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Research Article

Evaluation of Fungicides for the Management of Garlic White Rot (*Sclerotium cepivorum*) at Debre Berhan, Central Ethiopia

Zenebu Shewakena[1], Negash Hailu[2]*, Buzayehu Desta[2]

[1]*Department of Plant Science, Jinka University, Jinka, Ethiopia;* [2]*Department of Plant Science, Debre Berhan University, Debre Berhan, Ethiopia*

ABSTRACT

Garlic is one of the most important crops widely cultivated throughout the world including Ethiopia. It is the second most widely cultivated Allium species next to onion. The production of the crop is majorly threatened by fungal diseases. White rot of garlic caused by *Sclerotium cepivorum*, is the most devastating constraint in Ethiopia. A field experiment was conducted to evaluate the effect of fungicide types on incidence and severity of garlic white rot, yield and yield components of garlic and to identify the effective method of fungicides application under rain fed supplemented with irrigation at Debre Berhan University Research site in 2017/18 .The experiment was consisted of three types of fungicides (Apron star, MORE 720 WP and Mancozeb) with three methods of application (clove, clove plus foliar and foliar). The experiment was laid out as RCBD in a factorial arrangement with three replications. Fungicide types and methods of application significantly affected disease incidence, percentage of disease severity, area under disease progress curve (AUDPC), yield and yield components. Clove and clove plus foliar applied Apron star was the most effective in reducing the disease epidemics and gave better yield advantage. Clove applied Apron star has reduced the initial severity, final severity and incidence by 64.7%, 70.9% and 80.6% respectively, as compared to the untreated plots. About 63.6% and 51.9% increment of average bulb weight and yield were recorded in clove applied Apron star respectively, as compared to the untreated plots. The highest net return (35,350 birr) was obtained from clove applied Apron star plots, while the lowest net return (2350 birr) was obtained from foliar applied Apron star plots. Hence, it could be concluded that clove applied with Apron star needs to use for the disease management in the study area.

Keywords: Garlic; Fungicides; White rot; *Sclerotium cepivorum*

INTRODUCTION

Garlic (*Allium sativum* L) belongs to the family Alliaceae, and is the second most widely cultivated Allium species next to onion [1,2], and its close relatives include the onion, shallot, and leek [3,4].It is widely produced for its culinary properties and medicinal role for centuries such as antibacterial, antifungal, antiviral, antitumor and antiseptic properties [3]. Keusgen [5] also reported that antibacterial and antiseptic property of garlic is well known and it contains remedies against headache, bites, worms and tumors. In addition, it has antibiotic properties, and it can lower blood pressure, blood cholesterol and blood sugar, prevent blood clotting, protect the liver and contains antitumor properties [6]. Garlic volatile oil has many sulfur-containing compounds that are responsible for the strong odor, its distinctive flavor and pungency as well as for its healthful benefits [7]. In Ethiopia, the Alliums group (garlic, onion and shallot) are important bulb crops produced by small and commercial growers for both local use and export markets. Production of cash crops like garlic and other spices is proved to be income generating activity for farmers, especially for those who have limited cultivated land or small holder farmers [8]. However, its cultivation decreased from 16,411.19 ha in 2013/14 to 15,381 ha in 2016/17 with a total production of 159, 093.58 and 138,664.3 tons of bulbs with the productivity of 9.7 and 9.02 t ha^{-1}, respectively [9]. It was reported that heavy damage to garlic due to fungal diseases, in later years, has become very important in major production areas of garlic [10]. Among the fungal disease; white rot (*Sclerotium cepivorum* Berk.), garlic rust (*Puccinia allii Rudolphi*), downy mildew (*Peronospora destructor* Berk), and basal rot (*Sclerotium rolfsii* Sacc.) are common [7,11]. However, onion and garlic white rot caused by *Sclerotium cepivorum* is a major production threat of garlic and onion in Ethiopia. It persists as small, dormant structures, called sclerotia, in soil. Sclerotia can survive for over 20 years, in the absence of a host plant [11]. It proliferates in cool soils,

Correspondence to: Negash Hailu, Department of Plant Science, Jinka University, Jinka, Ethiopia, Tel: +251911850734; E-mail: negash.hailu17@gmail.com

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and once white rot is in a field, it is very difficult to cultivate garlic and onions [10,12].

Root rot of garlic caused by *Sclerotium cepivorum* disease is prevalent in many Allium growing regions worldwide, and causes serious economic losses in garlic and onion crops. In Mexico and Brazil, losses up to 100% were reported [13]. In Ethiopia, yield loss due to white rot has been found to range between 20.7% and 53.4%. Around northern Shewa white rot incidence was reported at a level ranging from 37.28% to 42% in farmers' fields [4]. During favorable weather condition and when susceptible varieties are in the production system, the disease can cause 100% yield loss [14].

Management of garlic white rot is very difficult and need a multi-pronged management strategy. Fungicides are among the most effective options for garlic white rot disease management. It has been found that systemic as well as non-systemic fungicides significantly reduced the disease development and resulted in improved garlic yield. Several effective fungicides have been recommended against this pathogen [4]. Among these, Apron star 42 WS is the most effective means of controlling the disease and is also ecologically safe since it is used as clove or seed treatment [15]. MORE 720 WP fungicide is the active ingredient of Mancozeb 640 g/kg and Cymoxanile 80 g/kg. It is a systemic and contact fungicide used as foliar spray to provide both protective and curative action. It is also used for controlling other fungal diseases.

When the use of systemic fungicides became widespread, fungal plant pathogen appeared as resistant to previously effective fungicide and it became prompted the development of new strategies included the use of mixtures of fungicides in controlling plant fungal diseases [11,16]. However, foliar application of Mancozeb after planting was better in reducing white rot and increases the onion yield [17], the combination effects of different fungicides and their mode of application were not tested in the study area. Therefore, the objectives of this study were: to determine the effects of different fungicide types on incidence and severity of garlic white rot, and yield and yield components of garlic and to identify the effective method of fungicides application.

MATERIALS AND METHODS

Description of experimental site

The experiment was conducted at Debre Berhan University Agricultural Research Site under rain fed situation supplemented with irrigation in 2017/2018. It is located 125 km far from Addis Ababa. It is found at 9.66°N 39.52°E longitude and an altitude of 2975 meters above sea level and receives average annual rain fall of 897.8 mm with mean minimum and maximum temperatures of 6.1°C and 19.67°C respectively [18].

Experimental design and procedure

Treatment combinations of three different fungicides with three method of applications and one control treatment was arranged in (3×3)+1 factorial with randomized complete block design (RCBD) with three replications. The land was ploughed with a depth of 25-30 cm, pulverized and leveled. Ridges and furrows were prepared using hand tools manually. The experimental field plot size was 3.6 m2 (1.8 m × 2.0 m) with a total of six rows and 72 plants per plot for field experiment and the total plot size was 196 m^2 (24.5 m × 8 m) with 1 m spacing between blocks and 0.5 m between plots. The treated and untreated cloves were planted according to the standard planting density of 30 ×10 cm with 12 plants per row. The middle four rows were used as net plot for data collection. The variety used for research was local variety, which has been cultivated by the farmers in the areas for long period of time and the recommended rate of variety used for that study was, 600 kg ha^{-1} for each treatments [19].

Artificial fertilizers of DAP and urea were applied at the rate of 200 kg ha^{-1} and 150 kg ha^{-1} respectively. The DAP was applied at planting, whereas half rate of urea was applied during planting and the remaining half was applied at 30 days after planting. Some cloves were treated with the three fungicides before planting. Foliar application of the three fungicides was done after the onset of the disease. Clove and foliar application of each fungicide was done at a rate 0.18 Kg, 2 kg and 2.5 Kg per hectare of Apron star, MORE 720WP (Mancozeb 640g kg^{-1} plus Cymoxanil 80g kg^{-1}) and Mancozeb respectively.

Isolation and identification of *Sclerotium cepivorum*

Infected garlic bulbs showing symptoms of the disease and healthy bulbs were obtained from the experimental field and taken to the laboratory. Cloves from healthy bulb were chopped with clean mortar and pistil. Then several single sclerotia from infected bulb were placed onto potato dextrose agar (PDA) medium and incubated at 20°C in the dark for seven days. Similar sclerotia were also cultured without PDA using chopped health cloves as a media and incubated at 20°C in the dark for seven days [20]. Then the pathogen was identified by comparing with the morphological characters of white rot (*Sclerotium cepivorum* Berk) described by Bakonyi et al., [20]. The treatment combinations used in the experiment are presented in Table 1.

Data collection

Disease parameters: The disease incidence was assessed when the symptoms appear for the first time and it was calculated with the following formula;

DI=(No. of infected plants from the samples taken)/(Total No. of plants assessed) × 100

The disease severity: was recorded six times every 7 days interval from the first appearance of the disease in the plots, using 10 randomly selected garlic plants in the four central rows. It was recorded by estimating the percentage of leaf and stem area diseased

Table 1: Treatment combinations of the garlic root rot experiment at Debre Berhan during 2017/18.

No	Treatment Combinations
1	Local variety + Apron star clove
2	Local variety + Apron star clove + Apron star foliar
3	Local variety + Apron star foliar
4	Local variety + MORE 720 WP clove
5	Local variety + MORE 720 WP clove + MORE 720 WP foliar
6	Local variety + MORE 720 WP foliar
7	Local variety +Mancozeb clove
8	Local variety + Mancozeb clove + Mancozeb foliar
9	Local variety + Mancozeb foliar
10	Local variety without fungicide (untreated

using a scale from 0-5. The severity grade was then converted into percentage severity index (PSI) for analysis [21].

PSI=(Snr 100)/(Npr Msc)

Where, Snr is the sum of numerical ratings, Npr is number of plant rated; Msc is the maximum score of the scale. Means of the severity from each plot was used in data analysis.

The area under disease progress curve (AUDPC) was calculated for each treatment from the assessment of disease severity using the following formula [22].

$$\mathbf{AUDPC} = \sum_{i=1}^{n-1} 0.5\,[xi + xi + 1)\,(ti + 1 - ti)]$$

Where, n=total number assessment times, ti=time of the i^{th} assessment in days from the first assessment date, xi=percentage of disease severity at i^{th} assessment. AUDPC was expressed in percent-days, because severity (x) was expressed in percent and time (t) in days [22]. AUDPC values were used in the analysis of variance to compare the amount of disease among plots with different treatments.

Yield and yield component parameters: Days to maturity: The number of days required for maturity was determined as the number of days from planting to maturity when 75% of leaves fall over.

Plant height (cm): the length of the plant in cm was measured from 10 randomly selected plants in each plot from the soil surface to the tip of the plant at physiological maturity and the average was considered for statistical analysis.

Leaf number per plant: the total number of healthy leaves was counted from 10 randomly selected plants in the four central rows at physiological maturity.

Leaf Length: the average length of the leaf, at physiological maturity was measured in cm from 10 randomly selected plants in the four central rows.

Leaf width: the average width of leaves was considered from 10 randomly selected plants in the four central rows. One leaf from each sample plant was measured at the widest part at the time of physiological maturity.

Neck diameter (cm): thickness of neck was determined from 10 randomly selected plants of the four central rows. It was measured by using caliper meter after curing.

Shoot dry weight (g): the shoot fresh mass was oven-dried at the temperature of 65°C to a constant weight and its dry matter yield was determined.

Bulb length (cm): the length of the bulb was determined from 10 randomly selected plants of the four central rows. It was measured longitudinally by using caliper meter after curing.

Bulb diameter (cm): bulb diameter was determined from10 randomly selected plants of the four central rows. It was measured at the middle cross section of the bulb by using caliper meter after curing.

Average bulb weight (g): The average mature bulb weight per plant was registered after the weighing of all cured bulbs produced in the four central rows and divided by the number of bulbs.

Yield per plot (t ha^{-1}): The bulb weight of plants harvested from four central rows was weighted after curing for 10 days under shade in ambient condition and converted to tons per hectare.

Clove length (cm): The average clove length was measured in cm from 10 randomly selected plants.

Clove width (cm): the width of cloves was measured in cm from 10 randomly selected plants.

Average clove weight (g): The weight of 10 randomly selected plants from the four central rows was measured after curing and dividing by the number of cloves.

Clove number per bulb: The number of cloves produced from 10 randomly selected plants were counted and divided by number of bulbs.

Bulb dry matter (%): cloves from five randomly selected bulbs was chopped in to small pieces with the help of stainless steel knife, mixed thoroughly, and the exact weight of each sample was determined and recorded as fresh weight. The samples was placed in paper bags and dried in an oven at 65°C until a constant weight was obtained. Each sample was immediately weighed using digital sensitive balance and recorded as dry weight. Percent dry matter content for each sample was calculated by the following formula:

DW=[(DW + CW) – CW]/[(FW + CW) – CW] × 100

Where: DW= Dry Weight, CW=Container Weight, FW= Fresh Weight

Total dry biomass yield (g): this was determined by taking the total biomass weight which included dried bulbs, leaves, stems and roots after drying in an oven at 70°C until a constant weight was attained.

Data analysis

Experimental data analysis: Data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the SAS statistical package [23] version 9.2. List significant difference (LSD) at 0.05 probability level was used to separate treatment means.

RESULTS AND DISCUSSION

Effect of fungicides and methods of applications on disease parameters

Percentage of severity index: Garlic white rot symptoms were observed at 45 days after planting (DAP). The analysis of variance revealed that application of fungicides, methods of application and their interaction showed significant variations on disease severity started from 59 to 80 DAP ($P<0.001$) (Table 2). However, at 45 and 52 DAP, the interaction effect of types of fungicides and method of application of fungicide showed non-significant difference (Table 2). On the other hand, disease severity was significantly ($P< 0.05$) affected by of fungicide types at 45 DAP, by interaction effect of fungicides types and methods of applications at 52 DAP and highly significantly ($P<0.01$) affected by method of application at 45 DAP (Table 2).

At 45 DAP, application of Apron star fungicide recorded lower percentage severity index (PSI) as compared to Mancozeb. However, starting from 59 to 80 DAP, MORE 720 WP resulted the lowest

PSI as compared to Apron star and Macozeb (Table 3). At the final date of disease assessment, MORE 720 WP reduced PSI by 61.7% and 37.8% as compared to untreated and Mancozeb treated plots respectively. Such higher resistance due to application of MORE 720 WP could be because of the effective resistivity of the fungicide both at foliar and clove application. Starting from 45 to 66 DAP, clove and clove plus foliar application of fungicides resulted in a lower PSI as compared to foliar application. This could be due to clove treatment of fungicides reduced the initial disease severity of white rote by in activating the pathogen in infected cloves. However, at the final two (73 and 80) dates of recording clove plus foliar application has resulted the lowest percentage severity index as compared to clove and foliar applications (Table 3). At the final date of disease assessment, clove plus foliar application reduced the PSI by 58.7% and 38.6% as compared to the untreated and foliar applied respectively. The reduction of PSI at the final two dates of recording due to clove plus foliar application as compared to foliar application ascribed that treated cloves with fungicides before planting and supplemented by foliar application of fungicides might be protected from *Sclerotium cepivorum* for long period of time rather than foliar application.

At 52 DAP, the lowest percentage of severity index was recorded from clove and clove plus foliar applied Apron star, clove plus foliar applied MORE 72O WP and clove applied Mancozeb. However, foliar applied Apron star and clove plus foliar and foliar applied Macozeb recorded the higher percentage of severity index as compared to percentage of severity index recorded from other treated plots. At the first date of recording, clove applied Apron star fungicide reduced percentage of severity index by 66.7% as compared to untreated. Starting from 59 tol 80 DAP, foliar applied Apron star resulted in the highest percentage of severity index as compared to other treated plots. On these days, clove and clove plus foliar applied Apron star and clove plus foliar and foliar applied MORE 720 WP fungicides resulted in the lower percentage of severity index as compared to Mancozeb treated (Table 3). Clove treatment with fungicides could inactivate the pathogen in infected cloves or provide the foliar protection against the pathogen. This is in agreement with the finding of Abrha et al. [19] who reported that, the lowest severity was recorded from plots planted to Apron star treated cloves. Similarly, Makun et al. [24] revealed that apron star had significantly reduced the mycelial growth of seed-borne fungi of cowpea.

Disease incidence: Disease incidence showed a significance difference (P<0.001) on fungicide types, methods of application and their interaction (Table 4). Application of Apron star and MORE 720 WP fungicides resulted in lower incidence as compared to Mancozeb. Apron star reduced the disease incidence by 51% and 33.9% as compared to untreated and Mancozeb

Table 2: Mean square of percentage of severity index of garlic white rot at Debre Berhan during 2017/18 cropping season.

Source of variation	DF	Days After Planting (DAP)					
		45	52	59	66	73	80
Rep	2	2.80 ns	26.43ns	8.63 ns	0.53 ns	0.93 ns	1.23 ns
Fungicide	2	14.33*	9.15ns	386.04***	434.37***	489.37***	547.37***
Method	2	41.33**	36.04*	774.70***	796.59***	783.37***	765.59***
Fungicide*Method	4	9.33ns	33.37*	449.70***	599.93***	737.98***	817.65***
Error	18	3.69	7.69	11.3	8.83	5.16	6.57
CV (%)		19	14.8	15.87	11.9	6.7	7.8
LSD (0.05)		1.96	1.7	3.2	2.9	1.9	2.6

CV (%)=Coefficient of variation, ***Very highly significant (P < 0.001), **highly significant (P < 0.01), *Significant (P < 0.05), ns=non-significant, LSD=Least significance difference at 5% probability

Table 3: Effect of fungicide types and methods of application on percentage severity index of garlic white rot at Debre Berhan during 2017/18 cropping season.

Fungicides	Methods	Percentage of severity index at Days after planting (DAP)					
		45	52	59	66	73	80
Apron star	Clove	6	8.0d	9.0f	10.0g	16.0de	19.0e
	Clove + foliar	6	8.0d	8.7f	12.0fg	14.7e	20.7e
	Foliar	15	16.0a	48.0a	54.0a	61.0a	61.0a
MORE 720WP	Clove	11	12.0bc	16.0de	20.0de	28.0c	33.0d
	Clove + foliar	9	10.0d	10.0f	16.0ef	17.0d	20.0e
	Foliar	11	12.0bc	12.0ef	14.7fg	18.7cd	22.0e
Mancozeb	Clove	8	8.0d	20.0cd	24.0d	30.7c	37.3cd
	Clove + foliar	13	14.0ab	24.0c	31.3c	36.7b	40.0bc
	Foliar	14	16.0a	32.0b	36.7b	40.0b	43.3b
Untreated	Untreated	17	18	38	48	56	65.3
CV (%)		17.1	13.3	15.4	11.1	7.1	6.7
LSD (0.05)		3.4	3	5.5	5	3.4	4.5

Where, DAP: Days After Planting, LSD: Least Significant Difference At 5%, CV: Coefficient Of Variation treated respectively, (Table 5) which might be due to Apron star persists at toxic levels longer than Mancozeb for the pathogen. In line with this Tamire et al. [4] reported that, affectivity of captan fungicide to reduce final incidence rather than initial is due to its persistence at toxic levels for longer time. Clove and clove plus foliar application of fungicides resulted in lower disease incidence as foliar application. Disease incidence recorded from clove plus foliar application was reduced by 51% and 35.75% as compared to untreated and foliar treated plots respectively (Table 5). Clove and clove plus foliar applied Apron star resulted in the lowest disease incidence followed by foliar applied MORE 720 WP. However, foliar applied apron star resulted in a higher disease incidence. Disease incidence due to clove applied Apron star was increased by 80.7% and 80.6% as compared to foliar applied Apron star and untreated plots respectively (Table 5). The decrease in disease incidence due to clove and clove plus foliar application of Apron star fungicide might be due to the effective nature of this fungicide on garlic cloves by inactivating the pathogen. In line with this, Abrha et al. [19] reported that treating of clove with Apron star before planting is effective in reducing incidence and severity of white rot.

Area under disease progress curve: Fungicide types, methods of application and their interaction showed a significant effect (P<0.001) on area under disease progress curve (%-day) (Table 4). MORE 720 WP fungicide recorded the lowest area under disease progress curve (AUDPC) followed by Apron star. MORE 720 WP reduced the area under disease progress curve (AUDPC) by 63.7% and 39% as compared to the untreated and Mancozeb treated respectively (Table 5). Clove and clove plus foliar application resulted in a lower value of AUDPC as compared to foliar .Clove plus foliar application reduced the AUDPC by 61% and 42.6% as compared to the untreated and foliar application, respectively (Table 5).

Clove and clove plus foliar applied Apron star and clove plus foliar applied MORE 720 WP fungicides resulted in a lowest values of AUDPC. However, the highest (1540%-day) AUDPC value was recorded from foliar applied Apron star (Table 5). Clove plus foliar applied Apron star has reduced the AUDPC by 74.8% and 74.7% as compared to foliar applied Apron star and the untreated, respectively (Table 5).

Effect of fungicide types and methods on days to maturity and growth parameters

Days to maturity: Days to maturity was not significantly (P<0.05) affected by the main effects of fungicide types and method of applications. However, it was significantly affected by the interaction effect of fungicide types and methods of applications (Table 6).

Clove applied Apron star fungicide prolonged maturity time by 25 days as compared to foliar applied Apron star. Clove and clove plus foliar applied Apron star and clove plus foliar and foliar applied MORE 720 WP fungicides significantly prolonged days to maturity as compared to the other treatments. Clove applied Apron star treated plots were harvested 29 days later than untreated plots (Table 7). The extended days to maturity by clove applied Apron star might be due to the favoring of vegetative growth through controlling white rot severity. Similarly, Nyengedzeni, [25] reported that garlic leaf bioactivity increased as number of days increased.

Leaf number and width: Fungicide types and methods of application showed a significant effect on leaf number (P<0.05)

Table 4: Mean square of incidence and area under disease progressive curve of garlic white rot at Debre Berhan during 2017/18 cropping season.

Source	DF	Incidence	AUDPC
Rep	2	40.26 ^{ns}	1757.058 ^{ns}
Fungicide	3	1029.36***	290537.80***
Method	2	1316.72***	583051.50***
Fungicide*Method	4	1614.86***	426587.60***
Error	18	27.75	3484.76
CV (%)		12	7.9
LSD (0.05)		5.4	59.39

***Very highly significant (P < 0.001), **Highly significant (P < 0.01), *Significant (P< 0.05) and ns=non-significant

Table 5: Effect of fungicide types and methods of application on the incidence and area under disease progressive curve (AUDPC) of garlic white rot.

Fungicides	Methods	Incidence (%)	AUDPC
Apron star	Clove	15.5^{f}	388.5^{g}
	Clove + foliar	20.75^{f}	396.67^{g}
	Foliar	80.5^{a}	1540.0^{a}
MORE 720WP	Clove	52.0^{c}	686.0^{e}
	Clove + foliar	41.87^{d}	472.5^{fg}
	Foliar	32.0^{e}	516.83^{f}
Mancozeb	Clove	54.2^{c}	744.33^{e}
	Clove + foliar	54.0^{c}	927.5^{d}
	Foliar	68.6^{b}	1073.33^{c}
Untreated		79.7	1538.17
CV (%)		12.0	7.9
LSD (5%)		9.4	101.26

and width (P<0.01). However, their interaction effect showed a non-significant effect on these parameters (Table 6). Application of MORE 720 WP and Mancozeb fungicides resulted in a higher leaf number (8.8 cm) as compared to Apron star applied (8.02 cm). The mean number of leaf from MORE 720 WP and Mancozeb fungicides was increased by 9.1% and 8.88% as compared to the untreated and Apron star applied plots (Table 7). Application of MORE 720 WP and Apron star fungicides recorded in a higher mean value of leaf width as compared to Mancozeb. MORE 720 WP increased leaf width by 23.5% and 17.6% as compared to the untreated and Mancozeb treated, respectively (Table 7).

Shoot dry weight: Fungicide types, methods of application and their interaction effect of both showed a significant effect on shoot dry weight (Table 6). Application of MORE 720 WP resulted in the highest shoot dry weight followed by Apron star fungicide (Table 7). MORE 720WP increased the shoot dry weight by 32.58% and 29.2% as compare to the untreated and Mancozeb treated, respectively, the increase shoot dry weight might be due to the vigorous vegetative growth. Clove and clove plus foliar method of application resulted in a higher shoot dry weight as compared to foliar application. Treating of cloves with fungicides before planting increased the shoot dry weight by 21.7% as compared to the untreated (Table 7). The higher shoot dry weigh due to clove application of fungicides might be resulted from the effective reduction of disease severity and incidence with.

Clove plus foliar and foliar applied MORE 720 WP fungicide resulted in a higher shoot dry weight as compared to the other treated plots. However, foliar applied Apron star, clove plus foliar and foliar applied Mancozeb resulted in a lower shoot dry weight (Table 7).Foliar applied MORE 720 WP fungicide increased shoot dry weight by 35.7% and 37.5% as compared to the untreated and clove plus foliar applied Mancozeb, respectively. Similarly, the higher shoot dry weigh due to application of fungicides might be resulted from well-developed garlic shoot. On the other hand, infected leaves become yellow; wilt and prematurely dry that resulted in reduction of garlic shoot dry weight.

Bulb length and diameter: Fungicide types and methods of application showed a non-significant effect on bulb length. However, their interaction effect showed a significant (P< 0.05) effect on these parameters. On the other hand, the main effects and their interaction showed a significant (P<0.001) effect on bulb length. Application of Apron star resulted in a higher bulb diameter followed by MORE 720 WP. Bulb diameter recorded from Apron star was increased by 39% and 13% as compared to the untreated and Mancozeb treated, respectively (Table 8). Clove method of fungicide application resulted in a higher bulb diameter followed by clove plus foliar application. Clove application of fungicides increased bulb diameter by 42.9% and 24.5% as compared to the untreated and foliar application, respectively (Table 8).

The highest bulb diameter was recorded from clove applied Apron star followed by clove applied MORE 72 WP fungicide. Similarly, clove applied Apron star has increased the bulb length by 27.8% and 24% as compared to the untreated and foliar applied Apron star treated respectively. However, foliar applied Apron star has resulted in the lowest bulb length and diameter. Clove applied Apron star increased the bulb diameter by 48% and 35.2% as compared to the untreated and foliar applied Apron star, respectively (Table 8). The increase in bulb length and diameter of fungicide treated

Table 6: Mean square of days to maturity and growth parameters of garlic at Debere Berhan during 2107/18 cropping season.

Source	DF	DM	PH	LN	LL	LD	ND	SDW
Rep	16	334.7	9.8	0.2	5.6	0.01	0.08	3.45
Fungicide	2	87.1^{ns}	76.3^{ns}	1.75^{*}	4.16^{ns}	0.18^{**}	0.03^{ns}	572.7^{***}
Method	2	166.9^{ns}	30.2^{ns}	0.69^{ns}	1.80^{ns}	0.018^{ns}	0.03^{ns}	29.73^{***}
Fungicide*Method	4	75.5^{*}	2.67^{ns}	0.23^{ns}	2.00^{ns}	0.04^{ns}	0.05^{ns}	83.45^{***}
Error	2	762.6	21	0.3	3.1	0.02	0.01	4.5
CV (%)		19	4.2	6.9	5.6	10	12	4.7
LSD (0.05)		26.61	4.6	0.6	1.8	0.12	0.1	2.1

***Very highly significant (P < 0.001), **highly significant (P < 0.01), *Significant (P < 0.05) and ns=non-significant

Table 7: Effect of fungicide types and methods of application on growth parameters of garlic at Debre Berhan during 2017/18 cropping season.

Fungicides	Methods	DM (Days)	PH (cm)	LL (cm)	ND (cm)	SDW (g)
Apron star	Clove	155.0^{a}	46.15	1.45	1.45	50.5^{bc}
	Clove + foliar	153.3^{a}	43.93	1.65	1.65	48.0^{dc}
	Foliar	130.0^{bc}	43.10	1.60	1.60	36.0^{f}
MORE 720WP	Clove	135.0^{b}	52.85	1.79	1.79	45.0^{de}
	Clove + foliar	145.0^{a}	48.05	1.60	1.60	54.0^{ab}
	Foliar	152.5^{a}	49.55	1.70	1.70	56.0^{at}
Mancozeb	Clove	132.0^{bc}	48.37	1.49	1.49	43.0^{e}
	Clove + foliar	132.0^{bc}	46.43	1.28	1.28	35.0^{f}
	Foliar	132.0^{bc}	44.72	1.47	1.47	36.0^{f}
Untreated	Untreated	126.0	42.37	1.31	1.31	36.0
LSD (0.05)		19.0	4.14	1.45	1.45	3.5
CV%		6.9	9.50	9.97	9.97	4.6

Where, DM: Days To Maturity, PH: Plant Height, LL: Leaf Length, ND: Neck Diameter and SDW : Shoot Dry Weight

Table 8: Effect of fungicide types and methods of application on bulb length and diameter, clove diameter and length, average clove weight and clove number per bulb.

Fungicides	Methods	BL (cm)	BD (cm)	CD (cm)	CL (cm)	ACW (g)	CN
Apron star	Clove	4.50[a]	5.40[a]	1.23	2.96[a]	1.60[a]	19.40[a]
	Clove + foliar	4.40[ab]	4.80[c]	1.13	2.63[c]	1.40[c]	18.95[b]
	Foliar	3.40[cd]	3.50[g]	0.96	1.78[h]	0.70[g]	10.30[g]
MORE720 WP	Clove	3.90[a-c]	5.00[b]	1.07	2.76[b]	1.48[b]	18.40c
	Clove + foliar	3.60[cd]	3.89[e]	0.84	2.40[e]	1.00[d]	17.10[d]
	Foliar	3.80[b-d]	3.77[f]	1.01	2.50[d]	1.40[c]	18.50[c]
Mancozeb	Clove	3.95[a-c]	4.20[d]	1.07	2.30[f]	0.92[e]	16.93[d]
	Clove + foliar	3.90[a-d]	4.30[d]	1.04	2.08[g]	1.06[d]	16.03[e]
	Foliar	3.80[b-d]	3.85[ef]	1.05	2.10[g]	0.80[ef]	14.10[f]
Untreated	Untreated	3.25	2.80	0.82	1.50	0.70	10.20
CV (%)		10	1.68	12.1	1.8	3.67	2.5
LSD (5%)		0.68	0.12	0.21	0.07	0.07	0.7

Where, BL: Bulb Length, BD: Bulb Diameter, BL: Bulb Length, CD: Clove Diameter, CL: Clove Length, ACW: Average Clove Weight And CN: Clove Number Per Bulb

plots could be due to the good development of bulbs as a result of favorable vegetative growth. In agreement with this, Amin et al. [11] reported that mycelial growth spreads upwards from the roots and then attacks the roots, developing bulb and shoot growth.

Clove length and diameter: The result revealed that, methods of application showed a significant ($P < 0.05$) effect on clove diameter. However, fungicide types and the interaction of both showed non-significant effect on this parameter. On the other hand, the main effect and their interaction showed a significant ($P<0.001$) effect on clove length. MORE 720 WP fungicides resulted in the longest cloves followed by Apron star. Clove length recorded from MORE 720 WP was increased by 43% and 20.2% as compared to the untreated and Mancozeb treated, respectively. Clove application resulted in the highest clove length followed by clove plus foliar application of fungicides. Clove application also resulted in the highest clove diameter as compared to foliar. Clove application of fungicides increased the clove length by 42.3% and 23.1% as compared to the untreated and foliar applied, respectively. Similarly, it has increased the clove diameter by 28.53% and 15.12% as compared to the untreated and foliar applied, respectively (Table 8). The increase in clove length and diameter due to clove application of fungicides might be due to the result of well-developed bulb.

Planting cloves treated with clove applied Apron star resulted in the highest clove length followed by clove applied MORE 720 WP fungicides. However, foliar applied Apron star resulted in a shortest clove length as compared to other fungicide treated plots. Clove applied Apron star has increased clove length by 49% and 39.86% as compared to the untreated and foliar applied Apron star, respectively, while foliar applied Apron star increased clove length by 16% as compared to the untreated plots (Table 8). Lowering of clove length and diameter due to the untreated plots could be as a result of poor bulb development that results in reduced clove length and width. This is in agreement with Maude, [25]; Mueller et al. [26] who reported that, once the bulb is infected by white rot, the plant soon loses vigor, white mycelia fill the bulb and results in poor development of bulb and rotting.

Average clove weight: This study revealed existence of significant ($P<0.001$) variations for the average clove weight among fungicide types, methods of application and their interaction. Application of Apron star fungicides and MORE 720 WP resulted in a higher average clove weight. Average clove weight obtained from MORE 720 WP treated plots was increased by 46% and 30.8% over the untreated and Mancozeb treated plots, respectively while Mancozeb fungicide increased the average clove weight by 22% as compared to the untreated. Clove application resulted in the highest average clove weight followed by clove plus foliar application of fungicides. The average clove weight obtained from clove treated plots was increased by 41.7% and 16.7% as compared to the untreated and foliar applied, respectively, while foliar application increased the average clove weight by 30% as compared to the untreated (Table 8).Reduction of average clove weight could be the result of disease impact on bulbs.

The highest average clove weight (1.6 g) was recorded from clove applied Apron star fungicide followed by clove applied MORE 720 WP fungicide (1.48 g). However, the lowest (0.7 g) average clove weight was recorded from foliar applied Apron star fungicide. Clove applied Apron star has increased average clove weight by 56.3% as compared to the untreated plots. Similarly, clove applied MORE 720 WP has shown 52.7% increment as compared to the untreated (Table 8). This is attributed to plots protected from white rot have prolonged days for maturity that might lead to a higher bulb and clove weight.

Clove number: Clove number per bulb is significantly ($P<0.001$) affected by the main effect and their interaction. Plots treated by MORE 720 WP resulted in the highest clove number per bulb followed by Apron star fungicide. Number of cloves obtained from MORE 720 WP treated plots was increased by 44.4% and 12.8% as compared to the untreated and Mancozeb treated plots, respectively. Similarly, Apron star fungicide also reduced the clove number by 38% as compared to the untreated plots. Plots treated with clove application resulted in the highest clove number per bulb followed by clove plus foliar application. Clove application of fungicides increased the number of cloves by 44.4% and 20.6% as compared to the untreated and Mancozeb treated, respectively (Table 8).

The highest number of cloves per bulb was recorded from clove followed by clove plus foliar applied Apron star fungicide. However, foliar applied Apron star recorded the lowest clove number per bulb among fungicide treated plots. Clove applied Apron star increased the number of cloves by 47.4% and 46.9% as compared to the untreated and foliar applied Apron star, respectively (Table 8). The increase in number of cloves due to clove applied Apron star might be due to the result of effective protection of bulbs from white rot that eventually resulted in a higher number of cloves.

Bulb dry matter: Bulb dry mater is significantly (P<0.001) affected by the main effects and their interaction. The highest dry matter content of bulbs was recorded from Apron star followed by MORE 20 WP treated plots. The dry matter content of bulbs obtained from Apron star treated plots increased by 32.8% and 13% as compared to the untreated and Mancozeb fungicide treated plots, respectively, while Mancozeb fungicide increased the bulb dry matter by 23.1% as compared to the untreated plots. Bulbs harvested from clove and clove plus foliar applied plots resulted in a higher dry matter content as compared to foliar application. Clove application increased the bulb dry matter by 32% and 11.8% as compared to the untreated and foliar application, respectively (Table 9).

The highest dry matter content of bulbs recorded from clove applied Apron star fungicide followed by clove plus foliar applied Apron star and foliar applied MORE 720 WP fungicides. However, foliar applied Apron star and Mancozeb fungicides recorded the lowest bulb dry matter. Clove applied Apron star has increased the percentage of bulb dry matter by 42.9% and 37.4% as compared to the untreated and foliar applied Apron star treated plots, respectively (Table 9).This could be due to well-developed bulbs resulted in a higher dry matter content. This is in agreement with Malashri and Shashidhar, [27] who reported that, increase in bulb weight, bulb diameter and clove size had direct influence on accumulation of dry matter content.

Total dry biomass: Fungicide types, methods of application and their interaction significantly (P<0.001) affected total dry biomass. Application of MORE 720 WP fungicides recorded in the highest total dry biomass followed by Apron star treated plots. More 720 WP fungicides has increased the total dry biomass by 54.3% as compared to the untreated plots. Clove application resulted in the highest total dry biomass followed by clove plus foliar application of fungicides. Total dry biomass of plots treated with clove application was increased by 50.5% and 22.2% as compared to the untreated and foliar treated plots, respectively (Table 9).This could be the inactivating of the pathogen that resulted in a good vegetative growth and in then a higher total dry biomass. In line with this, Malashri and Shashidhar, [27] reported that, higher photosynthetic rate translocation of more and more photosynthesis from source to sink resulted in all morphological character ultimately led to higher total biomass.

Clove applied Apron star and foliar applied MORE720 WP fungicides resulted in the highest dry biomass of garlic. However, foliar applied Apron star resulted in the lowest total dry biomass. Clove applied Apron star fungicide has shown 58.18% and 58.6% increment of total dry biomass as compared to foliar applied Apron star and the untreated plots, respectively (Table 9).The lowest total dry biomass by foliar applied Apron star might be due to leave death, bulb rotting, stem and dieback of whole plant.

Average bulb weight: The highest average bulb weight was recorded from application of MORE 720 WP followed by Apron star fungicide was higher as compared to Mancozeb. MORE 720 WP has increased the average bulb weight by 67.2% and 22.5% as compared to the untreated and Mancozeb treated plots, respectively. Clove application resulted the highest average clove weight followed by clove plus foliar applied plots. Average bulb weight obtained from clove application of fungicides has increased by 67.7% and 24.58% as compared to the untreated and foliar application, respectively, while foliar application increased the Average bulb weight by 57.2% as compared to the untreated plots (Table 9). The reduction of Average bulb weight could be due to the result of infected bulbs by white rot.

Clove applied Apron star has shown 63.6% and 57.1% increment of Average bulb weight over the untreated and foliar applied Apron star treated plots, respectively. Clove applied MORE 72O WP increased the Average bulb weight by 63.2% and 56.6% as compared to foliar applied Apron star and the untreated plots, respectively (Table 9). The increase of Average bulb weight might be due to the higher number of healthy and well developed bulbs harvested from net rows. Similarly, Tamire et al. [4] reported that,

Table 9: Effect of fungicide and method of application on bulbs dry matter, total dry biomass yield, harvesting index, average bulb weight per plots and yield per hectare of garlic.

Fungicides	Methods	BDM	TDB (g)	ABW (g)	Yield (t ha^{-1})
Apron star	Clove	41.50a	33.0a	77.0a	2.1a
	Clove + foliar	42.15b	30.0b	68.0a	1.78a-c
	Foliar	27.00f	13.8f	33.0c	1.0cd
MORE720 WP	Clove	31.0e	29.0b	76.0a	2.07a
	Clove + foliar	37.6c	24.75c	51.5b	1.44a-d
	Foliar	43.0b	34.5a	72.0a	1.9ab
Mancozeb	Clove	38.0c	24.0c	51.0b	1.4b-d
	Clove + foliar	33.6d	23.0d	41.0bc	1.14b-d
	Foliar	29.5ef	18.3e	47.0b	1.3b-d
Untreated	Untreated	26	14	28	0.7
CV (%)		2.85	2.81	12	7.1
LSD (0.05)		1.7	1.18	101	0.6

Where, BDM: Bulb Dry Matter, TDB: Total Dry Biomass, ABW: Average Bulb Weight fungicide application resulted in better development of garlic bulbs resulted in a higher marketable yields.

Garlic yield: Fungicide types, methods of application and their interaction significantly (P<0.001) affected garlic yield. Application of MORE 720 WP and Apron star resulted in a higher yield per hectare as compared to Mancozeb. About 69.6% and 22.6% increment of yield per hectare was shown from application of MORE 720 WP fungicide as compared to the untreated and Mancozeb treated plots, respectively, while Mancozeb fungicide has increased the yield per hectare by 60.67% as compared to the untreated plots. Clove application resulted in the highest yield per hectare followed by clove plus foliar application of fungicides. The yield obtained from clove application was increased by 69.6% and 29.9% as compared to the untreated and foliar applied plots, respectively, while foliar application has shown about 60% yield increment as compared to the untreated (Table 9).

Clove application of Apron star has shown 66.7% and 52.3% yield increment over untreated and foliar applied Apron star treated plots, respectively. Similarly, clove applied MORE 720 WP has also increased the yield per hectare by 66.2% and 15% as compared to the untreated and foliar applied Apron star plots respectively, while foliar applied Apron star has increased the yield per hectare by 30% as compared to the untreated plots (Table 9). The yield reduction due the untreated plots could be due to the severe infection of the bulb by the pathogen that led to early maturity and lower bulb yield. On the other hand, fungicide applied plots mature latterly and in then resulted in a higher bulb yields. In line with this, Malashri and Shashidhar [27] reported that, due to higher photosynthesis the bulb characters have developed to the maximum extent and resulted in higher bulb yields. Similarly, Potgieter [28] reported that, as harvest dates postponed where leaf diseases were controlled, resulting in a higher yield in groundnut.

Economic analysis

To estimate the profitability of the fungicides, the fungicide costs, fungicide application cost (man power used for spraying of fungicides, equipment like knapsack sprayer), and garlic prices were considered. The price of the garlic crop was estimated based on the current market price.

RN=YiP-(Fc+Ac)

Where, Rn=the net return from fungicide application (birr ha^{-1}); Yi=is yield increase from fungicide application (kg ha^{-1}), obtained by subtracting the yield in the control treatment from the yield in the fungicide treatment, P=is the garlic prices (birr kg^{-1}); Fc=is the fungicide cost (birr ha^{-1}); and Ac=the fungicide application cost (birr ha^{-1}). Results from assessment of economic returns in this study indicated that fungicide application for garlic whit rote management in garlic could be profitable. The highest net return (35,350 birr ha^{-1}) was obtained from Apron star clove treated plots followed by (34,210 birr ha^{-1}) was obtained from MORE 720WP foliar sprayed plots. The lowest net return (2350 birr ha^{-1}) was obtained from Apron star foliar sprayed plots (Table 9).

In Ethiopia, garlic (*Allium sativum* L.) is one of the most widely grown bulb crops next to onion and it is grown under a wide range of climatic and soil adaptation. Garlic yield is, however, reduced due to many factors of which diseases are economically important problems. Garlic white rot which is caused by *Sclerotium cepivorum* is a major production threat of garlic and onion in Ethiopia. Management of diseases caused by soil borne pathogens, especially those that produce sclerotia is very difficult and needs effective management strategy. No attempts have been made to find the effective management of white rot. Fungicides with effective method of applications are among the most effective options for garlic white rot disease management. In the present study field trial was conducted to evaluate the effects of evaluate the effect of fungicides of different fungicides and method of applications on incidence and severity of garlic white rot, and yield and yield components of garlic under field conditions at Debre Berhane University during 2017/ 2018 main cropping season supplemented by irrigation. The three fungicides, Apron star, MORE 720 WP and Mancozeb at 1.8 kg ha^{-1}, 2kg ha^{-1}, 2.8 kg ha^{-1} rates respectively with three methods of applications (clove, clove plus foliar and foliar) including untreated plots were evaluated. The treatments were tested for their effects on incidence and severity of the disease, the consequent yield and yield components of garlic.

The fungicide types, methods and their interaction treatments created different severity and incidence levels that resulted in different garlic yield losses and the final levels of severity were high. At the final date of recording, Up to 65.30% disease severity was exhibited when the plots were left untreated with fungicides while application of MORE 720 WP fungicide has reduce the disease severity by 61.7% and significantly reduced the degree of disease (AUDPC). This fungicide and Apron star had significantly reduced the disease incidence. With the exception of shoot dry weight, each of the three fungicides had not significant effect on days to maturity and growth parameters of garlic. However, all the yield parameters recorded from fungicide treated plots were higher in percent as compared to untreated plots. MORE 720 WP and Apron star fungicides resulted higher value of average clove weight. The maximum 46% increment of average clove weight obtained from MORE 720 WP fungicide as compared to untreated. Total bulb weight recorded from this fungicide was also higher as compared to Apron star and Mancozeb. This MORE 720 WP fungicide has increase the total bulb weight by 67.2% as compared to the untreated plots. Application of MORE 720 WP and Apron star resulted in a higher yield per hectare as compared to Mancozeb, while the about 69.6% increment of yield per hectare was observed from MORE 720 WP as compared to untreated.

On the other hand, fungicides method of application had difference response to the disease and yield and yield components. Clove plus foliar application of fungicides reduced the percentage of severity index by 58.7% as compared to the untreated and by 38.6% as compared to Mancozeb. Likewise, lower disease incidence and degree of disease (AUDPC) was recorded from clove plus foliar application of fungicides. Fungicide method of application significantly not affect the garlic growth parameters; however shoot dry weight recorded from clove and clove plus foliar application was higher. The maximum (41.7%) increment of average bulb weight over the untreated was observed from clove application as compared to the other two application methods.

CONCLUSION

Interaction effect of Fungicides with methods had also different response with regard to severity and incidence of the disease, and yield and yield components. Among them, clove application of

Apron star has reduced the incidence, severity and degree of disease (AUDPC), and resulted in significantly high yields as compared to the other fungicide treated plots. It reduced the finial severity by 66.7% and the incidence by 80.7% as compared to the untreated. Plots treated with clove applied Apron star fungicide has matured 29 days later than untreated plots. However, among growth parameters, shoot dry weight recorded from foliar application of MORE 720 WP fungicides has in a higher value over other treated treatments. About 56.3% increment of total bulb weight has also recorded from clove applied Apron star fungicide. Likewise, clove applied MORE 72O WP increased the total bulb weight and yield per hectare by 63.2% and by 66.2% as compared to the untreated respectively. About 66.7% relative yield loss per hectare was obtained on untreated plots as compared to clove and clove plus foliar applied Apron star treated plots. The higher net return also obtained from plots of clove applied Apron star fungicide treated as compared to Mancozeb and MORE 720 WP treated plots.

From this research result, it can be concluded that garlic white rot can be controlled with the selected fungicides and with selective method of application. clove applied Apron star fungicide is highly recommended for surrounding farmers to properly manage white rot of garlic and maintain the productivity of garlic in the study areas.

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