Novelty Journals

ISSN 2394-966X

International Journal of Novel Research in Life Sciences
Vol. 6, Issue 1, pp: (1-12), Month: January - February 2019, Available at: www.noveltyjournals.com

MANAGEMENT OF SEPTORIA TRITICI BLOTCH (*Septoria tritici*) OF BREAD WHEAT (*Triticum aestivum* L.) IN THE CENTRAL HIGHLANDS OF ETHIOPIA

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Abstract: **Septoria tritici blotch (STB) is an economically important foliar disease in the major wheat-growing areas of Ethiopia. The current research was conducted to determine the impact of wheat varieties and fungicides on disease development and wheat yield. Besides, the effect of bread wheat varieties and fungicides on STB development, wheat yield was evaluated at Holleta and Kulumsa in a factorial field experiment involving three bread wheat varieties and six fungicide spray schedules. At Holetta,variety Kekeba had the highest AUDPC (2548) value followed by Madawalabu and Alidoro; whereas at Kulumsa the highest AUDPC (1509) was recorded on variety Madawalabu followed by Alidoro and Kekeba varieties. STB incidence and severity were significantly reduced by the application of fungicides across varieties but fungicide-variety combinations had differential effects on disease development. Wheat grain yields were the lowest from unsprayed plots regardless of variety and location. Kekeba variety treated with Mancozeb-Tilt-Mancozeb-Tilt (MTMT) fungicide combination produced the highest yield (5.05t/ha). The highest (577.31%) and lowest (-19.95%) marginal rate of return were obtained from Tilt and MTMT sprayed fields at Holetta planted with Kekeba and Madawalabu varieties, respectively. On the other hand, at Kulumsa, the highest marginal rate of return (886.88%) and the lowest marginal rate of return (-63.98%) was obtained from Tilt and Mancozeb sprays on Madawalabu and Alidoro varieties, respectively. The present findings confirmed the importance of STB in Ethiopia and the role fungicides play in managing the disease on partially resistant varieties.**

Keywords: **AUDPC, Bread wheat, Cost-benefit analysis, Septoria tritici Blotch.**

1. INTRODUCTION

Wheat (*Triticum* spp.) is considered among the most commonly cultivated cereal crops with over 755 million metric tons harvested each year (FAO, 2017). It is the fourth most important cereal crop in agriculture. Although the crop is widely cultivated at altitudes ranging from 1500 to 3000 m.a.s.l, in Ethiopia, the most suitable area falls between 1700 and 2800 m.a.s.l (CSA, 2017). Bread wheat (*Triticum aestivum* L.) accounts for approximately 20% of the totally consumed human food calories and provides the most stable food for 40% of the human population (Kumar *et al*., 2015). In spite of the production and yield increases, average grain yield of wheat is still low (<2.7 t/ha) and highly variable and below the world's average (3.09 t/ha) (FAO, 2017). Crop yields are dependent on interactions of socio-economical, biological, technological and ecological factors. The crop can be grown in most locations where annual rainfall ranges from 250 to 1750 mm. About 75% of the wheat grown world-wide receives an average rainfall between 375 and 875 mm

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annually. However, too much precipitation can lead to yield loss from diseases and poor root growth and development problems (Bear *et al.*, 2004).Despite its importance as food and industrial crop, wheat production and productivity around the globe is hampered by a number of factors including biotic and abiotic stresses as well as low adoption of new agricultural technologies (Tesfaye *et al*., 2001). Of the biotic stresses, diseases caused by fungi are the most important factors constraining wheat production. Yellow rust (*Puccinia striiformis f.sp. tritici*), stem rust (*P. graminis f.sp. tritici*), leaf rust (*P. triticina*) and Septoria diseases especially *Septoria tritici* blotch (STB) are prevalent throughout the country (Endale *et al*., 2015). STB caused by the fungus *Septoria tritici* (*Mycosphaerella graminicola*), is a major disease of wheat in all wheat-growing areas of the world causing serious economic losses (Ghaffary *et al*., 2012). It is one of the most aggressive diseases on common wheat (*Triticum aestivum L.*) and durum wheat (*T. turgidum L. var. durum)* globally (Kema *et al*., 1996). *Septoria tritici* blotch is by far the most important disease in Northern and Eastern Africa and the Middle East (Benbelkacem, 2016). However, according to Teklay *et al.* (2015), the prevalence and severity of the disease is more dependent on weather conditions of the season and varieties grown. The combination of mild temperatures with high humidity in areas, where susceptible wheat varieties are grown on large scale, creates the perfect conditions for the leaf blotch pycnidiospores to spread rapidly. The disease is one of the major constraints of wheat in all wheat-growing areas of Ethiopia, causing 42% economic loss annualy (Abera *et al*., 2015; Alemar *et al*., 2016).

Range of disease management options are recommended to control STB in wheat fields. Among these, cultural management options designed to reduce inoculum pressure are the first one. Bio-control has also been tested as another STB management option. Fungicides of various modes of actions have been recommended to manage STB but their use in Ethiopia has been limited mainly due to economic reasons. Several sources of resistance have been reported but breeding for resistance has not always been successful in protecting wheat from the damaging effects of the disease; as expression of resistance is often correlated with morphological traits (Eyal *et al*., 1985). Moreover, wheat cultivars resistant in one part of the world may display susceptibility elsewhere. Even within a country, a difference observed in pathogen virulence that may be associated with fungal genetic variability is hindering the development of wheat varieties with broad spectrum of resistance. Resistance in wheat could be durable if the type of resistance in the variety is partial, which is polygenic, or non-specific to particular pathogen genotypes. Selection for partial resistance to STB may be restricted if that trait has a significant cost, for example reduced yield, which is the most important target for many wheat breeders.

Overall STB has remained an important constraint to wheat production all over the world including in Ethiopia. However, effective and sustainable managing of the disease is yet to be achieved under Ethiopian condition. In Ethiopia, wheat is grown in different agro-ecological zones. The areas vary in-terms of weather conditions, wheat varieties grown and crop management practices. The crop contributed a great deal to the country as source of food and income but it is continuously ravaged by diseases and other biotic constraints. The disease occurs almost in all wheat growing places but its intensity varies from place to place due to variability in weather conditions, differential responses of wheat varieties to the disease and as a result of variations in crop management practices. As a result there is a need to develop disease management option and recommended in areas, where the disease is prevalent and economically important. Thus, this study was designed with the following objectives:

2. OBJECTIVES

General objective:

To contribute towards improved wheat production in the central highlands of Ethiopia through effective and sustainable management of *Septoria tritici* blotch

Specific objective:

✓ To evaluate the effect of wheat varieties and fungicides on STB and wheat yield

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

The study was conducted at Holetta and Kulumsa Agricultural Research Centers, Ethiopia. Holetta Agricultural Research Center is located at 29 Km West of Addis Ababa at 09^{0} 04'N latitude and $38^{0}38$'E longitude and at elevation of 2390 m.a.s.l. The average annual rainfall of the area is 1100mm and the maximum and minimum annual mean temperatures are

22.2^{0}C and 6.13^{0}C, respectively. Kulumsa Agricultural Research Center is located at 169 Km South-east of Addis Ababa at 08^{0}01'10''N latitude and 39^{0}09'11''E longitude and at elevation of 2200m.a.s.l. The average annual rainfall of the area is 809mm and the maximum and minimum annual mean temperatures are 23.8^{0}C and 9.89^{0}C, respectively. Both sites are suitable for bread wheat production, and STB pressure is generally high during the rainy season.

3.2. Treatments and Experimental Design

The experiment was conducted in the main cropping season of 2016/17 (June to January). The experiment consisted of factorial treatment combination of three bread wheat cultivars with differential reaction to STB, and six spray schedules of systemic (Tilt) and contact (Mancozeb) fungicides. All the three varieties were planted at a seed rate of 125 kg ha^{-1} and fertilizer rates of 64 and 46 kg ha^{-1} N and P_2O_5, respectively. Treatments were arranged in randomized complete block design (RCBD) with three replications. Fungicides were applied using manual knapsack sprayer. Tilt was applied at a rate of 0.5lt/ha and Mancozeb at a rate of 3kg/ha with four up to eight spray frequencies, respectively, beginning from the time of disease onset. During fungicide sprays, plastic sheet was used to separate the plots being sprayed from the adjacent plots and prevent inter-plot interference due to spray drift. Unsprayed plots were included as negative checks. Twenty plants per plot were tagged for evaluation of disease parameters. Agronomic data were collected from the central four rows. All recommended agronomic practices to the area were adopted.

3.3. Data collected

The field experiments were conducted under natural infections, and disease incidence and severity were assessed on the central four rows every seven days starting from the first occurrence of disease symptoms up to maturity of the crop. Incidence of STB was assessed by counting the number of infected plants in the middle four rows and was expressed as percentage of total plants infected as shown below.

$$\text{Disease incidence} = \frac{\text{No. of diseased plants}}{\text{Total no. of plants examined}} \times 100$$

The severity of *Septoria tritici* blotch was recorded using the double-digit scale (00–99) developed as a modification of Saari and Prescott's severity scale to assess wheat foliar diseases (Saari and Prescott, 1975; Eyal *et al*., 1987). The first digit (D1) indicates vertical disease progress on the plant and the second digit (D2) refers to severity measured as diseased leaf area. Percent disease severity is estimated based on the formula:

% Disease severity (PDS) = ((D1/Y1) x (D2/Y2) x 100), Where D1 and D2 represent the score recorded (00-99 scale) and Y1 and Y2 represent the maximum score on the scale (9 and 9) (Sharma and Duveiller, 2007).

Area under Disease Progress Curve (AUDPC) values were calculated for each plot using the equations developed by Sharma and Duveiller (Sharma *et al*., 2002) as follows.

AUDPC= $\sum_{i=1}^{Ni-1} \frac{(Xi+Xi+1)}{2}(ti+1-ti)$ Where,

Xi= the cumulative disease severity expressed as a proportion at the ith observation,

ti = the time (days after planting) at the ith observation and

n= total number of observations. Since Septoria tritici blotch severity had been expressed in percent and time (t) in days, AUDPC values can be expressed in %- days (Cambell and Madden, 1990). Then AUDPC values are used in analysis of variance to compare amount of disease among different treatments.

All agronomic, yield and yield related data were recorded on the middle four rows of each experimental plot. These data along with their details are mentioned below:

1. Plant height (PH) (cm): An average height of ten plants, tagged in each experimental plot before commencement of tillering measured in centimeters from ground level to the tip of the spike excluding awns.

2. Spike Length (SL): the length (cm) of main spikes from the five sampled plants.

3. Number of Kernels per spike (NKPS): The numbers of grains of the main tillers of each of the ten randomly taken plants for each experimental unit were recorded and the average of the ten plants was used for analysis.

4. Thousand Kernel weight (TKW) (g): One thousand grains selected at random were weighed in grams for each experimental unit.

5. Hectoliter weight (HLW) (Kg/hL): - grain weight of one-liter volume (random sample) was estimated for each experimental unit by following standard procedure (AACC, 1983) and the result were converted to Kg/hL. The moisture content was adjusted at 12.5%.

6. Grain yield (GY) (tones): Grain yield in g/plot at 12.5% moisture content were recorded and converted to t/hectare.

3.4. Cost benefit analysis

Price of wheat grains (8 Birr/kg) was computed based on the current local market, total price of 100kg (800Birr) obtained from a hectare basis, costs that vary like fungicides (Tilt=600Birr/lt, Mancozeb=200Birr/kg) and labor costs to apply the fungicide were recorded and taken into account. Before doing the economic analysis (partial budget), the statistical analysis was done on the collected data to compare the average yield between treated and untreated treatments respectively. The partial budget analysis was calculated using the formula established to calculate marginal rate of return by CIMMYT (2011). The difference between treatments and the economic data were used to do partial budget analysis as follows: Marginal rate of return was calculated using the following formula.

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

Where, MRR = Marginal rate of returns (Cost benefit ratio).

DNI = the difference in net income compared with the control.

DIC = the difference in input cost compared with the control.

3.5. Data Analysis

Data on STB severity and incidence were subjected to log transformation before analysis. Data analysis was carried out using the general linear model of the SAS computer package version 9.3 (SAS, 2014). Means for treatments were compared using Duncan's New Multiple Range Test (DNMRT).

4. RESULTS AND DISCUSSION

4.1. Disease incidence

At Holetta, Septoria leaf blotch was first observed on Septemer 3, 2016 while at Kulumsa it first appeared on September 15, 2016 (Table 1). At the time of disease onset, STB incidence was not significantly different among varieties regardless of the locations. The varieties started to show significant differences in terms of STB incidence at the second assessment date after planting at Holetta and Kulumsa, respectively (Table 1). STB incidence recorded during the final assessment was generally high for all varieties. Final STB incidences were significantly different among varieties at both locations but they were lower at Kulumsa as compared to the levels at Holetta, most notably on the Alidoro variety. The highest disease incidence (98% and 66% at Holeta and Kulumsa, respectively) was recorded on unsprayed plots of Kekeba variety, while the lowest disease incidence (10% and 5% at Holeta and Kulumsa, respectively**)** was recorded on Alidoro variety sprayed with Tilt fungicide.

4.2. Disease severity

STB severity did not vary significantly across treatments during the first (56 DAP) assessment date at Holetta (Table 2). At third assessment date (84 DAP), the unsprayed plots showed significantly higher (38%) disease severity, while other treatments did not vary significantly from each other. At 112 DAPs, significantly the highest (97%) severity was recorded on unsprayed plots of variety Kekeba. The second highest (93%) STB severity was recorded from unsprayed plots of Madawalabu variety during the last assessment date (112 DAPs).The lowest (45%) disease severity was recorded from Alidoro variety sprayed with Tilt. This showed that the level of disease development is considerably affected by level of fungicide application or improvement of varietal resistance to STB as a result of fungicide spray. Eyal *et al*. (1987) showed the effect of crop resistance level on latent period of STB pathogens and the rate of disease development.

At Kulumsa, treatments show significant difference in disease severity during the initial assessment date (76 DAPs) (Table 2). At second assessment date (83 DAPs); the lowest (11.3%) disease severity was recorded on Alidoro variety sprayed with Mancozeb (Table 2), while the highest STB severity (60%) was recorded from unsprayed plots of Madawalabu variety. During the final assessment date (104 DAPs), the highest (85%) disease severity was recorded from Madawalabu variety unsprayed plots, while the lowest (22%) disease severity was recorded from Alidoro variety sprayed with Tilt, MMTT, TTMM and MTMT fungicides schedules. The second highest (63%) disease severity was recorded from unsprayed plots of Kekeba variety and Madawalabu variety sprayed with Mancozeb fungicide. The fungicide applications were significantly ($p \leq 0.05$) different in their effects on disease severity from second to fifth assessment dates (70, 84, 98 and 112 DAS) and from first to sixth assessment dates (65,76, 83, 90,97 and 104 DAPS) at Holetta and Kulumsa, respectively, (Table 2). Moreover, wheat cultivars resistant in one part of the country may display susceptibility elsewhere demonstrating the lack of consistent reaction across locations. This could be attributed to prevailing weather conditions that may affect host resistance to the disease or variation in pathogen populations.

At both locations and on all tested varieties, STB severity continually increased from one assessment date to the next. On both locations and on all leaves, the highest severity of STB was recorded during the last assessment date on unsprayed plots of all varieties compared with their respective sprayed plots. Final STB severity was 85, 97, and 93 % at Holetta; whereas it was 35, 63 and 85% at Kulumsa (Table 2) on Alidoro, Kekeba and Madawalabu, respectively. In general, STB was severe in both locations; however, it was more severe at Holetta than at Kulumsa. This might be due to more favorable environmental conditions prevailing in Holetta during the crop growing season; i.e. with rainy, cool and suitable average monthly maximum temperature range of 19^oC – 27^oC throughout crop growing season. The range of temperature (20^oC – 25^oC) together with rainy and cloudy condition can best favor infection process of *Septoria tritici* (Eyal *et al*., 1987).

According to results of the present study, the currently grown high yielding wheat variety, Kekeba, was the most susceptible to STB suggesting the need to prioritize the deployment of resistance genes. Use of resistant variety is the best control strategy of fungal diseases in general and to *Septoria tritici* blotch in particular for resource poor farmers in developing countries and the most environmentally friendly and profitable strategy for commercial farmers (Tekelay *et al*., 2015). Alternatively, this variety can be supplemented with fungicide sprays to minimize STB development. Current results also revealed that spraying wheat fields could be an effective measure to reduce STB levels even on susceptible varieties. In practice, the rate and frequency of fungicide application must depend on the level of risk acceptable to the producer, which in turn depends on the economic return from the crop (Beard, 2004). STB severity assessments were made up to 112 DAP at Holetta and 104 DAP at Kulumsa, and then stopped because of leaves senses. This hastened premature leaves senses along with moisture stress due to low/no rain fall at the later growth stage of the crop could have negative impact on STB (Tanner *et al*., 1991). Although complete control of STB development was not achieved and level of control varied across varieties, spraying Tilt fungicide schedules significantly reduced the severity level on all varieties at both locations (Holetta and Kulumsa). Inability of fungicide to reduce STB severity to zero level might be due to the presence of conducive environmental condition for the development of STB at growing period; especially sufficient rain fall and suitable temperature. The presence of sufficient rain fall not only favors development of STB but also it might reduce the efficiency of fungicide.

4.3. Area under disease progress curve

STB area under disease progress curve (AUDPC) across treatments expressed as AUDPC%-days ranged from 866 to 3879 at Holetta and from 592 to 2057 at Kulumsa (Table2).Results of the current work revealed highly significant ($p \leq 0.001$) differences among treatments in terms of AUDPC at both locations. AUDPC is a very convenient summary of plant disease epidemics that incorporates initial intensity, the rate parameter, and the duration of the epidemic which determines final disease intensity (Madden *et al*., 2008).

AUDPCs were generally higher on unsprayed plots than on sprayed plots. The maximum values recorded on unsprayed plots were 3879%-days on wheat variety Kekeba, 2890%-days on Madawalabu and 1734%-days on Alidoro, at Holetta. At Kulumsa, AUDPC values of 2057%-days, 1699%-days and 762 %-days, on Madawalabu, Kekeba and Alidoro varieties, respectively. On the other hand, wheat variety Alidoro sprayed with MTMT fungicides combination had the lowest (866%-days) at Holetta; whilst variety Alidoro treated with MTMT fungicide had the lowest AUDPC (591%-days) at Kulumsa. All fungicide spray schedules have reduced AUDPC compared to the unsprayed plots but only MTMT and Tilt sprays significantly affected AUDPC value at Holetta and Kulumsa, respectively. This agrees with that of Abera *et al*. (2015) and Alemar *et al.* (2016), who reported maximum AUDPC values (2275%-days) from unsprayed plots.

4.4. Yield and Yield Components

4.4.1. Grain Yield

Grain yield showed a significant ($p \leq 0.05$) difference among treatments at both Holetta and Kulumsa (Table 3). The highest yield (5.05t/ha) was recorded on Kekeba variety sprayed with MTMT fungicide combination at Holeta; whereas at Kulumsa, the highest yields (4.78t/ha and 4.71t/ha) were recorded from Madawalabu variety sprayed with MMTT fungicide combination and Alidoro variety sprayed with Tilt fungicide, respectively. Grain yield from unsprayed plots, which averaged from 3.12 to 3.26 t ha^{-1} at Holetta and from 2.9 to 3.7 t ha^{-1} at Kulumsa were significantly lower than those from sprayed plots. Abera *et al.* (2015) also reported lower qualitative and quatitative grain yield from untreated plots in comparison with treated one.

4.4.2. Spike Length

The longest spike (12cm at Holetta and 10cm at Kulumsa) was recorded from Alidoro variety sprayed with MTMT fungicide combination; whereas, the shortest spike (7cm at Holetta and 5.5cm at Kulumsa) was recorded from unsprayed wheat variety Kekeba (Table 3).

4.4.3. Number of kernels Per Spike

The highest number of kernels per spike (58 in Holetta and 44 in Kulumsa) was recorded on Alidoro sprayed with MTMT fungicide combinations; whereas, the lowest number of kernels per spike (46 in Holetta and 23 in Kulumsa) were recorded on Madawalabu unsprayed plots (Table 3).

4.4.4. Plant Height

The tallest plant (109cm in Holetta and 102cm in Kulumsa) was recorded from Alidoro variety sprayed with MMTT combinations; whereas, the shortest plant (87cm in Holetta and 82cm in Kulumsa) was recorded from unsprayed wheat variety Kekeba (Table 3).

4.4.5. Thousand Kernel Weight

Analysis of variance (ANOVA) revealed that fungicide applications showed significant difference in thousand kernels weight at both Holetta and Kulumsa. Under Holetta conditions, thousand kernels weight was significantly highest on Kekeba variety sprayed with Tilt (47gm) and TTMM (46gm) fungicides (Table 3). On the other hand, unsprayed plots of same variety (35.2gm) and variety Madawalabu (36.9gm) had significantly the lowest thousand kernels weight as compared to other treatments. At Kulumsa, the highest thousand kernels weight (42 and 41.33gm) was recorded from Kekeba and Madawalabu variety sprayed with Tilt fungicide; whereas, the lowest thousand kernels weight (34.67 and 34.8gm) was recorded from unsprayed Kekeba and Madawalabu variety, respectively, (Table 3).

4.4.6. Hectoliter Weight

The highest hectoliter weight (76.6kg/hl) was recorded on variety Alidoro sprayed with Tilt and TTMM fungicides; whereas, the lowest hectoliter weight (66.9kg/hl) was recorded on unsprayed Madawalabu variety at Holetta condition (Table 3). At Kulumsa, the highest hectoliter weight (80.57 and 79.93kg/hl) was recorded on variety Kekeba sprayed with Tilt and MMTT fungicides schedule, respectively; whereas, the lowest hectoliter weight (77.8 and 77.9kg/hl) was recorded on variety Madawalabu unsprayed and Mancozeb sprayed plots, respectively. There was no significance difference between different fungicide treatments in hectoliter weight at both locations.

4.5. Cost Benefit Analysis

Partial budget analysis indicated that the contact fungicide Mancozeb had the highest total cost while the unsprayed plots had the lowest cost (Tables 4 and 5). On the other hand, partial budget analysis indicated that all fungicide spray schedules used on the three varieties gave high gross field benefit and marginal rate of return. At Holetta on variety Kekeba, the partial cost benefit analysis showed that the maximum total gross yield benefit 40,400 Ethiopian Birr per hectare was obtained from plots treated with Mancozeb and Tilt alternatively (MTMT). This was followed by plots treated with Mancozeb with a gross yield benefit of 39,680 Ethiopian Birr per hectare. Even though lower gross yield benefits were obtained from MM-TT sprayed plots, this fungicide combination gave higher gross yield benefit than control. The same was true at Kulumsa for variety Alidoro, but the moderately resistant varieties (Kekeba) gave less gross yield benefit than the susceptible variety Madawalabu at this location. Variation in net benefit had been observed among the three cultivars at both locations. At Holetta variety Alidoro had the highest net profit of 34,944 Ethiopian Birr per hectare with marginal rate of return (MRR) 577.31% from plots sprayed with Tilt followed by plots treated with TT-MM alternatively.

At Kulumsa, in each variety the highest net profit was obtained on plots treated with Tilt. Even if Madawalabu is a susceptible variety, it gave higher gross yield benefit and net benefit than the moderately resistant variety Alidoro, when sprayed with fungicides. This may be due to the high yielding nature of the variety. Therefore, reasonable benefits were obtained in the fungicide sprayed plots at both locations. Fungicides are used because they provide effective and reliable disease control, deliver production in the form of crop yield and quality at an economic price and can be used safely (Rechcing, 1997). However, farmers would refrain from using fungicides unless proven effective and profitable.

Table 1: Effect of bread wheat varieties and fungicides on disease Incidence at Holetta and Kulumsa.

Treatments		Incidence (%)					
Varieties	Fungicide	Holetta			Kulumsa		
		Initial	Final	Mean	Initial	Final	Mean
Alidoro	Control	8.3^{ef}	50^{abc}	9.5^{de}	5^{c}	10^{cd}	6.4^{def}
	Mancozeb	5f	21.7^{f}	5.03^{e}	5^{c}	6.67^{d}	3.7^{f}
	Tilt	8.3^{ef}	16.7^{fg}	6^{e}	5^{c}	8.33^{cd}	4.5^{f}
	MMTT	6.7^{f}	21.7^{f}	6.5^{e}	5^{c}	8.33^{cd}	4.9^{ef}
	TTMM	6.7^{f}	21.7^{f}	5.6^{e}	5^{c}	5^{d}	4.1^{f}
	MTMT	5^{f}	10^{g}	5.5^{e}	5^{c}	6.67^{d}	4.5^{f}
Kekeba	Control	41.7^{a}	98.3^{a}	35.8^{a}	10^{a}	66.67^{a}	26.7^{a}
	Mancozeb	33.3^{abc}	66.7^{bcd}	19.1^{bcd}	5^{c}	30^{bcd}	14.3^{bcd}
	Tilt	38.3^{ab}	53.3^{abc}	20.4^{bcd}	6.7^{bc}	35^{bc}	15^{bce}
	MMTT	32^{abc}	71.7^{bc}	25.4^{b}	5^{c}	48.33^{ab}	19.1^{ab}
	TTMM	30^{bcd}	63.3^{bcd}	18.3^{bcd}	5^{c}	26.67^{bcd}	13.9^{bcde}
	MTMT	25^{bcdef}	45^{cdef}	13.3^{cde}	6.7^{bc}	16.67^{cd}	10.03^{cdef}
Madawalabu	Control	28.3^{bcde}	83.3^{ab}	20.03^{bc}	8.3^{ab}	31.67^{bcd}	16.8^{bc}
	Mancozeb	25^{bcdef}	60^{bcd}	17.5^{bcd}	5^{c}	21.67^{cd}	13.5^{bcde}
	Tilt	16.7^{def}	38.3^{def}	10.2^{de}	6.7^{bc}	10^{cd}	8^{cdef}
	MMTT	20^{cdef}	45^{cdef}	12.9^{cde}	5^{c}	13.33^{cd}	10.3^{cdef}
	TTMM	13.3^{def}	38.3^{def}	10.4^{de}	5^{c}	13.33^{cd}	8.4^{cdef}
	MTMT	18.3^{cdef}	30^{ef}	12.3^{cde}	5^{c}	15^{cd}	10.1^{cdef}
	Mean	21.11	46.4	14.3	5.74	20.74	10.8
	CV	35.15	23.4	39.8	23.18	32.05	42.6
	LSD (5%)	17.48	26.56	9.4	2.21	22.93	7.6

Table 2: Effect of bread wheat varieties and fungicides on disease severity at Holetta and Kulumsa.

Treatments		Severity(%) at different DAP													
Variety	Fungicide	Holetta							Kulumsa						
		56	70	84	98	112	Mean	AUDPC	76	83	90	97	104	Mean	AUDPC
Alidoro	Control	11.3^{a}	12.3^{cd}	28.7^{bcde}	45.3^{bcd}	85^{abcd}	29.57^{cde}	1733.7^{de}	12.3^{b}	11.7^{d}	12^{c}	21.7^{efg}	35.3^{def}	22.84^{e}	761.8^{d}
	Mancozeb	11.3^{a}	11^{e}	11.3^{e}	18^{fg}	59.3^{efg}	18.4^{def}	1041.8^{ef}	12.3^{b}	11.3^{d}	11.3^{c}	18.3^{fg}	28.7^{ef}	20.67^{ef}	677.8^{d}
	Tilt	11.3^{a}	12de	15de	18.7^{fg}	45.3^{g}	17^{f}	992.8^{ef}	12.3^{b}	15.3^{d}	11^{c}	15^{g}	21.7^{f}	19.72^{ef}	634.7^{d}
	MMTT	11.3^{a}	11^{e}	15de	21.3^{fg}	56.7^{efg}	18.9^{def}	1086.2^{ef}	12.3^{b}	14.7^{d}	11.3^{c}	14.3^{g}	22.3^{f}	17.83^{ef}	593.8^{d}
	TTMM	11^{a}	11.3^{e}	11.3^{e}	22^{efg}	56^{efg}	18.17^{ef}	1037.2^{ef}	12.3^{b}	15^{d}	11^{c}	14.7^{g}	21.3^{f}	17.89^{ef}	592.7^{d}
	MTMT	11^{a}	11^{e}	11^{e}	11.7^{g}	49.7^{fg}	15.4^{f}	865.7^{f}	12.3^{b}	15^{d}	11^{c}	18^{fg}	22.3^{f}	17.11^{f}	591.5^{d}
Kekeba	Control	12.3^{a}	38^{a}	84.7^{a}	89^{a}	96.7^{a}	60.8^{a}	3879.2^{a}	17.7^{b}	47^{abc}	29.7^{a}	49.3^{b}	62.7^{b}	49.5^{b}	1698.7^{b}
	Mancozeb	11.3^{a}	20^{bcde}	42.7^{bcd}	43^{bcd}	78.3^{abcde}	35.13^{bc}	2146.7^{cd}	17.7^{b}	41^{bc}	22.3^{ab}	39^{bcd}	49^{bcd}	41.72^{d}	1403.5^{c}
	Tilt	11.7^{a}	30.3^{abc}	48.7^{bc}	42^{bcde}	70.3^{bcdef}	36.07^{bc}	2240^{bcd}	17.7^{b}	41^{bc}	18.7^{bc}	29^{def}	46^{cd}	39.22^{d}	1295^{c}
	MMTT	12^{a}	37.7^{a}	53^{b}	59^{b}	88^{abc}	47.13^{b}	2952.8^{b}	17.7^{b}	41^{bc}	22^{ab}	36^{cd}	52^{bc}	42.06^{cd}	1410.5^{c}
	TTMM	12^{a}	30^{abcd}	35.5^{bcde}	42^{bcde}	73.3^{bcde}	35.27^{bc}	2173.5^{cd}	17.7^{b}	43^{bc}	25.7^{ab}	32^{cde}	38.7^{cde}	38.17^{d}	1289.2^{c}
	MTMT	11.7^{a}	32^{ab}	29^{bcde}	42^{bcde}	62.3^{defg}	30.73^{cd}	1894.7^{d}	17.7^{b}	43^{bc}	25^{ab}	35.7^{cd}	48^{bcd}	42.33^{cd}	1422.2^{c}
Madawa labu	Control	11.3^{a}	20^{bcde}	53.7^{b}	77.3^{a}	92.7^{ab}	46.47^{b}	2889.8^{bc}	25^{a}	60.3^{a}	29^{a}	60.3^{a}	84.7^{a}	58.89^{a}	2056.8^{a}
	Mancozeb	12^{a}	17^{bcde}	42^{bcd}	48.7^{bc}	85^{abcd}	35.1^{bc}	2121^{cd}	25^{a}	56^{ab}	25.3^{ab}	42.3^{bc}	62^{b}	47.11^{bc}	1639.2^{b}
	Tilt	12^{a}	15^{bcde}	17.7^{de}	29^{cdefg}	69^{cdef}	24.8^{cdef}	1456^{def}	25^{a}	43^{bc}	22.3^{ab}	32.7^{cde}	39^{cde}	37.72^{d}	1272.8^{c}
	MMTT	11^{a}	25^{abcde}	28^{bcde}	35^{cdef}	69.7^{cdef}	29.73^{cde}	1799de	25^{a}	43^{bc}	25.3^{ab}	32.3^{cde}	49^{bcd}	41^{d}	1382.5^{c}
	TTMM	11.3^{a}	21^{abcde}	15de	25^{defg}	69^{cdef}	25.27^{cdef}	1488.7^{def}	25^{a}	35.7^{c}	26.3^{ab}	32.7^{cde}	42^{cde}	40.6^{d}	1331.2^{c}
	MTMT	11.3^{a}	22^{abcde}	21.7^{cde}	32^{cdefg}	59.3^{efg}	24.33^{cdef}	1457.2^{def}	25^{a}	41^{bc}	28.7^{a}	36^{cd}	46.3^{cd}	39.94^{d}	1369.7^{c}
	Mean	11.5	20.9	31.3	38.9	70.3	31.83	1847.55	18.3	34.3	20.4	31.1	42.8	36.06	1190.2
	CV	13.7	26.8	14.5	13.9	9.3	21.68	23.04	8.5	13.8	10.4	11.0	8.9	5.21	10.88
	LSD (5%)	1.48	15.48	23.97	17.82	20.0	10.77	706.24	4.55	15.0	8.4	10.4	13.6	4.91	202.43

Means in a column followed by the same letters are not significantly different according to LSD at 5% probability level.

Table 3: Effect of bread wheat varieties and fungicides on yield and yield components at Holetta and Kulumsa

		Holetta						Kulumsa					
Treatments		SL(cm)	NKPS	PH	TKW	HLW	Yield(t/ha)	SL(cm)	NKPS	PH	TKW	HLW	Yield(t/ha)
Variety	Fungicide												
Alidoro	Control	10.67^{ab}	52.3^{a}	106.8^{ab}	39.2^{fg}	74.6^{ab}	3.20^{de}	9.33^{ab}	35.67^{abc}	99.17^{a}	36.67^{defg}	78.47^{bcd}	3.73^{ab}
	Mancozeb	11.33^{ab}	52^{a}	106.85^{ab}	42.27^{bcdef}	76^{ab}	4.22^{abc}	8.67^{abc}	42.67^{ab}	98.33^{ab}	39.33^{abcde}	78.8^{bcd}	3.95^{ab}
	Tilt	11.44^{ab}	52.67^{a}	106.11^{abc}	41.27^{cdef}	76.9^{a}	4.92^{a}	8.83^{abc}	44.67^{a}	98.33^{ab}	39.03^{abcdefg}	79.2^{abcd}	4.71^{a}
	MMTT	11.67^{ab}	56^{a}	108.87^{a}	40.27^{efg}	76.4^{ab}	4.34^{abc}	10^{a}	44^{a}	101.67^{a}	38.67^{abcdefg}	79.33^{abc}	4.38^{a}
	TTMM	10.22^{bc}	54^{a}	105.89^{ab}	40.8^{defg}	76.9^{a}	4.53^{ab}	9.5^{ab}	43.33^{ab}	99.67^{a}	37.07^{bcdefg}	78.87^{bcd}	4.6^{a}
	MTMT	12^{a}	58^{a}	103.2^{abcd}	40.4^{efg}	75.3^{ab}	4.32^{abc}	9.83^{a}	44.33^{a}	96.33^{ab}	38.27^{abcdefg}	78.97^{bcd}	4.55^{a}
Kekeba	Control	7.1^{e}	45^{a}	86.6^{g}	35.2^{h}	72.7^{b}	3.26^{de}	5.67^{f}	25^{c}	86.17^{cde}	34.67^{g}	78.4^{cd}	3.66^{ab}
	Mancozeb	7.67^{de}	46.67^{a}	93.47^{defg}	44.8^{abcd}	76.2^{ab}	4.96^{a}	6.17^{def}	31.33^{bc}	89.17^{bcde}	37.07^{bcdefg}	79.13^{abcd}	4.27^{a}
	Tilt	8de	47.3^{a}	89.8^{fg}	46.8^{a}	76.7^{ab}	4.85^{ab}	5.67^{f}	25.67^{c}	84.17^{de}	42^{a}	80.57^{a}	4.36^{a}
	MMTT	8.1^{de}	52^{a}	93.2^{defg}	42.27^{bcdef}	76.3^{ab}	4.49^{abcd}	7.0^{cdef}	34^{abc}	89.17^{bcde}	37.2^{bcdefg}	79.93^{ab}	3.83^{ab}
	TTMM	7.78^{de}	51.67^{a}	88.88^{g}	45.6^{ab}	76.5^{ab}	4.79^{abc}	5.5^{f}	30.33^{c}	81.83^{e}	40.27^{abcd}	79.17^{abcd}	3.86^{ab}
	MTMT	8.4^{de}	54^{a}	92.4^{defg}	45.3^{abc}	76.3^{ab}	5.05^{a}	5.83^{ef}	29.67^{c}	85.83^{cde}	35.6^{efg}	78.97^{bcd}	4.33^{a}
Madawalabu	Control	8.67^{cde}	46.3^{a}	95.67^{cdefg}	36.9^{gh}	66.9^{c}	3.12^{e}	8^{abcd}	23.33^{c}	96^{ab}	34.8^{fg}	77.8^{d}	2.9^{b}
	Mancozeb	9.1^{cd}	47.67^{a}	99.77^{abcde}	41.6^{bcdef}	75.07^{ab}	4.31^{abcd}	8.67^{abc}	24.33^{c}	97.17^{ab}	37.07^{bcdefg}	77.87^{cd}	4.47^{a}
	Tilt	8.56^{de}	46.67^{a}	98.76^{abcdefg}	42.8^{abcdef}	74.6^{ab}	4.47^{abc}	8.67^{abc}	28^{c}	94.17^{abc}	41.07^{ab}	79.27^{abcd}	4.78^{a}
	MMTT	8.9^{cd}	50^{a}	91.5^{efg}	44.9^{abcd}	74.5^{ab}	4.71^{ab}	8.33^{abc}	25.67^{c}	95^{abc}	39.87^{abcde}	78.23^{cd}	4.09^{ab}
	TTMM	8.2^{de}	56.67^{a}	95.9^{bcdefg}	44.4^{abcde}	73.7^{ab}	4.16^{abcde}	7.67^{bcde}	24.67^{c}	94.17^{abc}	41.33^{a}	79.1^{bcd}	4.33^{a}
	MTMT	9^{cd}	53^{a}	96^{cdefg}	42.27^{bcdef}	73.4^{ab}	3.59^{bcde}	8^{abcd}	26.33^{c}	92.5^{abcd}	36.93^{cdefg}	78.53^{bcd}	4.16^{ab}
	Mean	9.27	51.22	97.77	42.06	74.95	4.24	7.85	32.39	93.27	38.16	78.92	4.16
	CV	9.19	14.26	4.99	5.18	3.29	14.98	13.53	20.7	5.36	5.89	0.96	14.85
	LSD (5%)	1.41	12.12	7.33	3.61	4.09	1.43	1.76	11.13	8.30	3.64	1.27	1.65

Means in a column followed by the same letters are not significantly different according to LSD at 5% probability level.

Table 4: Partial budget analysis for the management of wheat *Septoria tritici* blotch during the main cropping season of 2016 at HARC.

Wheat varities	Fungicides	Yield (t/ha)	WSP (B/kg)	SR (B/ha)	TIC (B/ha)	MC (B/ha)	NB (B/ha)	MB (B/ha)	MRR (%)
Alidoro	Unsprayed	3.20	8.00	25600	2387	0	23213	0	0
	MMMM	4.22	8.00	33760	8883	6496	24877	1664	25.62
	TTTT	4.92	8.00	39360	4419	2032	34944	11713	577.31
	MMTT	4.34	8.00	34720	6651	4264	28069	4856	113.88
	TTMM	4.53	8.00	36240	6539	3152	29701	6488	205.84
	MTMT	4.32	8.00	34560	6835	3448	27725	4512	130.86
Kekeba	Unsprayed	3.26	8.00	26080	2387	0	23693	0	0
	MMMM	4.96	8.00	39680	8883	6496	30797	7104	109.36
	TTTT	4.85	8.00	38800	4419	2032	34381	10688	525.98
	MMTT	4.49	8.00	35920	6651	4264	29269	5576	130.77
	TTMM	4.79	8.00	38320	6539	3152	31781	8088	256.60
	MTMT	5.05	8.00	40400	6835	3448	33565	9872	286.31
Madawalabu	Unsprayed	3.12	8.00	24960	2387	0	22573	0	0
	MMMM	4.31	8.00	34480	8883	6496	25597	3024	46.55
	TTTT	4.47	8.00	35760	4419	2032	31341	8768	431.50
	MMTT	4.71	8.00	37680	6651	4264	31029	8456	198.31
	TTMM	4.16	8.00	33280	6539	3152	26741	4168	132.23
	MTMT	3.59	8.00	28720	6835	3448	21885	-688	-19.95

Y=Yield, WSP= Wheat selling price, SR= Sell revenue, TIC= Total Input Cost, MC= Marginal Cost, NB= Net benefit, MB= Marginal benefit, MRR= marginal rate of return, HARC= Holetta Agricultural Research center

Table 5: Partial budget analysis for the management of wheat *Septoria tritici* blotch during the main cropping season of 2016 at KARC.

Wheat var	Fungicides	Y(t/ha)	WSP(B/kg)	SR(B/ha)	TIC(B/ha)	MC(B/ha)	NB(B/ha)	MB(B/ha)	MRR (%)
	Unsprayed	3.73	8.00	29840	2387	0	27453	0	0
	MMMM	3.95	8.00	31600	7259	4872	24341	-3112	-63.88
	TTTT	4.71	8.00	37680	3911	1524	33769	6316	414.44
	MMTT	4.38	8.00	35040	4227	1840	30813	3360	182.61
	TTMM	4.6	8.00	36800	4227	1840	32573	3360	182.61
Alidoro	MTMT	4.55	8.00	36400	4227	1840	32173	5120	278.26
	Unsprayed	3.66	8.00	29280	2387	0	26893	0	0
	MMMM	4.27	8.00	34160	7259	4872	26901	8	0.16
	TTTT	4.36	8.00	34880	3911	1524	30969	4076	267.45
	MMTT	3.83	8.00	30640	4227	1840	26413	-480	-26.09
	TTMM	3.86	8.00	30880	4227	1840	26653	-240	-13.04
Kakaba	MTMT	4.33	8.00	34640	4227	1840	30413	3520	191.30
	Unsprayed	2.9	8.00	23200	2387	0	20813	0	0
	MMMM	4.47	8.00	35760	7259	4872	28501	7688	157.8
	TTTT	4.78	8.00	38240	3911	1524	34329	13516	886.88
	MMTT	4.09	8.00	32720	4226.67	1840	28493	7680	417.39
	TTMM	4.33	8.00	34640	4226.67	1840	30413	9600	521.74
Madawalabu	MTMT	4.16	8.00	33280	4226.67	1840	29053	8240	447.83

Y=Yield, WSP= Wheat selling price, SR= Sell revenue, TIC= Total Input Cost, MC= Marginal Cost, NB= Net benefit, MB= Marginal benefit, MRR= marginal rate of return,

5. CONCLUSION AND RECOMMENDATION

Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops in Ethiopia. It is widely grown in most of the regions in the country, including the Central highlands. However, its production is affected by abiotic and biotic factors. Among the biotic factors, *Septoria tritici* blotch (*Septoria tritici*) (STB) is one of the important problems of wheat production in the country. The major objective of the study was to contribute towards improved wheat production in the central highlands of Ethiopia through effective and sustainable management of *Septoria tritici* blotch. STB resulted in significant yield loss of bread wheat varieties, when left unchecked. However, fungicide treatments significantly reduced STB severity relative to untreated plots. The highest disease incidence (98% and 66% at Holeta and Kulumsa, respectively) was recorded on unsprayed plots of Kekeba variety, while the lowest disease incidence (10% and 5% at Holeta and Kulumsa, respectively**)** was recorded on Alidoro variety sprayed with Tilt fungicide. Final STB severity was 85, 97, and 93 % at Holetta; whereas it was 35, 63 and 85% at Kulumsa on Alidoro (moderately resistant), Kekeba (moderately susceptible) and Madawalabu (susceptible), respectively. Current results also revealed that spraying wheat fields could be an effective measure to reduce STB levels even on susceptible varieties. The efficacy of both mancozeb and propiconazole fungicides to control STB has been verified by this study. Therefore, giving more attention to develop different STB management strategies including breeding and screening for STB resistance varieties, and variety-fungicide combinations is important.

ACKNOWLEDGMENTS

First of all, I would like to thank the **Almighty God and St. Marry** for making all things possible with their boundless and kind supply of unconditional supports. I would like to express my sincere thanks to my major-advisor **Dr. Alemayehu Chala** and co-advisor **Dr. Bekele Kassa** whose help from the beginning to the end of this thesis was precisely substantial. I am very much indebted to them for their maximum cooperation in providing me with the required scientific skills for doing the thesis study and their encouragement. I said thank you very much for **my brother Fikadu Tadesse** "you are my base line for mine success throughout my life from the beginning up to know, I wish best for you. My special thanks goes through my beloved teachers Dr. Ferdu Azerefegn (Hawassa university known Senior Entomologist), Teacher Getahun Tadesse (Mehalwenze Elementary school and Teacher Atile Assefa (Balabarase Yilma weldeyes elementary school). My special thanks goes to the staff of Holetta and Kulumsa Agricultural Research Centers group. I am also very grateful to Ethiopian Institute of Agricultural Research for sponsoring and supporting me to pursue the postgraduate study. I would like to thank Hawassa University for providing me MSc training. Finally, I would like to deep-heartedly express my affectionate thanks to my beloved wife Bire Kifle for her irreplaceable support throughout my life. Thanks to God and the mother of my Lord for making all ups and down possible. I have no word to say anything about my sweet families due to so many support God bless all too.

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