Yield Loss Due to 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 on wheat. The current research was conducted to determine the yield loss of STB on wheat at Holeta and Kulumsa in 2017. Maximum relative grain yield loss (36%) was recorded on unsprayed plots of the variety Kekeba at Holetta. Whereas; at Kulumsa, maximum relative grain yield loss (39%) was on unsprayed plots of the variety Madawalabu. Disease severity, incidence and AUDPC 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. The present findings confirmed the importance of STB in Ethiopia and the role fungicides play in managing the disease on partially resistant varieties.
Keywords: Correlation, Septoria tritici blotch, Yield Loss, Yield recovery.
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Background and Justification

Wheat is one of the oldest cereal crops. It is grown under a wide range of cli-mates and soils and adapted to temperate regions with annual rainfall of 30–90 cm (FAO,2017). It is the fourth most important cereal crop in agriculture after teff (*Eragrostis tef* (Zucc.)Trotter),   maize (*Zea mays* L) and sorghum (*Sorghum bicolor* (L.) Moench). In terms of total grain production, it ranks third after maize and teff (CSA, 2017). 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. Ethiopia is the second largest producer of wheat in Sub-Saharan Africa after South Africa (Negasa and Chauhin, 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).

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. However, too much precipitation can lead to yield loss from diseases and poor root growth and development problems (Blandford, D. and Hassapoyannes, K., 2018).

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 (Bharadwaj, D.N., 2016). 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 (Singh *et al.*, 2016). It is one of the most aggressive diseases on common wheat (*Triticum aestivum L.*) and durum wheat (*T. turgidum L. var. durum)* globally (Serfling *et al.*, 2017). *Septoria tritici* blotch is by far the most important disease in Northern and Eastern Africa and the Middle East (Benbelkacem, 2016). However, according to Tadesse *et al.* (2018), the prevalence and severity of the disease is more dependent on weather conditions of the season and varieties grown. The disease is one of the major constraints of wheat in all wheat-growing areas of Ethiopia, causing 42% economic loss annually (Takele *et al.*, 2015; Said *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. Pseudomonads have been tested as potential biocontrol agents (Ponomarkeno *et al.*, 2011). 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. Breeding for resistance is likely to be the most practical method of controlling STB (Takele *et al.*, 2015). 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. 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 (McDonald *et al.*, 2016) is hindering the development of wheat varieties with broad spectrum of resistance. 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 (Miedaner *et al.*, 2016).

Overall STB has remained an important constraint to wheat production all over the world including in Ethiopia (Randhawa *et al*., 2019). However, effective and sustainable managing of the disease is yet to be achieved under Ethiopian condition. *Septoria tritici* blotch (STB) is one of the major diseases of wheat around the world and across wheat growing regions of Ethiopia. Yield loss assessment studies have been carried out in fewer areas and they are largely based on data from field surveys. As a result there it is very crucial to develop disease management option and recommended in areas, where the disease is prevalent and economically important. Thus, our study was designed with the objectives of determine the yield loss of each cultivars due to STB and determine the correlation between yield components and disease parameters.

Materials and Methods

Study areas

Our study conducted at Holetta and Kulumsa Agricultural Research Centers, Ethiopia. Both sites are suitable for bread wheat production, and STB pressure is generally high during the rainy season (Birhan, 2011; Beyene *et al*., 2016).

Treatments and Experimental Design

The treatment arrangement of our experiment was (6 different spray schedules of propiconazole (Tilt 250 EC) and Mancozeb (unsprayed plot, Tilt, Mancozeb, Mancozeb-Tilt-mancozeb-Tilt, Tilt-mancozeb- Tilt-mancozeb and mancozeb- mancozeb- Tilt- Tilt) were combined with three wheat varieties (Alidoro, Kekeba and Madawalabu). Our treatments were arranged in randomized complete block design (RCBD) with three replications. The fungicide Tilt was applied at a rate of 0.5lt/ha and Mancozeb at a rate of 3kg/ha based on recommendation.

Data collected

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.

$$Disease\ Incidence = No.\ of\ disease\ \frac{plants}{Total}\ no.\ of\ plants * 100$$

The severity of *Septoria tritici* blotch was recorded using the double-digit scale (00–99) (Saari and Prescott, 1975; Eyal *et al*., 1987). Percent disease severity is estimated based on the formula:

$$\%\ Disease\ Severity(PDS) = \left(\frac{D1}{Y1}\right) * \left(\frac{D2}{Y2}\right) * 100$$

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).

$AUDPC = \sum_{i=1}^{Ni-1} \frac{(Xi+Xi+1)}{2}(ti + 1 - ti)$ 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. AUDPC values are used in analysis of variance to compare amount of disease among different treatments. 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:

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

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:

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

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

All agronomic, yield and yield related data were recorded on the middle four rows of each experimental plot.

Data Analysis

Data analysis was carried out by SAS computer package version 9.3 (SAS, 2014). Means for treatments were compared using Duncan's New Multiple Range Test. Correlation analysis was done using the Proc Corr procedures to see the relationship between yield, yield components and disease parameters.

Results and Discussion
Disease incidence in percent
STB incidences were significantly different among varieties at both locations. The highest disease incidence was recorded on unsprayed plots of Kekeba variety, while the lowest disease incidence was recorded on Alidoro variety sprayed with Tilt fungicide (Table 1). This result strongly agreed with the finding of (Said *et al*., 2016), who reported maximum STB incidence value from unsprayed plots of each varieties.

Table 1. Cummulative impact of wheat cultivars and Mode of application of chemicals.

Wheat cultivars	Schedule	Holetta			Kulumsa		
		Final Incide	Final Severity	AUDPC	Final Incide	Final Severity	AUDPC
Alidoro	Control	50[abc]	85[abcd]	1733.7[de]	10[cd]	35.3[def]	761.8[d]
	Mancozeb	21.7[f]	59.3[efg]	1041.8[ef]	6.67[d]	28.7[ef]	677.8[d]
	Tilt	16.7[fg]	45.3[g]	992.8[ef]	8.33[cd]	21.7[f]	634.7[d]
	MMTT	21.7[f]	56.7[efg]	1086.2[ef]	8.33[cd]	22.3[f]	593.8[d]
	TTMM	21.7[f]	56[efg]	1037.2[ef]	5[d]	21.3[f]	592.7[d]
	MTMT	10[g]	49.7[fg]	865.7[f]	6.67[d]	22.3[f]	591.5[d]
Kekeba	Control	98.3[a]	96.7[a]	3879.2[a]	66.67[a]	62.7[b]	1698.7[b]
	Mancozeb	66.7[bcd]	78.3[abcde]	2146.7[cd]	30[bcd]	49[bcd]	1403.5[c]
	Tilt	53.3[abc]	70.3[bcdef]	2240[bcd]	35[bc]	46[cd]	1295[c]
	MMTT	71.7[bc]	88[abc]	2952.8[b]	48.33[ab]	52[bc]	1410.5[c]
	TTMM	63.3[bcd]	73.3[bcde]	2173.5[cd]	26.67[bcd]	38.7[cde]	1289.2[c]
	MTMT	45[cdef]	62.3[defg]	1894.7[d]	16.67[cd]	48[bcd]	1422.2[c]
Madawalabu	Control	83.3[ab]	92.7[ab]	2889.8[bc]	31.67[bcd]	84.7[a]	2056.8[a]
	Mancozeb	60[bcd]	85[abcd]	2121[cd]	21.67[cd]	62[b]	1639.2[b]
	Tilt	38.3[def]	69[cdef]	1456[def]	10[cd]	39[cde]	1272.8[c]
	MMTT	45[cdef]	69.7[cdef]	1799[de]	13.33[cd]	49[bcd]	1382.5[c]
	TTMM	38.3[def]	69[cdef]	1488.7[def]	13.33[cd]	42[cde]	1331.2[c]
	MTMT	30[ef]	59.3[efg]	1457.2[def]	15[cd]	46.3[cd]	1369.7[c]
	Mean	46.4	70.3	1847.55	20.74	42.8	1190.2
	CV	23.4	9.3	23.04	32.05	8.9	10.88

CV= Coefficient of Variation, MMTT=Mancozeb-Mancozeb-Tilt-Tilt, TTMM=Tilt-Tilt-Mancozeb-Mancozeb, MTMT= Mancozeb-Tilt - Mancozeb-Tilt

Percent disease severity
At Holeta the highest (97%) severity was recorded on unsprayed plots of variety Kekeba. While the lowest (45%) disease severity was recorded from Alidoro variety sprayed with Tilt. At Kulumsa 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 different fungicides. This indicates that the level of disease development is considerably affected by level of fungicide application or varietal resistance to STB.

In general, STB was severe in both locations; however, it was more severe at Holeta than at Kulumsa. 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 to *Septoria tritici* blotch for resource poor farmers in developing countries and the most environmentally friendly and profitable strategy for commercial farmers (Tekelay *et al*., 2015).

Area under disease progress curve
STB AUDPC values across treatments ranged from 866 to 3879 at Holeta and from 592 to 2057 at Kulumsa (Table1). AUDPCs were generally higher on unsprayed plots than on sprayed plots. The maximum AUDPC values recorded on unsprayed plots were 3879%-days on wheat variety Kekeba, 2890%-days on Madawalabu and 1734%-days on Alidoro, at Holeta respectively. At Kulumsa, AUDPC values recorded as follows: 2057%-days, 1699%-days and 762 %-days, on Madawalabu, Kekeba and Alidoro varieties, respectively. Wheat variety Alidoro sprayed with MTMT fungicides schedules had the lowest (866%-days) at Holeta and 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. This agrees with that of Takele *et al*., (2015) who reported maximum AUDPC values (2275%-days) from unsprayed plots.

Yield and Yield Components Loss
Yield loss
At Holeta, maximum relative grain yield loss was 36%, and this was recorded on unsprayed plots of the variety

Kekeba (Table 2). On Madawalabu variety, grain yield loss of about 34% was recorded when STB was allowed to develop naturally. For Alidoro variety, grain yield reduction of about 35% was recorded on unsprayed plots.

At Kulumsa, maximum relative grain yield loss was 39% on unsprayed plots of the variety Madawalabu. On the variety Kekeba, grain yield loss of about 16.1% was recorded from unprotected plots, while grain yield reduction of about 21% was recorded on unsprayed plots of the variety Alidoro (Table 2).

Our result agrees with the findings of Said *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. 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 (Ayele *et al*., 2019).

Loss in thousand kernel weight

At Holeta, thousand kernel weight (TKW) was most affected on wheat variety Kekeba. The loss in TKW on this variety reached 25% on unsprayed plots (Table 2). On the other hand, a 7% loss in TKW was recorded on unsprayed plots of variety Alidoro, which is considered the lowest loss in TKW.

At Kulumsa, thousand kernel weight (TKW) was most affected on wheat variety Kekeba. The loss in TKW on this variety reached 18% on unsprayed plots (Table 2). On the other hand, 6.8% loss in TKW was recorded on unsprayed plots of variety Alidoro, which is considered as the lowest loss in TKW. Current results are in agreement with previous reports of Takele *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 Oxley 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 (Sharma *et al*., 2002).

Hectoliter weight loss

Only the Tilt fungicide treatments 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 2). 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, Ayele *et al*. (2019) 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 2. Effect of fungicide Spray Schedules on yield and yield components loss (%).

| Treatments | | Holetta | | | | | | Kulumsa | | | | | |
Variety	Fungicide	TKW	RTL	HLW	RHL	Yield	RYL	TKW	RTL	HLW	RHL	Yield	RYL
	Control	39.2^{fg}	7.3	74.6^{ab}	2.9	3.2^{de}	35	37^{defg}	6.8	78.5^{bcd}	1.1	3.7^{ab}	20.8
Alidoro	Mancozeb	42.3^{bcdef}	0	76^{ab}	1.1	4.2^{abc}	15	39^{abcde}	0	78.8^{bcd}	0.7	3.95^{ab}	16.14
	Tilt	41.3^{cdef}	2.4	76.9^{a}	0	4.9^{abcd}	0	39^{abcdefg}	0.8	79^{abcd}	0.2	4.7^{a}	0
	MMTT	40.27^{efg}	4.7	76.4^{ab}	0.6	4.3^{abc}	13	38.7^{abcdefg}	1.7	79.3^{abc}	0	4.38^{a}	7.01
	TTMM	40.8^{defg}	3.5	76.9^{a}	0	4.5^{ab}	8.5	37.1^{bcdefg}	5.8	78.9^{bcd}	0.6	4.6^{a}	2.34
	MTMT	40.4^{efg}	4.4	75.3^{ab}	2.1	4.3^{abc}	13	38^{abcdefg}	2.7	79^{bcd}	0.5	4.55^{a}	3.4
	Control	35.2^{h}	25	72.7^{b}	5.2	3.3^{de}	36	34.7^{g}	18	78^{cd}	2.7	3.7^{ab}	16.06
Kekeba	Mancozeb	44.8^{abcd}	4.3	76.2^{ab}	0.6	4.96^{a}	1.8	37^{bcdefg}	12	79^{abcd}	1.8	4.3^{a}	2.06
	Tilt	46.8^{a}	0	76.7^{ab}	0	4.9^{a}	3.9	42^{a}	0	80.57^{a}	0	4.36^{a}	0
	MMTT	42.3^{bcdef}	9.7	76.3^{ab}	0.5	4.5^{ab}	11	37^{bcdefg}	11	79.9^{ab}	0.79	3.8^{ab}	12.16
	TTMM	45.6^{ab}	2.6	76.5^{ab}	0.2	4.79^{a}	5.2	40^{abcd}	4.1	79^{abcd}	1.74	3.86^{ab}	12.06
	MTMT	45.3^{abc}	3.1	76.3^{ab}	0.5	5.05^{a}	0	36^{efg}	15	79^{bcd}	1.99	4.33^{a}	0.69
	Control	36.9^{gh}	18	66.9^{c}	11	3.12^{e}	34	34.8^{fg}	16	78^{d}	1.9	2.9^{b}	39.3
Madawalabu	Mancozeb	41.6^{bcdef}	7.4	75.1^{ab}	0	4.3^{abcd}	8.7	37^{bcdefg}	10	78^{cd}	1.8	4.47^{a}	6.5
	Tilt	42.8^{abcdef}	4.7	74.6^{ab}	0.6	4.5^{ab}	5.1	41^{ab}	0.6	79^{abcd}	0	4.78^{a}	0
	MMTT	44.9^{abcd}	0	74.5^{ab}	0.7	4.7^{ab}	0	39.87^{abcde}	3.5	78^{cd}	1.3	4.09^{ab}	14.4
	TTMM	44.4^{abcde}	1.2	73.7^{ab}	1.8	4.2^{abcde}	12	41.3^{a}	0	79^{bcd}	0.2	4.33^{a}	9.4
	MTMT	42.27^{bcdef}	5.9	73.4^{ab}	2.2	3.6^{bcde}	24	37^{cdefg}	11	79^{bcd}	0.9	4.16^{ab}	13
	Mean	42.06		74.95		4.24		38.2		78.9		4.2	
	CV	5.18		3.29		14.98		5.89		0.96		14.9	

MMTT=Mancozeb-Mancozeb-Tilt-Tilt, TTMM=Tilt-Tilt-Mancozeb-Mancozeb, MTMT= Mancozeb-Tilt - Mancozeb-Tilt, CV= Coefficient of Variation, TKW=Thousand kernel weight, HLW= Hectoliter weight, YLD= Yield, RTL= Relative Thousand kernel weight loss, RHL= Relative Hectolitter weight loss, RYL = Relative Yield loss,

Yield and Yield Components Recovery

The highest yield recovery over unsprayed plot, 55% and 65%, were recorded from Kekeba variety sprayed with MTMT at Holeta and Tilt sprayed Madawalabu variety at Kulumsa (Table 3). These results were higher than those obtained from the work of Tari *et al*. (2009), which resulted in up to 42% yield loss control 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 (Vrapi *et al*., 2009).

Correlation between Disease Parameters, Yield and Yield Components

At both locations 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 (Tables 4 & 5). The highest value of correlation coefficient indicated strong relationships between and within disease parameters. 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 3. Effect of fungicide Spray Schedules on yield and yield components Recovery(%) .

Treatments		Holeta						Kulumsa					
						TKW IOUP	HLW					TKW IOUP	HLW
Variety	Fungicide	Yield	YIOUP	TKW	TKW IOUP	HLW	HLW IOUP	Yield	YIOUP	TKW	TKW IOUP	HLW	HLW IOUP
Alidoro	Control	3.2[de]	0	39[fg]	0	75[ab]	0	3.7[ab]	0	37[defg]	0	78.5[bcd]	0
	Manco	4.2[abc]	32	42[bcdef]	7.8	76[ab]	1.9	3.95[ab]	6	39[abcde]	7.3	78.8[bcd]	0.4
	Tilt	4.9[abcd]	54	41[cdef]	5.3	77[a]	3.1	4.7[a]	26	39[abcdefg]	6.4	79[abcd]	0.9
	MMTT	4.3[abc]	36	40[efg]	2.7	76[ab]	2.4	4.4[a]	17	39[abcdefg]	5.5	79[abc]	1.1
	TTMM	4.5[ab]	42	41[defg]	4.0	77[a]	3.1	4.6[a]	23	37[bcdefg]	0.9	78.9[bcd]	0.5
	MTMT	4.32[abc]	35	40[efg]	3	75[ab]	0.9	4.6[a]	22	38[abcdefg]	4.4	78.97[bcd]	0.6
Kekeba	Control	3.3[de]	0	35[h]	0	73[b]	0	3.7[ab]	0	34.67[g]	0	78[cd]	0.0
	Mancoze	4.96[a]	52	45[abcd]	27	76[ab]	4.8	4.3[a]	17	37[bcdefg]	6.9	79[abcd]	0.9
	Tilt	4.9[ab]	49	46.8[a]	33	77[ab]	5.5	4.4[a]	19	42[a]	21	80.6[a]	2.8
	MMTT	4.5[abcd]	38	42[bcdef]	20	76[ab]	4.9	3.8[ab]	5	37[bcdefg]	7.3	79.9[ab]	1.9
	TTMM	4.8[abc]	47	45.6[ab]	30	77[ab]	5.2	3.9[ab]	6	40[abcd]	16	79[abcd]	1.0
	MTMT	5.1[a]	55	45[abc]	29	76[ab]	4.9	4.3[a]	18	35.6[efg]	2.7	79[bcd]	0.7
Madawalab	Control	3.1[e]	0	36.9[gh]	0	67[c]	0	2.9[b]	0	34.8[fg]	0	77.8[d]	0
	Mancoze	4.3	28	41.6	11.3	75.1	10.8	4.47	35	37	6	78	0.26
	Tilt	4.5[abc]	43	43[abcdef]	16	75[ab]	12	4.78[a]	65	41.1[ab]	18	79[abcd]	1.9
	MMTT	4.7[ab]	51	45[abcd]	22	75[ab]	11	4[ab]	41	40[abcde]	15	78[cd]	0.6
	TTMM	4.2[abcd]	33	44[abcde]	20	74[ab]	10	4.3[a]	49	41.3[a]	19	79[bcd]	1.7
	MTMT	3.6[bcde]	15	42[bcdef]	15	73[ab]	9.7	4.2[ab]	44	37[cdefg]	6	79[bcd]	0.9
	Mean	4.24		42.06		74.9		4.2		38.16		78.9	
	CV	14.98		5.18		3.29		43.5		5.89		0.96	

Table 4. Correlation Coefficient among Disease Parameters, Yield and Yield Components at Holetta.

	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 α=0.05, **: refers to mean square values significant at α=0.01, ns: refers to mean square values not significant at α=0.05

Table 5. Correlation Coefficient among disease parameters, Yield and Yield Components at Kulumsa.

	PDI	PDS	AUDPC	SL	PH	NKPS	YLD	TKW	HLW	ADS
PDI										
PDS	0.88**									
AUDPC	0.97**	0.92 **								
SL	-0.56* *	-0.42**	-0.53**							
PH	-0.40**	-0.29*	-0.42**	0.74**						
NKPS	-0.73**	-0.57**	-0.65**	0.49 **	0.37**					
YLD	-0.29*	-0.32*	-0.31 *	0.23^{ns}	0.29*	0.06^{ns}				
TKW	-0.17^{ns}	-0.26^{ns}	-0.21^{ns}	0.15^{ns}	-0.08^{ns}	0.01^{ns}	0.01^{ns}			
HLW	-0.24^{ns}	-0.18^{ns}	-0.22^{ns}	-0.20^{ns}	-0.28*	0.18^{ns}	0.18^{ns}	0.30*		
ADS	0.97**	0.92**	0.99**	-0.56**	-0.45**	-0.31*	-0.31*	-0.19^{ns}	-0.19^{ns}	

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 α=0.05, **: refers to mean square values significant at α=0.01, ns: refers to mean square values not significant at α=0.05

Conclusion and recommendation

A field experiment was conducted at Holetta and Kulumsa in 2016 main cropping season to determine the effect of STB disease on yield and yield components loss and recovery of bread wheat varieties. At Holetta, maximum relative grain yield loss was 36%, and this was recorded on unsprayed plots of the variety Kekeba whereas at Kulumsa, maximum relative grain yield loss was 39% on unsprayed plots of the variety Madawalabu. The highest yield recovery over unsprayed plot, 55% and 65%, were recorded from Kekeba variety sprayed with MTMT at Holeta and Tilt sprayed Madawalabu variety at Kulumsa. STB resulted in significant yield loss of bread wheat varieties, when left unchecked. STB severity, incidence and AUDPC also showed highly significant and negative correlations with grain yield and yield components.

Acknowledgments

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