

Searching and Evaluating of Cost Effective Management Options of Garlic White rot (*Sclerotium cepivorum* Berk) in Tigray, Northern Ethiopia

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Abstract

White rot caused by a soil borne fungus (*Sclerotium cepivorum* Berk.) is a major production threat of garlic, where ever the crop is grown. The objectives of this study were evaluating the effectiveness of fungicides against garlic white rot, and to determine the cost effectiveness of the fungicides on management of garlic white rot. Field experiment was conducted at Mekelle Agricultural Research Center on garlic white rot naturally infested field in 2010 main crop season. Three fungicides (tebuconazole, captan and mancozeb) were used as a clove treatment. A randomized complete block design with three replications was employed. A total of four treatments were evaluated per replication. All fungicides were effective in reducing the disease epidemics and improving garlic yield over untreated plot. However, among fungicide treated plots tebuconazole was the most effective in reducing the disease epidemics and gave better yield advantage. In tebuconazole treated plots, 83.33%, 74.33% and 75.47% reduced initial, final incidence and severity was recorded respectively, as compared to untreated plot. Significantly higher increment on total and marketable yield was observed in tebuconazole treated plot, as compared to captan and mancozeb treated and untreated plot. In tebuconazole treated plot, 3.36 t ha⁻¹ total and 3.18 t ha⁻¹ marketable yield increments was obtained as compared untreated plot. Tebuconazole treated plot maximized the net benefit, which exceeded by \$4,950.340 was obtained over untreated plot. The marginal rate of return on tebuconazole treated plot over untreated plot was 658.201%. Based on the observation and findings garlic is high value crop, and white rot is potential threat in the major garlic growing areas of in the study area. Therefore, application of tebuconazole can be considered as management strategy to reduce disease epidemics and improve garlic yield.

Keywords: Cost effective; Garlic; Disease epidemics; Management options; *Sclerotium cepivorum*; White rot

Introduction

Garlic (*Allium sativum* L., 2n=16) that belongs to the family *Alliaceae*, and is the second most widely cultivated *Allium* Spp. next to onion [1]. Garlic has played an important dietary, as well as medicinal, role for centuries. Even today the medicinal value of garlic is widespread and fast growing. Garlic is one of the best studied medicinal plants that its antibacterial and antiseptic property is well known. It contains remedies against headache, bites, worms and tumours [2]. Han et al. [3] also reported that garlic has antibiotic properties, and has been used to treat wounds when other antibiotics were not available. Proponents advise eating a raw clove of garlic a day to boost the immune system [4]. Generally, garlic can rightfully be called one of nature wonder. It can inhibit and kill bacteria, fungi, parasites, lower blood pressure, blood cholesterol and blood sugar, prevent blood clotting, protect the liver and contains antitumor properties [5]. Reported in market circulation, it is one of competitive commodity and high value crop. In Germany alone, the sale of garlic preparations rank with those of the leading prescription drugs [6].

Economic significance of garlic in Ethiopia is quite considerable. It is grown as spice and used for flavouring local dishes, and contributes to the national economy as export commodity [7]. 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].

World garlic cultivation was increased from 771,000 ha of land in 1989/90 to 1,204,711 ha of land in 2007 with total production from 6.5 million to 15.68 million tons, and productivity from 8.43 t/ha and 13.02 t/ha, respectively [9].

In Ethiopia, the total area under garlic production in 2006/07 reached 9,266 hectares, and the production is estimated to be over 68300 tons annually [10]. In South east and East Tigray high lands, garlic is widely cultivated under rain fed and supplemented by irrigation. In spite of its importance and increased production, garlic productivity, in many parts of the world, is low due to genetic, a biotic and biotic factors. Numerous production problems accounted for the low yield of garlic in Ethiopia: Lack of proper disease and insect pest management practices, improved planting material, inappropriate agronomic practices, and marketing facilities are the prominent ones. However, the most important constraint for garlic production and productivity are fungal diseases. Among the fungal diseases, white rot caused by *Sclerotium cepivorum* [11], rust caused by *Puccinia allii*, neck rot caused by *Botrytis allii*, *B. squamosa* and *B. cinerea* [12] are the most important ones worldwide, including in Ethiopia. As in many parts of the world, the main limiting factor for garlic production is the disease known as white rot caused by *Sclerotium cepivorum* Berk [11].

White rot persists as small, dormant structures, called sclerotia, in soil. Sclerotia can survive for over 20 years, in the absence of a host plant [13]. It only attacks *Allium* species [14], and can infect plants from

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12 inches below the surface and spread rapidly to adjacent plants [15]. It proliferates in cool soils below 75°F, and once white rot is in a field, it is very difficult to cultivate garlic and onions [15].

S. cepivorum damages *Allium* tissue during infection by degrading plant cell walls ahead of hyphal elongation through the secretion of a fungal toxin, oxalic acid [16]. The disease is prevalent in many *Allium* growing regions worldwide, and causes serious economic losses in garlic and onion crops [15,17]. Coley-Smith [18] also reported that the disease is global importance and serious threat of the *allium* industry. It causes important economic losses in garlic production worldwide. In Mexico and in Brazil, losses up to 100% were reported. The disease is also serious in Canada and incidence was exceeding up to 65% in commercial fields [19]. In Ethiopia, around northern Shewa white rot incidence was reported at a level ranging from 37.28% to 42% in farmers fields [20]. Mengistu [21] also reported that garlic white rot become major problem in major garlic production area of the country. In Ethiopia, yield loss due white rot has been found to range between 20.7% and 53.4% [22].

Management of diseases caused by soil borne pathogens, especially those that produce sclerotia is very difficult and needs effective management strategy. Crop rotation used for primary inoculum reduction [23], but has been viewed as impractical for *Allium* white rot control due to the persistence and longevity of the sclerotia in the soil, soil solarization [24]. According to Porter and Merriman [25] and Stewart and Fullerton [26], the technique requires 3-4 months, in which no other crops can be grown, as well as the expense of coating infested fields with plastic, soil solarisation might only be cost-effective in countries where the climate aids the process, sclerotia germination stimulants [27], composted onion waste [28,29] host resistant, the is no difference in susceptibility exist among *Allium* species [30]. Fungicides are among the most effective options for garlic white rot disease management. According to Tamire et al. [22], systemic as well as non-systemic fungicides significantly reduced incidence of white rot, its progress rate, severity, and there by improved garlic yield. Fullerton and Stewart [31] also found that procymidon reduced incidence of white rot up to 75-95% applied as bulb and soil treatment. According to Meler-Vara et al. [32] and Duff et al. [33], tebuconazole was effective in reducing the incidence and progress of the disease, and in increasing the yield when applied as a clove treatment. However, no such attempt has been made to find effective fungicide for the management of white rot under Tigray regional state garlic production conditions. Therefore, this study was initiated with the following objectives:

To evaluate the effectiveness of fungicides on disease epidemics, yield and yield components garlic, and to determine the cost effectiveness the fungicides against garlic white rot.

Materials and Methods

Description of the experimental site

Field experiment on management of garlic white rot using fungicides was conducted during 2010 cropping season with supplement irrigation at Mekell Agricultural Research Center experimental site, which is located 13°31' N latitude and 039°58' E longitude. It lies at an altitude of 2000 m.a.s.l. The mean annual rain fall and mean annual temperature are 576.8 mm and 19.5°C, respectively. The relative humidity of the field experiment is 50%. The field experiment was conducted on 7.47 soil pH cultivated clay loam soil. The trial was conducted in fields naturally infested with sclerotia of *S. cepivorum*.

Experimental materials

Varieties: Local cultivar was used for the field trial. The local cultivar has been cultivated by the farmers in the areas for long period of time.

Fungicides: The fungicides used in this study were tebuconazole (Folicur 25 EC 2.1 ml kg⁻¹), mancozeb (80 WP 4.17 g kg⁻¹) and captan (Merpan 50 WP 4.17 g kg⁻¹). Clove coating with wettable powders of mancozeb and captan were done by making slurry of the required fungicide in 5 ml of water, and then coating on 480 g cloves in a polythene bag by rotating repeatedly. Clove dip treatment of tebuconazole was done by dipping 480 g cloves in solution of 1.01 ml tebuconazole in 1 liter of water.

Experimental design

A randomized complete block design (RCBD) with three replications in 4.8 m² plots, with 1 m spacing between blocks and 0.5 m between plots. The plots were fertilized with 200 kg di-ammonium phosphate and 150 kg Urea ha⁻¹. Cloves of a similar size were hand planted on July 17/07/2010 at Mekelle Agricultural Research Center experimental site. The planting was made in a plot of 8 rows, with 0.3 m spacing between rows and 0.1 m between plants.

Data collection

Data for initial and final plant stand count at emergence and harvest, and disease incidence (percent diseased plants) was recorded from each plot. Garlic initial stand establishment was determined as percentages of germinated cloves at 30 DAP (days after planting), and final stand count as the harvested bulb. Plant height was also recorded from 20 randomly selected plants at the maximum growth stage. White rot incidence was recorded six times every 15 days interval from the first appearance of the disease in the plots. The numbers of infected plants were counted from six central rows of each plot at 40, 55, 70, 85, 100 and 115 DAP (days after planting).

Bulbs were harvested from the middle six rows, and the bulbs collected from each plot were allowed to dry for 15 days and weighed to determine yield. Infected bulbs were selected from harvested bulbs from, and severity was rated on 0-5 scale where 0=healthy; 1=bulb covered with mycelium but not rotted; 2=1-25% of the bulb rotted; 3=25-50% of the bulb rotted 4=50-75% of the bulb rotted and 5=75-100% of the bulb rotted [34]. Disease severity scores were converted into percentage as per producers stated below for analysis.

$$\text{Disease severity (\%)} = \frac{\text{Total points score}}{\text{Total number of bulbs scored} \times \text{Highest scored on the scale}} \times 100$$

Sclerotial density was determined by extracting sclerotia from soil samples of each plot. Soil samples collected up to 15 cm depth were drawn from all plots at harvest and air dried until the weight loss established. The soil samples were processed to estimate density of sclerotia by the wet sieving method [35]. Sclerotia were collected and recovered from each air dried (22-24°C) 500 g soil sample, which was blended with 500 ml of water in a blender at low speed for 30 seconds, and then passed through stacked 0.85 and 0.25 mm soil screens under a water spray. The residue from 0.25 mm screen was washed into 1000 ml beaker with about 500 ml of water, and decanted back on to the 0.25 mm screen. The sclerotia remaining on this sieve was collected and counted under a stereoscopic binocular microscope (10× and 100× magnification) in counting dishes.

Data analysis

Disease incidence was transformed using monomolecular model $\ln(1/1-y)$ [36] transformation before analysis. Transformed data were subjected to linear regression to determine disease progress rate. The disease progress rate for each plot was estimated as the slope of the regression line of the disease progress data. In all cases, DAP (Days after planting) was used as predictor and incidence as response variables. Area under disease progress curve (AUDPC) was calculated for each treatment from the assessment of disease incidence using the formula:

$$AUDPC = \sum_{i=1}^{n-1} \frac{1}{2}(X_i + X_{i+1})(t_{i+1} - t_i)$$

Where x_i is the disease incidence in percentage at i th assessment, t_i is the time of the i th assessment in days from the first assessment date, and n is the total number of days the disease was assessed [36]. Because incidence was expressed in percent and time in days, AUDPC was expressed in %-days. All data were analyzed and ANOVA was performed for a randomized completely blocks design with factorial arrangement to evaluate the effect of fungicides and varieties using the SAS Institute [37] system. In the trial, where differences existed between treatments, means were compared using fisher's least significant difference (LSD).

Cost benefit

Prices of garlic bulbs (Birr ton⁻¹) were obtained from local market and farmer union in the locality, and total sale from one hectare was computed. The price of local garlic cultivar was birr 24000/800 kg. The price of fungicides tebuconazol, captan and mancozeb were (\$18.201 per liter, \$16.09 per Kg and \$6.43 per Kg), respectively. Cost of labor to treat garlic bulbs was computed. Cost of labour was \$1.072 per man days. All input costs from one hectare were calculated. Cost benefit analysis was performed using partial budget analysis. Partial budget analysis is a method of organizing data and information about the cost and benefit of various agricultural alternatives [38]. Partial budgeting is employed to assess profitability of any new technologies (practice) to be imposed to the agricultural business. Marginal analysis is concerned with the process of making choice between alternative factor-product combinations considering small changes. Marginal rate of return is a criterion, which measures the effect of additional capital invested on net returns using new managements compared with the previous one [38]. It provides the value of benefit obtained per the amount of additional cost incurred percentage. The formula is as follows:

$$MRR = \frac{DNI}{DIC}$$

Where, MRR is marginal rate of returns, DNI, difference in net income compared with control, DIC, difference in input cost compared with control.

The following points were considered during cost benefit analysis using partial budget.

- Costs for all agronomic practices were uniform for all treatments.
- Price of garlic bulb per tons for the local variety was taken based local price
- Costs of labor was taken based on local price
- Costs and benefit were calculated per hectare basis. It was assumed that, farmers produce garlic varieties under managements of garlic white rot using fungicides garlic provided 100% marginal rate of returns.

Results

White rot incidence, severity and AUDPC

White rot symptoms were evident at 40 days after planting. Infected plants had yellowish lower leaves, and wilting symptoms. Significant difference of disease incidence was observed at all assessment dates among the treatments ($P < 0.01$). Significantly lowest initial and final disease incidence was observed on fungicide treated plots, as compared to untreated plot (Table 1). Significant difference in disease incidence was recorded among fungicide treated plots (Table 1). Tebuconazole treated plot provided significantly lowest initial and final disease incidence compared to captan and mancozeb treated plot. A lower disease incidence was observed on captan and mancozeb treated plot compared to untreated plot, but there was no significant difference between captan and mancozeb treated plot (Table 1). In tebuconazole treated plot, the final disease incidence was reduced by 74.33% compared with untreated plots. Disease Severity evaluated on harvested bulbs also indicated significant difference among treatments ($P < 0.01$). Significant highest severity was recorded on untreated plot compared fungicide treated plots, and by 77.54% reduced severity was observed in tebuconazole treated plots over untreated plots. Significantly lower severity was reflected in captan and mancozeb treated plots compared to untreated plots, and by 43.31% and 40.9% reduced severity was observed in captan and mancozeb treated plot, respectively over untreated plots, but there was no significant difference between the two fungicides treated plot. Statically significant difference among treatments was observed on AUDPC value at ($P < 0.01$). Significantly lowest AUDPC value was obtained in tebuconazole treated plot, as compared to the other two fungicide treated plots and untreated plots. Significantly lowest AUDPC value was obtained in all fungicide treated plot, as compared to untreated plot and reduced AUDPC value by 79.15%, 41% and 39.65% days in tebuconazole, captan and mancozeb treated plots was observed, respectively, as compared to untreated plots.

Disease progress rate

The effect of different fungicides on disease incidence was assessed six times during the cropping season. The effect of fungicide on disease progress rate was also evaluated. The rate of disease progress was significantly different among treatments at ($P < 0.01$) (Table 2). The disease progress rate on mancozeb and captan treated plot was about three times faster than tebuconazole treated plot, where as in untreated plot the disease progress was 4.28 times faster than tebuconazole treated plots. Least disease development was observed in tebuconazole treated

Treatments	Initial white rot incidence (%) ¹	Final white rot incidence (%) ²	White rot severity ³ (%)	Sclerotia density 500 g ⁻¹ **	AUDPC
Local+Captan	19.15b	33.91b	21.51b	20.52b	2109.3b
Local+Mancozeb	20.07b	39.45b	21.46b	24.83b	2219.5b
Local+Tebuconazole	5.58c	13.60c	8.65c	10c	661.7c
Control	33.08a	53.68a	37.31a	44.86a	3211.2a
CV (%)	19.99	14.19	13.86	10.99	10.61
LSD (5%)	7.33	9.39	5.80	5.19	409.53

Means in every columns with same letters are not significant difference at ($P < 0.05$) CV=Coefficient of Variation; LSD=Least Significant Difference

¹Initial white rot incidence at 40 days after planting (DAP)

²Final white rot incidence at 115 days after planting (DAP)

³White rot severity on harvested bulbs; ns=no significant difference

*Sclerotial density at harvest per 500 g of soil sample

AUDPC=Area under Disease Progress Curve

Table 1: Effect of fungicide treatment of garlic cloves on white rot incidence, severity, sclerotial density and AUDPC at Mekell, Ethiopia.

Treatments	Intercept	SE* of Intercept	Disease progress rate (unit day ⁻¹)	SE* of rate	R ² (%) **	Significant
Local+Captan	0.0407	0.0423	0.00384	0.0005	93	0.0018
Local+Mancozeb	0.0380	0.0282	0.0041	0.0004	97	0.0003
Local+Tebuconazole	-0.0047	0.0132	0.0013	0.0002	94	0.0014
Control	0.1429	0.0615	0.00553	0.0008	93	0.0018

*Standard error of the parameter estimates; **Coefficient of determination

Table 2: Disease progress rate and other parameter estimates for white rot (*S. cepivorum*) incidence on garlic under evaluation of fungicides at Mekelle, Ethiopia.

Treatments	Initial stand count (%) ¹	Plant height (cm)	Bulb harvested (%) ²	Total yield (t ha ⁻¹)	Marketable Yield (t ha ⁻¹)
Local+Captan	74.34b	70.38a	87.10b	4.79b	4.04b
Local+Mancozeb	71.97b	69.42a	86.42b	4.39b	3.67b
Local+Tebuconazole	83.37a	75.62a	94.07a	6.92a	6.1a
Control	64.02c	55.01b	70.69c	3.09c	2.24c
CV (%)	4.16	6.16	2.84	6.34	15.85
LSD (5%)	5.75	7.84	4.53	0.57	1.20

Means in every column with same letters are not significant different at (P<0.05)

ns=no significant difference; CV=Coefficient of Variation

LSD=Least Significant Difference;

¹Initial stand after 30 DAP of planting.

²Bulbs as percent of initial stand count

Table 3: Effect of fungicide treatment of garlic cloves on yield and yield components in (*Sclerotium cepivorum*) infested field at Mekelle, Ethiopia.

Cost benefit data	Treatments			
	Local+Captan	Local+Mancozeb	Local+Tebuconazole	Control
Local				
Marketable yield t ha ⁻¹	4.04	3.67	6.1	2.24
Price (\$ t ⁻¹)	1,608.58	1,608.58	1,608.58	1,608.58
Sale revenue	1,343.11	316.54	526.13	193.20
Total input cost (\$ ha ⁻¹)	1,343.11	1318.03	1327.14	1,286.86
Marginal cost (\$ ha ⁻¹)	56.24	31.17	40.33	00
Net benefit (\$ ha ⁻¹)	5155.55	4585.45	8,485.20	2,316.35
Marginal benefit (\$ ha ⁻¹)	2839.2	2,269.1	6,168.84	00
Marginal rate of return (%)	270.67	390.34	820.22	00

Table 4: Partial budget analysis for management of garlic white rot using fungicides and host resistant at Mekelle, Ethiopia.

plot (0.0013 unit day⁻¹). In untreated plot, 1.44 and 1.36 times faster than disease development respectively on captan and mancozeb treated plot was observed.

Parameter estimates are from a linear regression of $\ln(1/1-y)$ disease incidence proportion on time (days after planting). Intercept and slope represent the equation of the line.

Sclerotial density

Sclerotial density in each plot was determined at harvest. Significant differences in sclerotial density among treatments plot was observed (P<0.01) (Table 1). The average number of sclerotia in the untreated control plot was 42.4 sclerotia 500 g⁻¹ of soil sample, which was significantly highest of all the fungicide treated plot (Table 1). Significantly lower numbers of sclerotia were recovered in tebuconazole treated plots, as compared to captan and mancozeb treated plots. Similarly significantly lower number of sclerotia was recovered on captan and mancozeb treated plots over untreated plots.

Yield and yield components

Initial stand count was significantly different among the treatments (P<0.01). The untreated plot had got significantly lower initial stand establishment compared to all fungicides treated plot (Table 3). Significantly difference crop initial stand was recorded among fungicide treated plots (Table 3). Significantly highest crop initial stand was observed in tebuconazole treated plot compared to untreated plot,

and 34.76% increment of initial stand establishment over untreated plot was obtained. Significantly highest initial stand was recorded from tebuconazole treated plot, followed by captan and mancozeb treated plot as compared to untreated plot. In captan and mancozeb treated plot, significantly higher initial stand was recorded over untreated plot (Table 3), but there was no significant difference between each other. In captan and mancozeb treated plot, increased the plant stand by 16.57% and 14.73%, and respectively over the untreated plot was observed. Significantly varied plant height was observed among treatments (P<0.01). It has been found that fungicide treatment of garlic cloves has positive effect on plant height. Accordingly, significantly higher plant height was recorded from tebuconazole, captan and mancozeb treated plot compared with untreated plot, but they had no significant difference among themselves (Table 3). Bulbs were harvested at different dates for different treatments. Fungicide treated plot did not mature equally, with untreated four garlic cultivars and captan and mancozeb treated plot were harvested 7 days later than untreated plot, and also tebuconazole treated plot were harvested 22 days later than the untreated plots. The number of harvested bulbs (expressed as percent of initial stand) was evaluated, and there was a significant difference (P<0.01) among the treatments. The number of harvested bulbs was significantly higher in tebuconazole, followed by the other two fungicide treated plot than the control plot (Table 3). There was also highly significant difference on total and marketable yield among treatments (P<0.01). All fungicide treated plots had got significantly higher total and marketable yield over untreated plots (Table 3). Significantly highest marketable yield

was recorded from tebuconazole treated plot, compared to the other two fungicides and untreated plot (Table 3) was recorded, while the untreated plot gave the lowest yield.

Cost benefit analysis

Analysis of variances showed that significant difference was observed among treatments on total income, input cost, marginal cost, net benefit ($P < 0.01$). Significantly higher net profit was obtained from tebuconazole treated plot compared to untreated, and the other two fungicides treated plot. Application of tebuconazole as clove treatment provided net benefit (\$7493.24). The corresponding value of marginal rate of return was (820.22%). In tebuconazole treated plots, \$ 4,950.34 more net benefit was obtained as compared to untreated plots (Table 4). Higher net benefit was obtained in tebuconazole treated compared the other two fungicide treated plot (Table 4). The additional input cost in fungicide treated plots was (\$40.33, \$56.24 and \$31.17) in tebuconazole, captan and mancozeb, respectively.

Discussion

It was observed that all fungicide treated plots significantly reduced incidence of white rot, its progress rate, severity, AUDPC and also improved garlic yield and yield components over the untreated plots. Even if fungicide treatments were effective in reducing white rot incidence, its progress rate, severity, AUDPC and improved yield and yield components as compared to untreated plots, there was no complete control of garlic white rot. This finding is in line with the previous research finding by [20]. All fungicides have got significant effect in reducing initial disease incidence. Tebuconazole, captan and mancozeb reduced the disease incidence by 83.33%, 50.62% and 50.14% respectively, over untreated plots. Similarly significantly lower final disease incidence was observed on fungicides treated plots compared to untreated plots. In tebuconazole, captan and mancozeb treated plots less final disease incidences was observed as compared to untreated plots, and final incidence was reduced by 74.33%, 34.45% and 31.25% in tebuconazole, captan and mancozeb treated plots, respectively over untreated plots. The lowest severity of white rot was recorded from tebuconazole treated plots compared to the other fungicides and untreated plots. White rot severity reduced by 77.54% due to tebuconazole application. Moreover, significantly lowest sclerotia density was observed on tebuconazole treated plots compared with captan, mancozeb and untreated plots. The sclerotial density on untreated plots exceeded by 71.77% in control plots compared with tebuconazole treated plots. This finding is in line with previous results of [20], which reported that all fungicide treatments not only protected plants from white rot at different stages, but also reduced the formation of sclerotia in the soil as recorded at the time of harvesting. The degree of disease control achieved by treatment with tebuconazole was higher than that of the other two fungicides and untreated plots. According to Melero-Vara et al. [32], treatment of garlic cloves with tebuconazole and basal spray was achieved significant reduction in the rate of disease progress and the final incidence of plant death by (*Sclerotium cepivorum*). Fullerton et al. (1995) also achieved that disease incidence was reduced up to 85% in tebuconazole treated plots compared with untreated plots in onion. Prados-Ligero et al. [24] also reported that similar significant reduction of disease incidence and AUDPC value were observed both in solarised and tebuconazole treated cloves, and resulting in quantitative and qualitative yield improvement. Other researchers also reported that combinations of tebuconazole and a bio control agent enhanced the control of onion white rot [39].

In tebuconazole treated plots, significantly higher total and

marketable yield was obtained over other two fungicides treated plots and untreated plots (Table 3). Tebuconazole treated plots resulted in 3.36 t ha⁻¹ increase in total yield, and also there was significant increment in marketable yield 3.18 t ha⁻¹ observed over untreated plots. Duff et al. [33] also achieved that highest marketable yields were obtained from tebuconazole treated garlic cloves compared with procymidone treated garlic cloves on the trial conducted heavily infested with sclerotia of *Sclerotium cepivorum*.

It was found that tebuconazole treated plots provided significantly higher net benefit over the other two fungicides and untreated plots. Tebuconazole maximized the net benefit, and the net benefit was exceeded by 92323.89 birr over untreated plots. The marginal rate of return on tebuconazole treated plots over untreated plots was 12275.48%. Chaube and Sing [40] reported that the aim of disease control is to check reduction in economic gain from a crop, and if the control measures fail to increase economic gain, even if disease epidemic is reduced, no grower is likely to accept the recommendation for the plant disease control measures.

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