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Research paper

Determination of Fungicide Spray Frequency for the Management of Septoria Tritici Blotch (*Septoria tritici*) of Bread Wheat (*Triticum aestivum* L.) in the Central Highlands of Ethiopia

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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 fungicide spray frequency on disease development and wheat yield. The effect of bread wheat varieties and fungicides spray frequency on STB development, wheat yield was evaluated at Holleta in a factorial field experiment involving three bread wheat varieties and five fungicide spray frequency. Variety Kekeba had the highest AUDPC (4019) value followed by Madawalabu (3854) and Alidoro (2077) 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 yield were the lowest from unsprayed plots regardless of variety. Alidoro variety treated with five times Tilt fungicide spray produced the highest yield (6.67t/ha). The highest (3013%) and lowest (0%) marginal rate of return were obtained from Madawalabu variety two time fungicide spray and from all unsprayed fields, respectively. The present findings confirmed the importance of STB in Ethiopia and the role fungicides frequency play in managing the disease on partially resistant varieties.

Key Words: AUDPC, Bread wheat, Cost-benefit analysis, STB, Spray Frequency, Tilt.

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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). Ethiopia is the second largest producer of wheat in Sub-Saharan Africa after South Africa (Negasa *et al*., 2016). 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 ideal daily temperature for wheat development varies from 20-25^{0}C for germination, 16-20^{0}C for good tillering and 20-23^{0}C for proper plant development (Onwueme and Sinha, 1999). 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 annually (Onwueme and Sinha, 1999; Bear *et al*., 2004). However, too much precipitation can lead to yield loss from diseases and poor root growth and development problems (Bear *et al*., 2002).

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 (Eyal, 1999; 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 (Zillinsky, 1983; 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. Collections of Bacillus megaterium originating from the wheat rhizosphere and leaves of barley, oat chaff, and grain have been screened for their ability to inhibit STB. Pseudomonads also have been tested as potential biocontrol agents (Ponomarkeno *et al*., 2011). Resistance in wheat to *Septaria tritici* has been demonstrated by a number of researchers, and breeding for resistance is likely to be the most practical method of controlling STB (Arama, 1996). 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 (Eyal *et al*., 1985) 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 management of the disease is yet to be achieved under Ethiopian condition. 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. *Septoria tritici* blotch (STB) is one of the major diseases of wheat around the world and across wheat growing regions of Ethiopia. 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:

General objective

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

Specific objective:

- ✓ To evaluate the effect of wheat varieties and fungicides spray frequency on STB and wheat yield
- ✓ To determine the cost benefit analysis of each fungicide spray frequencies

MATERIALS AND METHODS

Description of the Study Areas

The study was conducted at Holetta Agricultural Research Center, Ethiopia. It 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 22.2^0C and 6.13^0C, respectively. The dominant soil type is clay soil (luvisols). It is very suitable for bread wheat production, and STB pressure is generally high during the rainy season.

Treatments and Experimental Design

The experiment was conducted in the main cropping season of 2017/18 (June to January). The experiment consisted of factorial treatment combination of three bread wheat cultivars with differential reaction to STB (Table 1), and five spray frequency of systemic (Tilt) fungicide with 0.5lt/ha. 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.

Table 1. Bread wheat varieties used in the field experiment.

No.	Varieties	Year of release	Adaptation (m.a.s.l.)	Days to maturity	Reaction	Yield(t/ha)
1	Alidoro	2007	2200-2900	118-180	MR	2.6-5.2
2	Kakaba	2010	1500-2200	90-120	MS	3.3-5.2
3	Madawalabu	1999	2300-2800	100-125	HS	3.5-4.5

MR= Moderately Resistant, MS= Moderately Susceptible, HS= Highly Susceptible

Tilt was applied at a rate of 0.5lt/ha with one up to five sprays 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.

Data collected

The field experiment was 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 i^{th} 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.

Yield Loss and Yield Recovery Estimation

The relative losses in yield and yield component of each variety were determined as a percentage of that of the protected plots of the respective variety.
Losses were calculated separately for each of the treatments as:

$$RL\ (\%) = \frac{(Y1-Y2)\ *100\%}{Y1}$$

Where, RL – relative loss (reduction of the parameters yield, yield component), Y1 – mean of the respective parameter on protected plots (plots with maximum protection) and Y2 - mean of the respective parameter in unprotected plots (i.e. unsprayed plots or sprayed plots with varying level of disease).
Percent yield recovery was also calculated to compare the yield difference among fungicide treatments using the formula:

$$YR\ (\%) = \frac{YSP-YUP^*\ 100\%}{YUP}$$

Where, YR is yield recovery in percent, YUP is yield of unsprayed plot and YSP is yield of sprayed plots.

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 (40Birr/LD) to apply the fungicide were recorded and taken into account. The total amount of these materials (fungicides, seeds, labor and water) used for the experiment were computed and its price converted. 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.

$$MRR=\frac{DNI}{DIC}*100\%$$

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.

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 Least Significant Difference at 5% (LSD at 5%).

RESULTS AND DISCUSSION

Disease incidence

At Holetta, Septoria leaf blotch was first observed on September 3, 2017 (Table 2). At the time of disease onset, STB incidence was not significantly different among varieties. The varieties started to show significant differences in terms of STB incidence at the second assessment date after planting (Table 2). STB incidence recorded during the final assessment was generally high for all varieties. Final STB incidences were significantly different among varieties. The highest disease incidence (100% and 97.3%) was recorded on unsprayed and one times sprayed plots of Kekeba variety, while the lowest disease incidence (47.5% and 38.7%) was recorded on Alidoro variety sprayed with four and five times Tilt fungicide, respectively.

Disease severity

STB severity did not vary significantly across treatments during the first (63 DAP) assessment date (Table 2). At third assessment date (78 DAP), the unsprayed plot of kekeba variety showed significantly higher (75%) disease severity, while other treatments did not vary significantly from each other. At 110 DAPs, significantly the highest (100%) severity was recorded on unsprayed plots of Kekeba and madawalabu varieties. The second highest (98.3%) STB severity was recorded from one times sprayed plots of Madawalabu variety during the last assessment date (110 DAPs).The lowest (48.3%) disease severity was recorded from Alidoro variety four times sprayed with Tilt fungicide. This showed that the level of disease development is considerably affected by level of fungicide application frequency 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. The fungicide applications were significantly ($p \le 0.05$) different in their effects on disease severity from second to fifth assessment dates (71, 78, 87,103,110 and 117 DAS), 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.

From all tested varieties, STB severity continually increased from one assessment date to the next. 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 70, 100, and 100 % on Alidoro (moderately resistant), Kekeba (moderately susceptible) and Madawalabu (susceptible), respectively. In general, STB was severe at Holetta. This might be due to more favorable environmental conditions prevailing during the crop growing season; i.e. with rainy, cool and suitable average monthly maximum temperature range of $19^{o}C - 27^{o}C$ throughout crop growing season. The range of temperature ($20^{o}C - 25^{o}C$) 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 (Van Ginkel *et al*., 1999; 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 117 DAP 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 varie across varieties, spraying Tilt fungicide frequently significantly reduced the severity level on all varieties. 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.

Area under disease progress curve

STB area under disease progress curve (AUDPC) across treatments expressed as AUDPC%-days ranged from 1148 to 4019 (Table2).Results of the current work revealed highly significant ($p \leq 0.001$) differences among treatments in terms of AUDPC. AUDPC is a very convenient summary of plant disease epidemics that incorporates initial intensity, the rate parameter, and the duration of the epidemic which determines final disease intensity (Madden *et al.*, 2008).

AUDPCs were generally higher on unsprayed plots than on sprayed plots. The maximum values recorded on unsprayed plots were 4019%-days on wheat variety Kekeba, 3854%-days on Madawalabu and 2077%-days on Alidoro. On the other hand, wheat variety Alidoro sprayed with tilt fungicide had the lowest (1148%-days). All fungicide spray frequency have reduced AUDPC compared to the unsprayed plots but only four and five times Tilt sprays significantly affected AUDPC value, respectively. This agrees with that of Abera *et al.* (2015), Alemar *et al.* (2016) and Yitagesu *et al.* (2019), who reported maximum AUDPC values (3879%-days) from unsprayed plots.

Table 2. Effect of bread wheat varieties and fungicides Spray Frequency on disease Incidence, AUDPC & Severity.

Treatments															
Variety	Spray frequency	Incidence(%) at different DAP							Severity(%) at different DAP						
		71	78	87	103	110	117	AUDPC	63	71	78	87	103	110
Alidoro	Control	11.7^{d}	15^{f}	42.7^{def}	59.7^{cde}	70^{bcd}	86^{ab}	2077.7^{cd}	0^{c}	18^{de}	21.7^{h}	38.3^{efg}	42.3^{e}	70^{abcd}
	1	11^{d}	12.3^{f}	35.3^{efg}	38.7^{ef}	52.7^{de}	84^{ab}	1663.3^{de}	0^{c}	13.3^{e}	18.3^{h}	31.7^{fg}	23.3^{f}	60^{bcd}
	2	11^{d}	12.7^{f}	21.7^{fg}	14.7^{g}	35.3^{ef}	49^{c}	1148.3^{e}	0^{c}	13.3^{e}	18.3^{h}	18.3^{g}	13.3^{f}	43.3^{d}
	3	11^{d}	15^{f}	18.3^{g}	17.7^{fg}	31.7^{f}	52^{c}	1248.3^{e}	0^{c}	15^{e}	20^{h}	18.3^{g}	11.7^{f}	53.3^{cd}
	4	15^{cd}	14.7^{f}	24.7^{fg}	21.7^{fg}	32^{f}	38.7^{c}	1370.8^{e}	0^{c}	16.7^{e}	18.3^{h}	23.3^{g}	21.7^{f}	50^{cd}
	5	11.7^{d}	12.3^{f}	32.7^{efg}	25^{fg}	38.7^{ef}	45.7^{c}	1467.5^{e}	0^{c}	16.7^{e}	18.3^{h}	25^{g}	20^{f}	58.3^{cd}
Kekeba	Control	50.3^{a}	76.3^{a}	80^{a}	88^{a}	94^{a}	100^{a}	4019.2^{a}	20^{a}	38^{ab}	75^{a}	88.3^{a}	86.3^{a}	100^{a}
	1	33^{b}	63.7^{bcd}	78.3^{abc}	86.3^{a}	92.7^{a}	97.3^{a}	3968.2^{a}	20^{a}	45^{a}	60^{bcde}	85^{ab}	83.3^{ab}	100^{a}
	2	29.7^{b}	70^{abc}	80^{abc}	80^{abc}	90^{a}	92.7^{ab}	3913.7^{a}	20^{a}	38^{ab}	71.7^{ab}	85^{ab}	70^{abc}	98.3^{a}
	3	30^{b}	60.7^{cd}	84.3^{a}	80.7^{abc}	88.7^{ab}	96.3^{a}	3974.2^{a}	20^{a}	40^{a}	65^{abc}	87.7^{a}	80^{ab}	100^{a}
	4	33^{b}	74.3^{ab}	65.7^{abcd}	67.7^{abcd}	77.7^{abc}	88^{ab}	3846.7^{a}	17^{ab}	44.3^{a}	71^{ab}	73^{abcd}	79.7^{ab}	96.7^{ab}
	5	32.3^{b}	68.7^{abc}	80^{abc}	75.7^{abcd}	80.7^{abc}	92.3^{ab}	3538.5^{a}	15^{ab}	40^{a}	60^{bcde}	78^{abcd}	67^{bcd}	85^{abc}
Madawalabu	Control	23^{bcd}	66^{abcd}	82^{ab}	86.7^{a}	92^{a}	95^{a}	3854.3^{a}	20^{a}	38^{ab}	63^{abcd}	80.7^{abc}	87.3^{a}	100^{a}
	1	29.7^{b}	55.7^{de}	77.7^{abc}	85^{ab}	89.7^{a}	93.7^{a}	3579.2^{a}	18^{ab}	30bc	53^{cdef}	67^{abcd}	80^{ab}	98.3^{a}
	2	25^{b}c	59.7^{cd}	71^{abc}	62.7^{bcd}	76^{abc}	87^{ab}	2866.7^{b}	13^{ab}	27^{cd}	52^{def}	63^{bcd}	43.3^{e}	80^{abcd}
	3	26^{b}c	45.7^{e}	67.3^{abc}	59.7^{cde}	70^{bcd}	84.3^{ab}	2635^{bc}	17^{ab}	27^{cd}	43.3^{fg}	55^{def}	45^{e}	67^{abcd}
	4	23^{bcd}	59^{cd}	60^{bcd}	59^{cde}	66.3^{cd}	73^{b}	2762^{b}	15^{ab}	27^{cd}	50^{efg}	58.3^{cde}	49.7^{de}	68^{abcd}

	5	25^{bc}	46^{e}	56.3^{cde}	56.7^{de}	66.7^{cd}	82^{ab}	2754.2^{b}	11.7^{b}	27^{cd}	38.3^{g}	56.7^{de}	51.7^{cde}	78^{abcd}
	Mean	23.9	46	59	59.2	69.2	79.8	2815.9	11.5	28.6	45.4	57.4	53.1	78.2
	CV	31.4	16.6	24.3	23.1	17.1	15.1	12.3	39.3	18.8	16.7	25.1	21.5	25.3
	LSD (5%)	12.5	12.6	23.8	22.7	19.6	20	575.1	7.5	8.9	12.6	23.8	18.9	32.7

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

Yield and Yield Components

Grain Yield

Grain yield showed a significant ($p \leq 0.05$) difference among treatments (Table3). The highest yield (6.5 & 6.67t/ha) was recorded on Alidoro variety four and five times tilt sprayed plots, respectively. There was no significant difference between yield of Alidoro and Kekeba variety sprayed fungicide. This finding is in agreement with Alemar *et al.*(2016), who recorded the highest yield from 10 days interval sprayed plots and the lowest yield from 30 days interval sprayed plots and unsprayed plot. Grain yield from unsprayed plots which averaged from 2.2 to 5.42 t ha^{-1}. Abera *et al.* (2015) also reported lower qualitative and quatitative grain yield from untreated plots in comparison with treated one. The susceptible variety Madawalabu gave lower yield than the moderately resistant cultivar Alidoro, when treated with a fungicide.

Spike Length

The longest spike 11.6cm was recorded from Alidoro variety; whereas, the shortest spike 7.6cm was recorded from Kekeba variety (Table 3). There was no significant difference in terms of spike length between fungicide sprays frequency but there was significant difference between spike lengths of varieties.

Number of kernels Per Spike

The highest number of kernels per spike (58) was recorded on Alidoro variety with five times fungicide sprayed combinations; whereas, the lowest number of kernels per spike (45) were recorded on Kekeba unsprayed plot (Table 3). Generally, there was no significant difference in number of kernels per spike across treatments.

Plant Height

The tallest plant (108cm) was recorded from Alidoro variety with five time sprayed frequency combinations; whereas, the shortest plant (89cm) was recorded from one times sprayed wheat variety Kekeba (Table 3). Wheat varieties treated with different fungicide regimes did not vary significantly in terms of plant height.

Thousand Kernel Weight

Analysis of variance (ANOVA) revealed that fungicide applications showed significant difference in thousand kernels weight. Thousand kernels weight was significantly highest on Madawalabu variety with three times (47.47g) and four times sprayed plots (46.93g) (Table 3). On the other hand, unsprayed plots of same variety (29g) had significantly the lowest thousand kernels weight as compared to other treatments. In most cases different fungicide regimes did not differ significantly in terms of thousand kernels weight regardless of the varieties.

Hectoliter Weight

The highest hectoliter weight (82.73kg/hl) was recorded on variety Kekeba five times sprayed plot; whereas, the lowest hectoliter weight (76.3kg/hl) was recorded on unsprayed Madawalabu variety **(**Table 3).

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

Treatments		SL(cm)	NKPS	PH	TKW	HLW	Yield(t/ha)
Variety	Spray frequency						
Alidoro	Control	11.6^{a}	52.3^{a}	106.67^{a}	38.53^{de}	76.9^{gh}	5.42^{bcde}
	1	10.93^{a}	52^{a}	106.27^{a}	41.73^{cd}	77.53^{fgh}	6.19^{abc}
	2	11.27^{a}	52.67^{a}	105.87^{a}	42.93^{bc}	77.43^{fgh}	6.15^{abc}
	3	11^{a}	56^{a}	105.87^{a}	42.67^{c}	78.23^{fgh}	6.3^{ab}
	4	11.47^{a}	54^{a}	105.6^{a}	41.87^{cd}	78.2^{fgh}	6.5^{a}
	5	11.27^{a}	58^{a}	107.67^{a}	43.07^{bc}	78.53^{efg}	6.67^{a}
Kekeba	Control	8.13^{cde}	45^{a}	93.4^{bcde}	32.13^{fg}	80.3^{cde}	3.77^{gh}
	1	7.6^{e}	46.67^{a}	88.47^{e}	34.13^{f}	80.67^{bcd}	3.96^{gh}
	2	8.13^{cde}	47.3^{a}	91.67^{de}	41.87^{cd}	81.5^{abc}	5.23^{def}
	3	8.53^{bcde}	52^{a}	89.6^{e}	40.4^{cd}	81.97^{abc}	4.37^{fg}
	4	7.67^{e}	51.67^{a}	93.4^{bcde}	40.67^{cd}	82.53^{ab}	5.38^{cde}
	5	7.93^{de}	54^{a}	92.4^{cde}	42.13^{cd}	82.73^{a}	5.77^{abcd}
Madawalabu	Control	9.6^{b}	46.3^{a}	95.6^{bcd}	29.2^{g}	76.3^{h}	2.2^{i}
	1	9.2^{bc}	47.67^{a}	96.87^{bcd}	34.53^{ef}	79.27^{def}	3.25^{h}
	2	9.2^{bc}	46.67^{a}	97.67^{bc}	43.73^{abc}	81.2^{abc}	4.84^{ef}
	3	9.07^{bcd}	50^{a}	99^{b}	47.47^{a}	81.8^{abc}	4.85^{ef}
	4	9.27^{bc}	56.67^{a}	96.27^{bcd}	46.93^{ab}	82.13^{abc}	4.99^{def}
	5	9.07^{bcd}	53^{a}	95.5^{bcd}	44.27^{abc}	81.9^{abc}	5.78^{abcd}
	Mean	9.5	51.22	98.24	40.46	79.95	5.09
	CV	6.79	14.26	3.01	6.15	1.31	9.5
	LSD (5%)	0.44	12.12	1.99	1.68	0.71	0.33

Yield and Yield Components Loss

Yield loss

At Holetta, maximum relative grain yield loss was 54.2%, and this was recorded on unsprayed plots of the variety Madawalabu (Table 4). On Kekeba variety, grain yield loss of about 36% was recorded when STB was allowed to develop naturally. For Alidoro variety, grain yield reduction of about 19% was recorded on unsprayed plots (Table 4).

Our result agrees with the findings of Alemar *et al*. (2016) in which STB was reported causing grain yield loss of up to 41%. It confirmed that susceptible genotypes showed higher yield losses as compared to resistant genotypes (Ahmad *et al*., 2010). Yield can be severely reduced if disease pressure is high and yield losses of 30 -50% have been reported in wheat (Eyal *et al.* 1987; Goodwin *et al.* 2011). Our results also confirm the findings of Goodwin *et al*. (2011) in which wheat grain yield losses of 30-50% were attributed to STB. Severe yield losses can occur in crops when the top two or three leaves (flag, second and third leaf of wheat plants) become infected (Marroni *et al*., 2006).

Loss in thousand kernel weight

At Holetta, thousand kernel weight (TKW) was most affected on wheat variety Madawalabu. The loss in TKW on this variety reached 38.5% on unsprayed plots (Table 4). On the other hand, a 10.5% loss in TKW was recorded on unsprayed plots of variety Alidoro, which is considered the lowest loss in TKW. Current results are in agreement with previous reports of Abera *et al*. (2015) in which yield, thousand seed weight, hectoliter weight, weight of kernel per spike, losses, due to STB were recorded as 41, 36, 5 and 44%, respectively. The reduction in TKW is mainly due to the effect of the disease on the size and mass of the seed (shriveling of the kernels). Dill-Macky *et al*. (1990) reported up to 45% reduction in 1000-kernel weight of wheat variety Oxely in Australia. Infection of wheat head and leaf sheaths by septoria affects the transport of assimilates to the developing kernel and results in shriveled kernel (Shafer and Satorre, 1999; Sharma *et al*., 2002).

Hectoliter weight loss

All the fungicide spray frequency showed significant effect (P< 0.05) over the control in terms of hectoliter weight of the variety Kekeba and Madawalabu. None of the spray treatments showed significant effect on hectoliter weight of Alidoro (Table 4). Reduction in test (hectoliter) weight is largely attributed to reduction in seed size. With small size more seeds would fit into a given volume. Even though not quantified, Beard *et al*. (2004) reported pronounced effect of septoria on hectoliter weight and kernel plumpness of some winter Australian wheat cultivars. However, the effect may vary depending on the variety and location (Dill-Macky *et al*., 1990).

Table 4. Effect of fungicide Spray Schedules on yield and yield components loss (%) and recovery(%).

Treatments		Loss						YIOUP					
Variety	Fung spray frequency	TKW	Loss	HLW	Loss	Yield	Loss	TKW	Increame	HLW	Increame	Yield	Increame

Alidoro	Control	38.53^{de}	10.5	76.9^{gh}	2.0	5.4^{bcde}	19	38.53^{de}	0	76.9^{gh}	0	5.4^{bcde}	0
	1	41.73^{cd}	3.1	77.5^{fgh}	1.3	6.2^{abc}	7.1	41.73^{cd}	8.3	77.5^{fgh}	0.8	6.2^{abc}	14.8
	2	42.93^{bc}	0.3	77.4^{fgh}	1.4	6.2^{abc}	7.1	42.93^{bc}	11.4	77.4^{fgh}	0.7	6.2^{abc}	14.8
	3	42.67^{c}	0.9	78.2^{fgh}	0.3	6.3^{ab}	5.6	42.67^{c}	10.8	78.2^{fgh}	1.7	6.3^{ab}	16.7
	4	41.87^{cd}	2.8	78.2^{fgh}	0.3	6.5^{a}	2.6	41.87^{cd}	8.7	78.2^{fgh}	1.7	6.5^{a}	20.4
	5	43.07^{bc}	0	78.5^{efg}	0	6.67^{a}	0	43.07^{bc}	11.8	78.5^{efg}	2.1	6.67^{a}	23.5
Kekeba	Control	32.13^{fg}	25	80^{cde}	3.3	3.77^{gh}	36	32.13^{fg}	0	80^{cde}	0	3.77^{gh}	0
	1	34.13^{f}	19	81^{bcd}	2.1	3.96^{gh}	30.5	34.13^{f}	6.2	81^{bcd}	1.25	3.96^{gh}	5
	2	41.87^{cd}	0.6	82^{abc}	0.2	5.23^{def}	8.3	41.87^{cd}	30.3	82^{abc}	2.5	5.23^{def}	38.7
	3	40.4^{cd}	4.1	82^{abc}	0.2	4.37^{fg}	23.3	40.4^{cd}	25.7	82^{abc}	2.5	4.37^{fg}	15.9
	4	40.67^{cd}	3.5	82.5^{ab}	0.2	5.4^{cde}	5.3	40.67^{cd}	26.6	82.5^{ab}	3.1	5.4^{cde}	43.2
	5	42.13^{cd}	0	82.7^{a}	0	5.7^{abcd}	0	42.13^{cd}	31.1	82.7^{a}	3.4	5.7^{abcd}	51.2
Madawalabu	Control	29.2^{g}	38.5	76.3^{h}	7	2.2^{i}	54.2	29.2^{g}	0	76.3^{h}	0	2.2^{i}	0
	1	34.53^{ef}	27.4	79.3^{def}	3.3	3.25^{h}	31.3	34.53^{ef}	18.3	79.3^{def}	3.9	3.25^{h}	47.7
	2	43.73^{abc}	8	81^{abc}	1.2	4.84^{ef}	0	43.73^{abc}	49.8	81^{abc}	6.2	4.84^{ef}	120
	3	47.47^{a}	0	82^{abc}	0	4.7^{ab}	2.1	47.47^{a}	62.6	82^{abc}	7.5	4.85^{ef}	120.5
	4	46.93^{ab}	1.3	82^{abc}	0	4.2^{abcde}	12.5	46.93^{ab}	60.7	82^{abc}	7.5	4.99^{def}	126.8
	5	44.27^{abc}	6.7	82^{abc}	0	3.6^{bcde}	25	44.27^{abc}	51.6	82^{abc}	7.5	5.8^{abcd}	163.6
	Mean	40.46		79.95		5.09		40.46		79.95		5.09	
	CV	6.15		1.31		9.5		6.15		1.31		9.5	
	LSD (5%)	1.68		0.71		0.33		1.68		0.71		0.33	

TKW=Thousand kernel weight, HLW= Hectoliter weight, YLD= Yield, RYL = Relative Yield loss, YIOUP= Yield increased over unsprayed plots

Yield and Yield Components Recovery

The highest yield recovery over unsprayed plot, 163.6%, was recorded from Madawalabu variety five times sprayed plot at Holetta (Table 4). These results were higher than those obtained from the work of Tari *et al*. (2009), which resulted in up to 42% yield loss preventing by applying foliar fungicides to winter wheat**.** In general, on all varieties, STB developed after growth stage of Z70 (kernel and milk development stage) was found to be important for grain yield loss. So managing the disease before reaching this growth stage might provide reasonable recovery of yield. This might be related with protecting the top three leaves, especially flag leaf of the crop that contributes most to the grain yield (Ray, 1983; Vrapi *et al*., 2009).

Correlation between Disease Parameters, Yield and Yield Components

Correlations among disease parameters were positive and highly significant ($p \leq 0.01$), suggesting the possibility of using any of the parameters for STB assessment. However, cautions should be taken as each parameter is worth considering having a complete understanding of disease intensity. STB severity, incidence and AUDPC also showed highly significant and negative correlations with grain yield, spike length, plant height, and weight of kernel per spike, kernel number per spike, thousand seed weight and hectoliter weight (Table 5). The highest value of correlation coefficient indicated strong relationships between and within disease parameters. James (1974), and Forrer and Zadoks (1983) also observed that the greatest risk to wheat crop occurs, when conducive environmental factors favor spore dispersal during and shortly after flag leaf emergence, and the crop losses have been related to total leaf area infected including necrotic lesions and chlorotic flakes.

Table 5. Correlation Coefficient among Disease Parameters, Yield and Yield Components.

	PDI	PDS	AUDPC	SL	PH	NKPS	YLD	TKW	HLW	ADS
PDI										
PDS	0.69 **									
AUDPC	0.98 **	0.68**								
SL	-0.59* *	-0.47**	-0.59**							
PH	-0.47 **	-0.53**	-0.47**	0.72**						
NKPS	-0.29*	-0.09^{ns}	-0.29*	0.27 *	0.26^{ns}					
YLD	-0.43**	-0.21^{ns}	-0.40**	0.18^{ns}	0.23^{ns}	0.07^{ns}				
TKW	-0.33**	-0.11^{ns}	-0.31*	-0.20^{ns}	-0.24^{ns}	-0.09^{ns}	0.53 **			
HLW	-0.43**	-0.19^{ns}	-0.39**	0.12^{ns}	0.11^{ns}	0.03^{ns}	0.63**	0.55**		
ADS	0.98**	0.67**	0.99 **	-0.59**	-0.46**	-0.29*	-0.41**	-0.31*	-0.39**	

PDI=Percent disease incidence, PDS= Percent disease severity, AUDPC= Area under disease progress curve, SL= Spike length, PH= Plant height, NKPS= Number of kernels per spike, YLD= Yield(t/ha), TKW= Thousand kernel weight, HLW= Hecto litter weight and MDS= Mean disease severity.*:refers to mean square values significant at $\alpha=0.05$, **: refers to mean square values significant at $\alpha=0.01$, ns: refers to mean square values not significant at $\alpha=0.05$

Cost Benefit Analysis

Partial budget analysis indicated that five times fungicide spray frequencies had the highest total cost while the unsprayed plots had the lowest cost on all three varieties (Table 6). On the other hand, partial budget analysis indicated that all fungicide spray frequencies used on the three varieties gave high gross field benefit and marginal rate of return. At Holetta on variety Alidoro, the partial cost benefit analysis showed that the maximum total gross yield benefit 80,040 Ethiopian Birr per hectare was obtained from plots with five times spray frequencies. This was followed by plots with four times spray frequencies with a gross yield benefit of 78,000 Ethiopian Birr per hectare. Even though lower gross yield benefits were obtained from plots madawalabu variety with one time spray frequencies, this fungicide spray frequency gave higher gross yield benefit than control. Variation in net benefit had been observed among the three cultivars. At Holetta variety Alidoro had the highest net profit of 75,109.25 Ethiopian Birr per hectare with marginal rate of return (MRR) 489.68% with five times spray frequencies. Therefore, reasonable benefits were obtained in the fungicide sprayed plots. Shafer and Satorre (1999) indicated that when assessing a crop for risk, it is also necessary to asses it for the potential to cover the cost of application which depends on the potential yield. 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 6. Partial budget analysis for the management of wheat *Septoria tritici* blotch during the main cropping season of 2017/18 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	5.42	12.00	65040	2387	0	62653	0	0
	1	6.19	12.00	74280	2895.75	508.75	71384.25	8731.25	1716.22
	2	6.15	12.00	73800	3404.5	1017.5	70395.5	7742.5	760.93
	3	6.3	12.00	75600	3913.25	1526.25	71686.75	9033.75	591.89
	4	6.5	12.00	78000	4422	2035	73578	10925	536.86
	5	6.67	12.00	80040	4930.75	2543.75	75109.25	12456.25	489.68
Kekeba	Unsprayed	3.77	12.00	45240	2387	0	42853	0	0
	1	3.96	12.00	47520	2895.75	508.75	44624.25	1771.25	348.16
	2	5.23	12.00	62760	3404.5	1017.5	59355.5	16502.5	1621.87
	3	4.37	12.00	52440	3913.25	1526.25	48526.75	5673.75	371.75
	4	5.38	12.00	64560	4422	2035	60138	17285	849.39
	5	5.77	12.00	69240	4930.75	2543.75	64309.25	21456.25	843.49
Madawalabu	Unsprayed	2.2	12.00	26400	2387	0	24013	0	0
	1	3.25	12.00	39000	2895.75	508.75	36104.25	12091.25	2376.66
	2	4.84	12.00	58080	3404.5	1017.5	54675.5	30662.5	3013.51
	3	4.85	12.00	56400	3913.25	1526.25	52486.75	28473.75	1865.60
	4	4.99	12.00	50400	4422	2035	45978	21965	1079.36
	5	5.78	12.00	69360	4930.75	2543.75	64429.25	40416.25	1588.85

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

CONCLUSION AND RECOMMENDATION

A field experiment was conducted at Holetta in 2017 main cropping season to quantify the severity of *Septoria tritici* blotch and to determine the effect of this disease on yield and yield components of bread wheat varieties. Five times spray frequencies of propiconazole (Tilt 250 EC) combined with three wheat varieties (Alidoro, Kekeba and Madawalabu) to create different levels of STB. 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 (100%) was recorded on unsprayed plots of Kekeba variety, while the lowest disease incidence (38.7%**)** was recorded on Alidoro variety with four times spray frequencies. Final STB severity was 70, 100, and 100 % 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 highest yield (6.67t/ha) was recorded on Alidoro variety with five times spray frequency of tilt; whereas, the lowest yield (2.2t/ha) was recorded from susceptible variety Madawalabu with unsprayed plot. So, this study indicated that there is a highest yield gap between unsprayed and effectively controlled plots especially on susceptible wheat varieties. From this study we had conclude that STB is the most economical wheat foliar diseases which cause up to 54.2% yield reduction. The efficacy of propiconazole fungicides with different spray frequencies 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 different variety-fungicide spray frequencies is important.

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