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Research Article

Effect of Seed Treatment and Mixed Cropping on Management 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 objective of this study was to determine the effect of integrated management of garlic white rot using garlic/*Brassica* mixed cropping and tebuconazole application on epidemics of the disease, and yield and yield components garlic. Field experiment was conducted in H/wajirat at ''Gumsalasa'' irrigation schame on garlic white rot naturally infested field in 2013 and 2014. Five level of tebuconazole (0, 0.25, 0.5, 0.75 and 1 ml/kg) in a factorial treatment combination of garlic mixed cropped in rows with *Brassica* (G:B) in 1:1 was employed. Similar garlic sizes a clove treatment were treated with different level tebuconazole before planting. A randomized complete block design with three replications was employed. A total of ten treatments were evaluated per replication. Tebuconazole application at different rate gave reduced the disease epidemic and improved garlic yield. However, among tebuconazole different application rate treated plots tebuconazole application at 1 ml/kg was the most effective in reducing the disease epidemics and gave better yield advantage. In tebuconazole application at 1 ml/kg treated plot 62.8, 48.83 and 18.09% reduced incidence, area under disease progress and severity were recorded, respectively as compared to garlic/*Brassica* mixed cropping and untreated plot. Significantly higher increment on total and marketable yield was observed in 1 ml/kg tebuconazole application treated plot as compared to other treatments. In 1 ml/kg tebuconazole application rate treated plot 58.7% marketable yield increments were obtained as compared to untreated plot. Tebuconazole treated plot at 1 ml/kg maximized the net benefit, which exceeded by 115,746.67 was obtained over untreated plot. The marginal rate of return on tebuconazole at 0.25 ml/kg treated plot over untreated plot was 1375.88%. 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 at 0.25 ml/kg integrated with garlic/*Brassica* can be considered as management strategy to reduce disease epidemics and improve garlic yield in study area and other similar ago ecologies.

Keywords: Disease epidemics; Garlic; *Sclerotium cepivorum*; Seed treatment; Mixed cropping, 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]. Garlic also has antibiotic properties and has been used to treat wounds when other antibiotics were not available [3]. Proponents advise eating a raw clove of garlic a day to boost the immune system [4].

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Economic significance of garlic in Ethiopia is quite considerable. It is grown as spice and used for flavoring local dishes, and contributes to the national economy as export commodity [5]. 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 [6]. 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 [7].

In Ethiopia, the total area under garlic production in 2006 and 2007 reached 9,266 hectares and the production is estimated to be over 68300 tons annually [8]. 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 factor. 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* is the most yield limiting fungal disease other diseases like rust caused by *Puccinia allii*, neck rot caused by *Botrytis allii*, *B. squamosa* and *B. cinerea* are also caused significant role on yield reduction of the crop globally [9,10].

White rot persists as small, dormant structures, called sclerotia, in soil. Sclerotia can survive for several years, in the absence of a host plant [11]. It only attacks *Allium* species, and can infect plants from 12 inches below the surface and spread rapidly to adjacent plants [12,13]. 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 [14].

The disease is prevalent in many *Allium* growing regions worldwide and causes serious economic losses in garlic and onion crops [15]. In Ethiopia around Northern Sheowa and eastern Tigray highlands white rot incidence was reported at a level ranging from 42 to 53% in farmers' fields respectively [16,17]. Other researchers also reported that garlic white rot become major problem in major garlic production area of the country [18]. In Ethiopia yield loss due white rot has been found to range between 20.7%-53.4% [19].

Management of diseases caused by soil borne pathogens especially those that produce sclerotia is very complex and need a multi-pronged management strategy. Tebuconazole was effective in reducing the incidence and progress of the disease and in increasing the yield when applied as a clove treatment. However, regular *Allium* cultivation in such fields increases sclerotial density over time, increasing disease severity in subsequent seasons [20].

Survey conducted on garlic white rot disease in central Ethiopia showed that garlic fields mixed with *Brassica* spp., were almost free from the disease. This might be due to the biofumigant effect of the *Brassica* plant due to exudates of glucosinolates from its roots. Glucosinolates might be released from the living plant roots at the time when leaves were removed from the plant by farmers. *Brassica* species adversely affected the population of pathogens in the soil by releasing biocidal compounds. However, due to persistence and longevity of the nature of the diseases in the absence of the host plant no single method can gave the desired level of control. The most effective control systems to date have involved the integration of a number of systems for managing garlic white rot. There is no empirical research data on the effect of integrated disease management of garlic white rot by using garlic/*Brassica* mixed cropping and fungicide application to control the disease in Ethiopia in general in Tigray reginal state in particular. Therefore, this study was initiated with the following objective. To determine the effect of integrated management of garlic white rot using garlic/*Brassica* mixed cropping and tebuconazole on epidemics of the disease, and yield and yield components garlic.

MATERIALS AND METHODS

Experimental design and management

The trial was conducted fields naturally infested with sclerotia of (*S. cepivorum*) in major garlic growing areas of H/Wajrat district. A randomized complete block design was arranged in a factorial treatment combination of garlic mixed cropped in rows with *Brassica* (G:B) in 1:1 ratio and five rate of tebuconazole (0, 0.25, 0.50, 0.75 and 1 ml/kg) including untreated plot were employed. Accordingly, treatment combinations will be assigned randomly to the experimental plot within a block. The plots will be fertilized with 200 kg di-ammonium phosphate and 150 kg urea ha^{-1}. Cloves of a similar size were treated with four different level of tebuconazole and the control plot was treated with pour water for comparison purpose. The planting was done made in a plot of 8 rows with 0.3 m spacing between rows and 0.1 m between plants. Planting was done under irrigation in 2013 and 2014 in H/Wajrat district were the disease pressure is reached at epidemic level.

Data collection

Data for stand count 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. White rot incidence was recorded five times every 15 days interval from the first appearance of the disease in the plots. The numbers of infected plants was counted from six central rows of each plot at 40, 55, 70, 85, and 100 (days after planting).

Bulbs was harvested from the middle six rows and the bulbs collected from each plot was allowed to dry for 3 days and weighed to determine yield. Infected bulbs was 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. Disease severity scores was converted into percentage index as per producers stated below for analysis.

$$\text{Disease severity (\%)} = \frac{\text{Sum of all disease rating}}{\text{Total number of(rating) bulbs scored x Highest scored on the scale}} x100$$

Data analysis

Area Under Disease Progress Curve (AUDPC) was calculated for each treatment from the assessment of disease incidence using the formula:

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

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. Because incidence was expressed in percent and time in days, AUDPC was expressed in %-days. All data was analyzed and ANOVA was performed for a randomized completely blocks design with factorial treatment arrangement to evaluate the effect of garlic/*Brassica* mixed cropping, and five tebuconazole rates applications against garlic white rot disease epidemics and using the system. In the trial, where differences existed between treatments, means was compared using Fisher's Least Significant Difference (LSD).

Cost benefit analysis

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. Partial budgeting was employed to assess profitability of any new technologies (practice) to be imposed to the agricultural business. Marginal analysis was concerned with the process of making choice between alternative factor product combinations considering small changes. Marginal rate of return was a criterion which measures the effect of additional capital invested on net returns using new managements compared with the previous one. 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 is difference in net income compared with control.

DIC is difference in input cost compared with control.

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

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

RESULTS AND DISCUSSION

Disease incidence was observed at 40 days after planting. Disease plants had yellowing, leave dieback and mycelium growing around the base of the plants symptom. Significance difference disease incidence among treatments was observed at ($P<0.05$) (Table 1). Significantly lowest disease incidence was noted on different amount tebuconazole application compared to garlic/*Brassica* mixed cropping system and untreated plot. Different amount teboconazole application with garlic/*Brassica* mixed cropping system provided significantly lowest disease incidence compared to untreated, and garlic/*Brassica* mixed cropping plots. Tebuconazole application at level 1 ml/kg with garlic/*Brassica* mixed cropping gave lowest disease incidence compared to the other treatments. Tebuconazole application at a level 1 ml/kg integrated with garlic/*Brassica* mixed cropping system gave reduced disease incidence by 62.8% over untreated and garlic/*Brassica* mixed cropping plots alone. Tebuconazole treated plots at level 1 ml/kg provided significant lowest initial and final disease incidence in 2005 irrigation season compared to other treatments.

Significant difference among treatments was observed on AUDPC value at ($P<0.01$). Significantly lowest AUDPC value was obtained in tebuconazole treated plots at 1 ml/kg as compared to the other treatments. Significantly lowest AUDPC value was obtained in all tebuconazole applications levels compared to untreated and garlic/*Brassica* intercropping plots. Tebuconazole application at 1 ml/kg by 48.83% in days reduced AUDPC value was observed compared to control and garlic/*Brassica* intercropping plots.

Disease severity was assessed on harvested garlic bulbs, and significance difference disease severity among treatment was observed at ($P<0.05$) (Table 2). Significant highest diseases severity was reflected on untreated and garlic/*Brassica* mixed cropping system plots compared to the other treatments, and tebuconazole application at level 1 ml/kg with garlic/*Brassica* mixed cropping system gave reduced disease severity by 18.09% compared to the untreated plot.

All different levels of tebuconazole application had got significant higher marketable yield compared to untreated and garlic/*Brassica* mixed cropping system plots. According to (30) application of tebuconazole at naturally infested garlic white rot field gave better marketable and survival rate compared to other fungicide applications. Significant highest marketable yield was observed on tebuconazole application at level 1 ml/kg with garlic/*Brassica* intercropping followed by tebuconozole application at 0.75 ml/kg with garlic/*Brassica* intercropping over the other treatments. In tebuconazole application at level 1 ml/kg with garlic/*Brassica* inter cropping gave 58.7% marketable yield increment over untreated plot (Table 3).

Table 1: Effect of fungicide application and mixed cropping on disease incidence and area under progress rate at H/Wajrat, Ethiopia in 2013/2014.

Treatments	2004/5 IDI	2005/6 IDI	Mean	2004/5 FDI	2005/6 FDI	Mean	2004/5 AUPC	2005/6 AUPC	Mean
Garlic +*Brassica*+1 ml/kg	15.2^{a}	13.3	14.9^{a}	15.28^{a}	10.00^{a}	12.6^{a}	598^{a}	1328	963^{a}
Garlic +*Brassica* +0.75 ml/kg	18.23^{ab}	17.3	17.8^{ab}	18.23^{ab}	16.67^{ab}	17.45^{ab}	751^{ab}	1030	890.5^{a}
Garlic +*Brassica* +0.25 ml/kg	22.30^{bc}	18.3	20.3^{abc}	22.30^{bc}	16.67^{ab}	19.5^{abc}	942b^{c}	762	852^{ab}
Garlic+1 ml/kg	25.50^{c}	13.3	19.4^{bcd}	25.50^{c}	36.67^{c}	31.1^{bcd}	1076^{c}	1000	1038^{ab}
Garlic +*Brassica*+ 0.5 ml/kg	26.10^{c}	21.7	23.9^{abcd}	26.10^{c}	26.67^{abc}	26.4^{abcd}	1114^{c}	1312	1213^{ab}
Garlic+0.75 ml/kg	27.70^{c}	22.7	25.2^{d}	27.70^{c}	40.00^{c}	33.85^{d}	1176^{cd}	1745	1460^{ab}
Garlic+0.5 ml/kg	34.43^{d}	20.3	27.4^{cd}	34.43^{d}	30^{bc}	32.22^{cd}	1430de	1278	1354b^{c}
Garlic+0.25 ml/kg	39.73^{d}	31.7	35.7^{d}	39.73^{d}	33.33^{c}	36.53^{d}	1655^{e}	1562	1609^{b}
Garlic +*Brassica*	49.8^{e}	26.7	38.25^{cd}	49.80^{e}	13.33^{a}	31.6^{cd}	2073^{f}	1350	1712^{c}
Control	80^{f}	31.7	55.9^{e}	80^{f}	30^{bc}	55^{e}	3271^{g}	1362	2317^{d}
LSD (5%)	6.61	13.73	13.84	6.6	13.73	15.09	282.4	Ns	548.8
CV %	11.4	14.9	4.1	11.4	15.6	33.4	11.7	20.02	13

Note: Means in every column with same letters are not significant difference at (P<0.05), CV: Coefficient of Variation; LSD: Least Significant Difference, [1]Initial chocolate spot severity at 50 Days After Planting (DAP), [2]Final chocolate spot severities at 100 Days After Planting (DAP), [3]AUDP: Area Under Disease progress

Table 2: Effect fungicide application and mixed cropping on disease severity of garlic bulbs on naturally infested with sclerotia of (*S. cepivorum*) at H/Wajrat, Ethiopia in 2013/14.

Treatments	2013/14 % DS	2013/14 % DS	Mean
Garlic+*Brassica*+1 ml/kg	3.33^{a}	11.67^{a}	7.50^{a}
Garlic+*Brassica*+.75 ml/kg	9.00^{ab}	21.00^{a}	15^{ab}
Garlic+*Brassica*+.25 ml/kg	14.10^{bc}	21.67^{a}	17.88^{ab}
Garlic+1 ml/kg	17.80^{cd}	29.33^{ab}	22.23^{bc}
Garlic+*Brassica*+.5 ml/kg	18.10^{cd}	20.00^{a}	19.05^{ab}
Garlic+.75 ml/kg	18.33^{cd}	34.00^{abc}	26.17^{bcd}
Garlic+0.5 ml/kg	18.55^{cd}	48.00^{bc}	33.27^{cde}
Garlic+.25 ml/kg	22de	32.67^{abc}	27.33^{bcd}

Garlic+*Brassica*	27.41^{e}	48.67^{bc}	38.04^{de}
Control	36.10^{f}	55.00^{c}	45.55^{e}
LSD (5%)	7.828	23.57	13.58
CV %	24.7	21.35	4.6

Note: Means in every columns with same letters are not significant difference at (P<0.05); CV: Coefficient of Variation; LSD: Least Significant Difference, DS: Disease severity.

Table 3: Effect fungicide application and mixed cropping on stand count and yield of garlic under naturally infested with sclerotia of (*S. cepivorum*) at H/Wajrat, Ethiopia in 20013/2014.

Treatments	2013/14 SCH	2013/14 SCH	Mean	2013/14 MYt/ha	2013/14 MY t/ha	Mean
Garlic+*Brassica*+1 ml/kg	157.67	104	130.8	12.467^{f}	4.44	8.452^{d}
Garlic+*Brassica*+.75 ml/kg	157	92	124.5	10.363^{e}	4.01	7.186^{cd}
Garlic+*Brassica*+.25 ml/kg	157.67	91.3	124.5	8.985^{d}	3.11	6.045^{bc}
Garlic+1 ml/kg	154.33	105.3	129.8	6.667^{b}	4.62	5.642^{bc}
Garlic+*Brassica*+.5 ml/kg	158	117	137.5	8.494^{cd}	3.15	5.82^{bc}
Garlic+.75 ml/kg	155.33	100.3	127.8	7.100^{b}	3.13	5.556^{bc}
Garlic+0.5 ml/kg	156.67	103.7	130.2	7.100^{b}	3.13	5.112^{ab}
Garlic+.25 ml/kg	154.33	98.7	126.5	6.833^{b}	3.58	5.205^{ab}
Garlic+*Brassica*	150	89.3	119.7	5.257^{a}	1.94	3.601^{a}
Control	155.33	85.7	120.5	5.15^{a}	3.92	4.537^{ab}
LSD (5%)	Ns	Ns	Ns	1.1	Ns	1.688
CV %	1.9	14.3	8.1	8.1	3.13	25.5

Note: Means in every column with same letters are not significant difference at (P<0.05); CV: Coefficient of Variation; LSD: Least Significant Difference, NS: No Significant difference, SCH: Stand Count at Harvest, MY: Marketable Yield, t/ha: tone/hectare.

Cost benefit analysis

Highest net profit was observed on chemical application compared to untreated plots and tebuconazole application at different rate treated plots compare to untreated. Application of tebuconazole as clove treatment provided net benefit birr 115,746.67 in 1 ml/kg 98,233.33 in 0.75 ml/kg, 73,500 in 0.5 ml/k, 76,733.33 in 0.25 ml/kg and 40,905 untreated plots. The corresponding value of marginal rate of return was 898.10%, 1375.88%, 931.29% and 2149.70% respectively. Higher marginal rate of return tebuconazole application at 0.25 ml/kg rate followed by 0.75 ml/kg compared to other treatments. In tebuconazole application at 0.25 ml/kg treated plots 2149.70% more net benefit birr was obtained as compared to untreated plots.

Higher net benefit was obtained in tebuconazole application at 1 ml/kg followed by 0.75 ml/kg treated pots compared the other treatments (Table 4). The additional input cost in fungicide treated plots was (8,333.33, 4,166.67, 3,500, and 1666.67) birr in tebuconazole application at 1 ml/kg, 0.75 ml/kg, 0.5 ml/ respectively.

Table 4: Result of partial budget analysis for management of garlic white rot using fungicide application at H/Wajrat, Ethiopia in 20013/2014.

Treatments	Garlic+1 ml/Kg	Garlic+0.75 ml/Kg	Garlic+0.5 ml/Kg	Garlic+0.25 ml/Kg	Control
Adj. yield (t ha^{-1}) (yield × 0.25)	1.76	1.6	1.38	1.4	1.01
Price (Birr t^{-1})	70,400	64,000	56,000	56,000	40,400
Sale revenue (1 × 2)	1,24,080	1,02,400	77,000	78,400	40,905
Total input cost (Birr ha^{-1})	8,333.33	4,166.67	3,500	1666.67	0
Marginal cost (Birr ha^{-1})	8,333.33	4,166.67	3,500	1666.67	0
Net profit (3-4) (Birr ha^{-1})	1,15,746.67	98,233.33	73,500.00	76,733.33	40,905.00
Marginal benefit (Birr ha^{-1})	74,841.67	57,328.33	32,595	35,828	0
Marginal rate of return (7/5) (%)	898.1	1375.88	931.29	2149.7	0

CONCLUSION

Garlic white rot is one of the economically limiting biological factor for garlic production and productivity in garlic growing areas of the country in general and Tigray regional state in particular. Application of tebuconazole at different rate was the most effective in reducing disease epidemics, improved garlic yield and yield components. In fungicide treated plots significantly less white rot incidence was observed in all assessment days as compared to untreated plots. Application of tebuconazole at 0.25 ml/kg garlic glove gave higher marginal rate of return compared to other treatments. Garlic a high value crop, and white rot is potential threat in the study area. Therefore, application of tebuconazole @0.25 ml/kg integrated with Brassica can be used garlic white rot management options in the study area and other similar ago ecologies.

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