha and 0.75L/ha) and four spraying intervals (7, 14, 21, and 28 days) were used. During fungicide application, plastic sheet was used to separate the plot being sprayed from the neighboring plots to prevent inter-plot interference due to spray drift. Uniform size of local garlic variety from local market was used; planting was done during main cropping season on August 22, 2017.

The experiment were laid out in a factorial treatment combinations of three fungicide rates and four spray frequencies using a randomized complete block design (RCBD) with three replications. Thus, with the addition of one control (unsprayed plot); there were 13 total treatments. Spacing of 30 cm between rows and 10 cm between plants were uniformly adopted along other recommended cultural practices. Spacing of 0.5 m between plots and 1m between blocks were used. The middle three rows were used as net plot for data while the exterior single rows in both sides were left to control the border effect. All other agronomic practices, such as weeding and cultivation were implemented during the course of the study as per specific recommendation for garlic.

2.2. Disease Assessment

Disease severity were recorded on 12 pre-tagged plants from the middle three rows of each plot at an interval of seven days starting from one week after the appearance of the disease symptom. Seven assessments were done at both locations. Severity was rated by estimating the percentage of leaf area diseased using standard disease scales of 1-5 rust severity, where, 1 = 1 - 10%, 2 = 11 - 25%, 3 = 26 - 50%, 4 = 51 - 75%, and 5 = 76 - 100% of the leaf surface covered with lesion (Koike et al., 2001). The scores were changed into percentage severity index (PSI) for analysis using the following formula:

$$\text{Disease severity (\%)} = \frac{\textbf{Total points score x 100}}{\textbf{Total number of plants x highest score}}$$

Area under disease progress curve will be calculated for each plot by using the following formula:

$$\text{AUDPC} = \sum_{i=1}^{n-1} [0.5(y_{i+1} + y_i)(t_{i+1} - t_i)]$$

Where, y_i= the cumulative disease severity expressed as a proportion at the i^{th} observation,
t_i =the time of i^{th} assessment in days, n=the total number of observation.

2.3. Data Analysis

The data on disease severity were transformed using gompertz -ln [-ln(y)] model, before statistical analysis. The transformed data were then regressed over time and the disease progress rate was analyzed. Percentage severity index data from each assessment, disease progress rate, AUDPC and marketable yield data were subjected to ANOVA to determine treatment effect. Least significance differences (LSD) value was used to separate the means. Data analysis was conducted using the SAS statistical software, version 9.2 (SAS, 2008) using the general linear model (PROC GLM) procedure. For each response, assumption of ANOVA (normal distribution and constant variance of the error terms or homogeneity) was tested by examining the residuals.

3. Results

3.1. Percent severity index (PSI)

There was significant difference between the different fungicidal spray frequencies with regard to percentage severity index at both locations. During each disease assessment, the lowest PSI of garlic rust was recorded on seven days interval fungicide sprayed plots at rate of 0.75L/ha (0%) and 0.5L/ha (1.1%) at MWURS (Figure 1). Similarly, at SARC the lowest PSI was recorded on weekly sprayed plots at rate of 0.5 L/ha (0.5%) and 0.75 L/ha (0%). But the highest percentage severity index was recorded from unsprayed plot, at SARC (87.2%) and at MWURS (89.9%). At MWURS those plots treated at rate of 0.5L/ha had showed significant difference among different fungicidal spray frequencies, 7-day (1.1%), 14-day (28.86%), 21-day (37.2%) and 28-day (67.2%). Similarly, at SARC those plots treated at rate 0.5L/ha had showed significant difference among different fungicidal spray frequencies, 7-day (0.5%), 14-day (24.9%), 21-day (30.5%) and 28-day (59.4%) (Figure 1).

3.2. Area under disease progress curve (AUDPC)

AUDPC is a very convenient summary of plant disease epidemics that incorporates initial intensity, the rate parameter, and the duration of the epidemic which determines final disease intensity. Information on AUDPC is important for interpretation of epidemics and development of effective disease control measures. There were significant differences among spray intervals in AUDPC (Table 1). At both locations, AUDPC was higher on unsprayed control. In both locations, the short spray interval (7 days) had a lower AUDPC than the other spray intervals of natura. The AUDPC value at MWURS was higher than at SARC. The AUDPC value of 116.6-%-days was recorded at rate of 0.75L/ha at seven day interval and 2344.9%-days on unsprayed control. Similar trend was observed at SARC (Table 1).

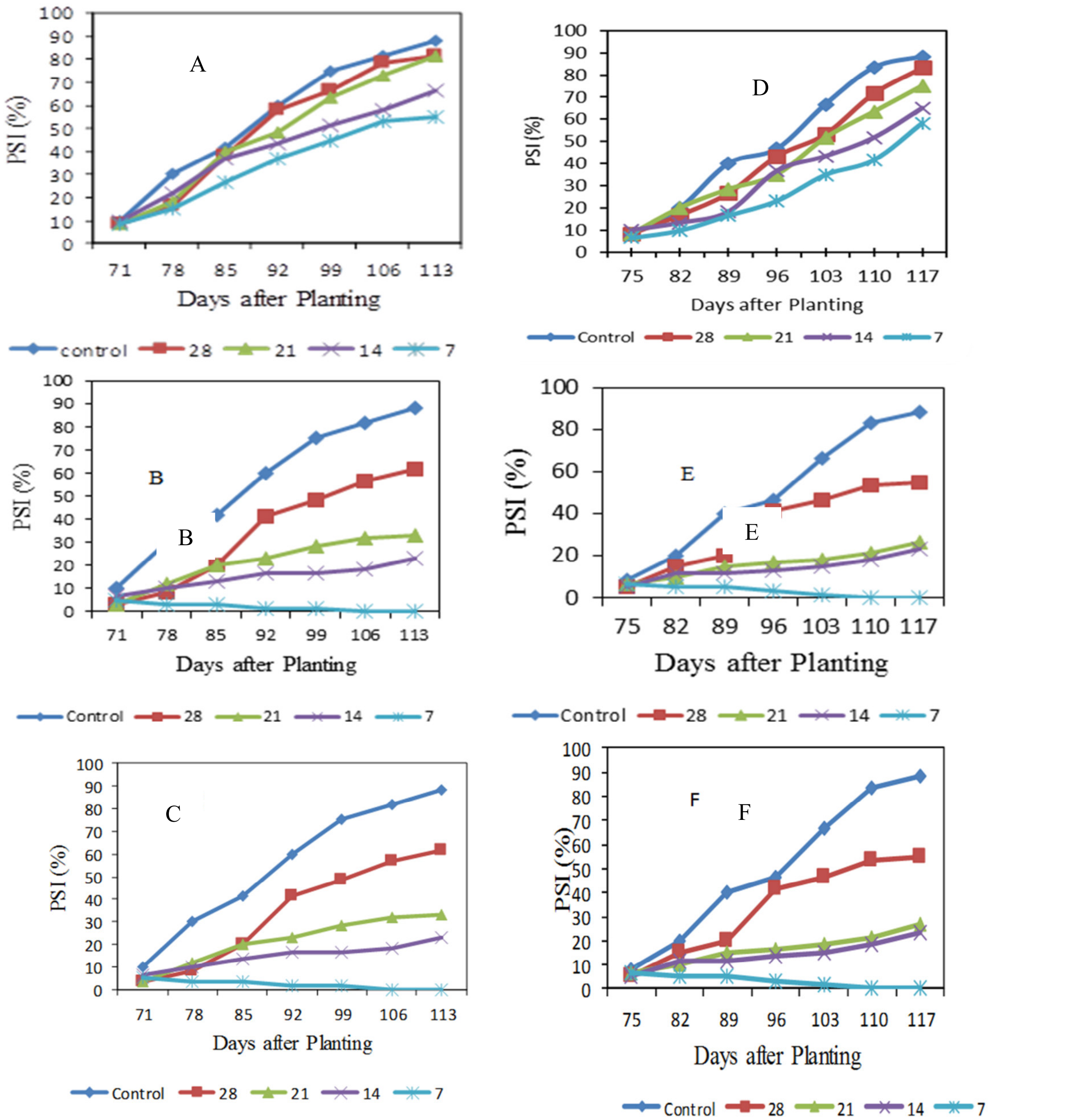

Figure 1. Garlic rust disease progress curve under different spray intervals at rate of (A) 0.25L/ha, (B) 0.5L/ha and (C) 0.75L/ha at MWURS and (D) 0.25L/ha, (E) 0.5L/ha and (F) 0.75L/ha in SARC during 2017 main cropping season. Disease severity was assessed every 7-days starting from 71 days after planting at MWURS and 75 days after planting at SARC

3.3. Disease Progress rate (DPR)

At MWURS the highest disease progress rate (0.075 units/day) was obtained in unsprayed control plots. Hence, rust progress rate was faster on unsprayed control plots and the next disease progress were estimated from 0.25L/ha fungicidal spray rates at 28-day (0.07 units/day), 21-day (0.06 units/day), 14-day (0.05 units/day), 7-day (0.04 units/day), whereas the lowest disease progress rate (-0.011 %-days) was estimated on garlic plots sprayed at weekly interval with 0.75 L/ha (Table 1), which was significantly different from all the other treatment tested.

At SARC, the highest disease progress rate (0.065 units/day) was estimated from unsprayed control, whereas the lowest infection rate (-0.011 units/day) was estimated on garlic plots sprayed at weekly interval at rate of 0.75L/ha (Table 1), which was significantly different from all the other treatment tested. From plots treated with fungicide higher disease progress rate was estimated at rate of 0.25L/ha, 28–day (0.062 units/day), 21-day (0.050 units/day), 14-day (0.040 units/day) and 7-day (0.035 units/day) intervals. Moreover, among the fungicide spray rates, lower infection rate was recorded from the plots treated with natura at 0.75 L/ha and 0.5 L/ha on all frequencies of fungicide spray than 0.25L/ha of foliar spray rate at both experimental sites.

3.4. Marketable Yield

Fungicide spray at different spray intervals significant affect marketable yields at both locations. At MWURS lower (3260 Kg/ha) marketable bulb yields were obtained from unsprayed control plots whereas, the highest (8481.7 Kg/ha) marketable yield was obtained from plots sprayed with of 0.75 L/ha treated in weekly basis. However, it was not significantly different in marketable yield (8308.76 Kg/ha) from plots treated at a rate of 0.75L/ha in 14-days interval. The marketable yield obtained from plots treated with 0.25L/ha at frequencies of 21 day (3588.76Kg/ha) and 28 day (3475.68 Kg/ha) interval were the least among sprayed plots, it was not statistically ($p > 0.05$) different from unsprayed control at both locations. At SARC, marketable yield ranged from 8679.63 Kg/ha obtained from 0.75L/ha to 4029.63 Kg/ha obtained from unsprayed plots.

Table 1. Area under disease progress curve (AUDPC) and disease progress rate (DPR) of garlic rust sprayed with natura at Madda Walabu University Research Site (MWURS) and Sinana Agricultural Research Center (SARC) in 2017 main cropping season.

Rate (L/ha)	Spray Frequency (days)	AUDPC		DPR (Units/day)	
		MWURS	SARC	MWURS	SARC
0.25	7	1521.72	1261.38	0.04	0.035
	14	1718.2	1527.8	0.05	0.04
	21	2050	1689.1	0.06	0.05
	28	2186.1	1887	0.07	0.062
	Control	2344.9	2085.5	0.075	0.065
	Mean	1964.18	1690.16	0.059	0.05
	CV (%)	3.5	6.7	5.07	7.74
	LSD (0.05)	130.3	220.2	0.005	0.008
0.5	7	120.6	97.85	-0.011	-0.013
	14	758.67	727.17	0.018	0.015
	21	968.12	840.3	0.022	0.02
	28	1569.47	1449.6	0.05	0.042
	Control	2344.9	2085.5	0.075	0.065
	Mean	1152.35	1040.08	0.0308	0.0258
	CV (%)	8.21	7.76	6.5	12.3
	LSD (0.05)	178.3	152	0.004	0.006
0.75	7	116.3	111.18	-0.011	-0.014
	14	669.5	603.86	0.014	0.012
	21	903.41	732.1	0.023	0.017
	28	1492.98	1385.5	0.047	0.04
	Control	2344.9	2085.5	0.075	0.065
	Mean	1105.42	983.63	0.0296	0.024
	CV (%)	4.71	7.8	0.029	11.7
	LSD (0.05)	98.2	144.8	0.003	0.005

MWURS, Madda Walabu University Research Site; SARC, Sinana Agricultural Research Center; CV, Coefficient of variation; AUDPC, area under disease progress curve, DPR, Disease progress rate.

Table 2: Effect of natura applications at different spray intervals and rates on marketable yield of garlic at MWURS and SARC, Ethiopia in 2017 main cropping season

Rate (L/ha)	Spray Frequency (day)	Marketable yield (Kg/ha) MWURS	SARC
0.25	7	5544.32	5975.3
	14	4309.87	4659.26
	21	3588.76	4508.64
	28	3475.68	4269.13
	Control	3260.24	4029.63
	Mean	4035.77	4688.39
	CV (%)	12.32	14.25
	LSD(0.05)	778	1260
0.5	7	8441.11	8629.75
	14	8155.56	8382.71
	21	7570.86	7703.7
	28	4965.93	5449.38
	Control	3260.24	4029.63
	Mean	6478.74	6839.03
	CV (%)	10.23	8.52
	LSD(0.05)	1463	1100.08
0.75	7	8481.72	8679.63
	14	8308.76	8443.33
	21	7846.42	7925.92
	28	5260.49	5809.87
	Control	3260.24	4029.63
	Mean	6631.53	6977.68
	CV (%)	4.66	8.1
	LSD(0.05)	582.4	1070

MWURS, Madda Walabu University Research Site; SARC, Sinana Agricultural Research Center; CV, Coefficient of variation

4. Discussion

Field experiment was conducted to determine the effects of natura fungicide sprayed at rates of 0.25, 0.5 and 0.75 L/ha and frequencies of 7, 14, 21, 28-day at MWURS and SARC. The fungicide treatments created significantly different severity levels. The severity levels created using different frequencies of fungicide application resulted in significantly different ($P < 0.05$) disease progress rates. The garlic rust epidemic lasted up to the end of the season at both locations and resulted in severe infection on the unsprayed control. Disease progress was compared among the different rates and frequencies of fungicide foliar spray using PSI, AUDPC and DPR. Disease progress rate helps to determine whether disease develops in one treatment faster than the other.

At both locations application of natura on garlic at weekly interval with 0.75L/ha completely control rust and followed by 0.5L/ha at weekly interval. Koike *et al*. (2001) reported that, in USA tebuconazole consistently provide best control of rust and gives the highest yields. Hence, tebuconazole is active ingredients of natura, those fungicides that contain tebuconazole as active ingredient were effective in controlling garlic rust and were recommended in different parts of the world for the management of garlic rust and other disease of garlic (Maria *et al*., 1998; Zewde *et al*., 2007; Worku, 2017). Generally, the disease was severe in all plots, except the weekly and 14-day sprayed ones at rates of 0.5L/ha and 0.75L/ha. This indicated that, garlic rust progression is difficult to control 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. Previous research studies revealed garlic rust can significantly minimize the garlic bulb quality i.e. bulb weight, bulb size, number of cloves per bulb and yield (Ahmed et al., 2017). Again bulbs infected with garlic rust remain small and are of low storage quality (Sartaj and Ahmad, 2005). Mueller *et al*. (2009) reported soybean yields from plots treated with fungicides were 16 to 114% greater than yields from no fungicide control plots in four locations in Paraguay.

Generally, from this finding, use of 0.75L/ha of natura fungicide at 14 day spray interval is recommended for end users. However, since the study was first hand exercise in determining the effect of different rate of natura and spray intervals to control *Puccinia allii*, similar study need to be conducted at different locations and more number of seasons.

Competing Interests
The authors declare that they have no competing interests.

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