Effect of Septoria Leaf Blotch (*Mycosphaerella graminicola*) on Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) in Western Amhara, Ethiopia

Belayneh Alamirew[1*], Merkuz Abera[2], Ayele Badebo[3]

Edited by:
Ayaz Farzand,
University of Agriculture, Faisalabad, Sub-Campus Burewala, Pakistan
Reviewed by:
Muhammad Naeem Sattar,
King Faisal University, Al-Hasa, Kingdom of Saudi Arabia
Muhammad Abid,
Bahauddin Zakariya University, Multan, Pakistan

Received
December 5, 2019
Accepted
March 8, 2020
Published Online
March 28, 2020

Abstract: Septoria leaf blotch (SLB) **(***Mycosphaerella graminicola*), is considered as the most economically important disease of wheat worldwide. A field experiment was carried out at Debre Tabor in 2017/2018 main cropping season to determine the effect of SLB on yield and yield components of bread wheat. Factorial combination of three varieties viz., Alidoro (Moderately resistant) Danda'a (Moderately susceptible) and Gambo (Susceptible) and four levels of fungicide spray frequencies (Control, one time, two times and three times) were tested in RCBD. Analysis of variance for grain yield showed significant variation among different fungicide spray frequencies ($P<0.05$). Significant differences ($P<0.05$) also have been observed in the yield components. The highest yield loss 46.42%, 39.09% and 26% was recorded on the unsprayed plots of Gambo, Danda'a and Alidoro, respectively. Similarly, at this location three frequencies (3times, 2times and 1times and control) of fungicide applications increased yield by 37.64%, 23.29% and 11.05% over unsprayed, respectively. The overall loss in grain yield of Gambo, susceptible variety was the highest compared with the other two varieties. Correlation analysis showed that, septoria leaf blotch severity with yield and most agronomic parameters on both all and flag leaves of all varieties were negatively correlated. Therefore, this study revealed that fungicide application will minimize the loss incurred by the pathogen; however the effect of this pathogen on quality of bread wheat should also be studied further.

Keywords: Fungicide, resistance, septoria leaf blotch, spray frequency, yield loss.

***Corresponding author:** Belayneh Alamirew: belayneh441@gmail.com

Cite this article as: Alamirew, B., M. Abera and A. Badebo. 2020. **Effect of Septoria leaf blotch (*Mycosphaerella graminicola*) on yield and yield components of bread wheat (*Triticum aestivum* L.) in Western Amhara, Ethiopia.** Journal of Environmental and Agricultural Sciences. 22(1): 41-48.

1. Introduction

Ethiopia is Africa's second largest wheat producer after South Africa and the largest producer in sub-Saharan Africa (ATA, 2015; Gebreselassie et al., 2017; Tadesse et al., 2019). Annually, 685 million tons of wheat is produced on 220 million hectares of land worldwide (Ayele et al., 2015). Africa produces 25.1 million metric tons on 9.9 million hectares with an average yield of 2.54 tones ha^{-1}, which is 4.5% of the world wheat production with the bulk of it coming from North Africa and Ethiopia produces about 76% of the total wheat production in Eastern and Central Africa (Ayele et al., 2015). Nationally, wheat contributes an estimated 12% to the daily per capita calorie intake, making it the third most important contributor to national calorie intake, after maize and sorghum (Guush et al., 2011). Bread (60%) and durum (40%) wheat are widely grown in the country (Aleemu et al., 2020; CIMMYT, 2015; Sall et al., 2019).

In spite of its economic significance the production and productivity of the crop is influenced by various biotic and abiotic stresses (Mann and

[1]Adet Agricultural Research Center, Bahir Dar, Ethiopia
[2]Bahir Dar University, College of Agriculture and Environmental science, Bahir Dar, Ethiopia
[3]International Maize and Wheat Improving Center, CIMMYT, Addis Ababa, Ethiopia

Warner, 2017). Among biotic stresses that retard production and productivity includes diseases, insects and weeds, and from the abiotic stresses drought, acidity, alkalinity, and depleted soil fertility (Ayele et al., 2015; Abera, 2017; Neumann et al., 2010; Singh et al., 2016). Septoria leaf blotch (*Mycosphaerella graminicola*, anamorph, *Septoria tritici*), is one of the most important pathogens of bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum turgidum* L. subsp. durum) in many parts of the world (Allioui et al., 2016; Boukef et al., 2012; Brennan et al., 2019; Goodwin et al., 2011). *M. graminicola* is among the top 10 economically important fungal pathogens in the world (Dean et al., 2012). This pathogen causes the most important disease with significant yield losses in Ethiopia (Mengistu et al., 1991). The pathogen has the ability to cause grain yield losses from 30% to more than 70% (Eyal et al., 1987). In Ethiopia up to 82% yield loss has been noted in susceptible varieties and it is becoming severe in all varieties (KARC, 2005).

Efforts for the management of Septoria leaf blotch disease is rarely addressed, despite it being one of the major yield limiting factors. Therefore, to determine the level of disease that returns reasonable yield response on disease management strategy the effect of varieties and fungicide spray frequency will determine the level of yield gained from SLB management. So far, there are some fungicides against Septoria leaf blotch but still, there is inadequate information on economic fungicide spray frequencies with different varieties having different reaction level. Therefore this study was carried out to investigate genotypic variations and efficacy of different frequencies of fungicide spray on occurrence of septoria leaf blotch disease and its effects on yield and yield components of bread wheat.

2. Materials and Methods

2.1. Description of the experimental area

The field experiment was conducted at Debre-Tabor Agricultural Research Sub Center at Debre Tabor, Ethiopia, during the main rainy seasons of 2017/2018. Debre-Tabor is one of the sub-centers of Adet Agricultural Research Center, situated 103 km northeast of Bahir Dar, found in South Gondar administrative zone at 11°88'N latitude and 37°98' E longitude and at 2591 m.a.s.l**.** The area receives an average annual rainfall of 1500.9 mm and the maximum and minimum annual mean temperatures are 25.5 and 6.1 ^{0}C, respectively. Soil at experimental station is characterized with Nitosol (Walleign, 2015).

2.2. Experimental materials, design and procedures

Three bread wheat cultivars having different susceptibility levels against Septoria leaf blotch i.e., moderately resistant (Alidoro), moderately susceptible (Danda'a), and susceptible (Gambo) were used in this experiment. These cultivars were reported to be resistant against other diseases like wheat rusts (Temesgen et al., 2000, Teklay et al., 2015). Four frequencies of fungicide Propiconazole (Tilt 250 EC; 0.5l ha^{-1}) spray (S0, S1, S2 and S3) were used as treatment. Experimental plot size was 6m^2 (2m width and 3m length). Each plot consisted of 10 rows and six harvestable central rows (3.6m^2). The space between rows, plots and replications was 0.2m, 1 m and 2m wide, respectively. The fungicide was sprayed using hand sprayer. The experiment was conducted in Randomized Complete Block Design (RCBD) in factorial arrangement with three replications at two sites. The fungicide was sprayed at a 10 days interval. The base for the 10 days interval is due to the relatively long latent period (14-21 days) of Septoria leaf blotch (SLB) (Eyal et al., 1987; Shaw, 1990). The fungicide spray was started after booting, flag leaves appearance, because of significant contribution of flag leaf in yield. Fungicide application at this stage is very critical and feasible because this is the most important spray as yield responses to flag leaf sprays are consistently profitable which contribute approximately 65% of yield (AHDB, 2016). During fungicide sprays, plastic sheets were used to separate the fungicide treated plots from non-treated plots, to prevent undesirable aerial movement of fungicide.

2.3. Data Collection

2.3.1. Disease data

SLB severity was assessed on 10 randomly pre-tagged plants of the middle rows per plot on weekly interval from the time of disease appearance on the susceptible check until the crop attained its physiological maturity. The severity for flag leaf was taken independently. The average severity of 10 plants per plot was used for analysis. SLB severity was scored visually using a double-digit (00 to 99), modified version of Saari and Prescott's scale (Saari and Prescott, 1975; Eyal et al., 1987) for wheat foliar diseases. The first digit (*D*1) indicates disease progress in plant height and the second digit (*D*2) refers to severity measured as the diseased leaf area. For each score, a percentage of disease severity was estimated based on the following formula: $severity = (\frac{D1}{9} x \frac{D2}{9})$ x100.

2.3.2. Agronomic Data's

Days to 50% heading: The numbers of days from planting to the time when 50% of plants showed head on plot basis was recorded. Days to 75% maturity: The number of days from planting to the date when 75% of the plants attain physiological maturity (while color of its peduncles turns to yellow) was recorded. Plant height in centimeter: Average height of main tillers from ten plants (tagged before commencement of tillering) was measured from ground level to the tip of the spike excluding the awns. Number of tillers per M^2: Total number of tillers from five rows of one-meter row length in each plot was recorded. Number of spikelet per spike: Number of spikelet from the ten plants was counted. Spike length (cm): length of spike in centimeter from 10 plants per plot was measured. Number of kernels per spike: the average number of kernels of the main tiller of the ten pre-tagged plants was recorded. Biomass t/ha: The weight of total above ground parts of the harvestable plot was measured. Thousand-kernel weight: The weight of thousand kernels was sampled at random from the total grains to be harvested from each experimental plot was measured using sensitive balance. Grain yield: Grain yield in g/per plot at 12.5% moisture content were recorded and converted to kg/ha. Only harvestable (the six internal rows) of the plots was harvested for yield and biomass estimations. Test weight/hectoliter weight is also measured for its flour extraction rate. Harvest Index: The ratio of dried grain yield at 12.5% moisture content to the total aboveground biomass was determined.

2.4. Data Analysis

All the collected data were subjected to analysis of variance (ANOVA) by using the methods described by Gomez and Gomez, (1984) using SAS computer software 9.0. Measured parameters were subjected to logarithmic transformation before analysis to normalize the data analysis. Least Significant Difference (LSD) values were used to separate treatment means.

2.4.1. Relative Yield Loss Estimation

The relative losses in yield and yield components of each variety were determined as a percentage of the sprayed plots of the respective variety. Losses were calculated separately for each of the treatments with different levels of disease by using the following formula.

$$RL(\%) = \frac{(Y1 - Y2)}{Y1} x100$$

Where, RL% =percentage of relative loss (reduction of the parameters; i.e. yield, yield component)

Y1 = mean of the respective parameter on sprayed plots (plots with maximum protection)

Y2 = mean of the respective parameter in unsprayed plots (i.e. unsprayed plots or sprayed plots with varying level of disease) (Alemar, 2013).

3. Results and Discussion

3.1. Effect of Septoria leaf blotch on grain yield

Analysis of variance for grain yield showed highly significant variation among different fungicide application frequencies (P<0.01) (Table 1). The lower grain yield (3508kg/ha) was obtained from control (unsprayed plots) while higher yield (5625.8 kg/ha) was obtained from plots treated with three times tilt fungicide application. Even though there were no significant variations among varieties the highest grain yield was obtained on the variety Alidoro (4689.5 kg/ha) while the lowest was obtained from Gambo (4547.5kg/ha) (Table 1).

Mean grain yield of three times tilt fungicide application increased by 37.64%, 23.29% and 11.05% over unsprayed, one times and two times application respectively, in contrast Hampton and Close, (1975) three times Benomyl application increase the grain yield by 16.9%. Similarly, Thorn, (1965) reported that two or three times application of fungicides delayed the senescence of flag leaves which is a function of grain size and yield. The result of this study is contrasted with Loughman and Thomas, (1991) application of three times spray does not have yield advantage. Bhathal et al. (2003) also reported that infection of the flag or penultimate leaf appeared also to be a good predictor of yield loss in field trials conducted in Western Australia. But in contrast with, Loughman and Thomas, (1991) three sprays provided no additional yield advantage.

3.2. Effect of Septoria leaf blotch on yield components

There were highly significant (P<0.01) differences except in tiller number and thousand kernel weights among varieties and fungicide applications (Table 1). Extended days to heading, and late maturity were recorded on Alidoro variety. Similarly, the highest plant height, spike length, number of spikelet per spike, number of kernels per spike and biomass weight was recorded on Alidoro variety (Table 1).

Table1. Effect of Septoria leaf botch on yield and yield components of three bread wheat varieties under different foliar fungicide spray frequency at Debre Tabor

Treatment	DTH	DTM	PH (cm)	SL (cm)	NSPS	NKPS	NT/M^2	BM (t ha^{-1})	Yield (kg ha^{-1})	TKW (g)	HLW
Variety											
Alidoro	72.58^{b}	132.41^{a}	102.12^{a}	11.13^{a}	19.96^{a}	61.07^{a}	418.25	11.93^{a}	4689.5	33.50	74.38^{b}
Danda'a	75.08^{a}	132.58^{a}	99.75^{a}	8.85^{b}	18.51^{b}	57.90^{a}	433.83	11.69^{a}	4602.8	32.85	72.04^{c}
Gambo	66.25^{c}	123.83^{b}	86.14^{b}	7.24^{c}	14.99^{c}	46.00^{b}	442.00	10.16^{b}	4547.5	31.97	76.06^{a}
Sig.difference	**	**	**	**	**	**	ns	**	Ns	Ns	**
FAF											
Unsprayed	70.66^{b}	126.88^{c}	93.71^{c}	8.57^{c}	17.08^{c}	50.51^{b}	424.11	9.93^{c}	3508.0^{d}	26.88^{c}	69.90^{c}
One times	71.77^{a}	129.33^{b}	96.86^{ab}	8.88^{bc}	17.65^{bc}	52.93^{b}	438.56	10.74^{bc}	4315.3^{c}	31.84^{b}	74.17^{b}
Two times	71.22^{ab}	131.33^{a}	94.83^{bc}	9.21^{b}	18.10^{ab}	57.90^{a}	408.44	11.53^{b}	5003.8^{b}	35.57^{a}	75.77^{a}
Three times	71.55^{a}	130.88^{ab}	98.62^{a}	9.63^{a}	18.45^{a}	58.64^{a}	454.33	12.84^{a}	5625.8^{a}	36.78^{a}	76.80^{a}
Sig.difference	*	*	*	*	*	*	ns	**	**	**	**
CV (%)	1.07	1.44	3.14	4.60	4.31	6.88	8.54	7.38	8.24	4.91	2.11

Means with the same letter are not significantly different. FAF, fungicide application frequency; DTH, days to heading; DTM, days to maturity; PH, plant height; SL, spike length; NSPS, number of spikelet spike^{-1}; NKPS, number of kernels spike^{-1}; NT, number of tillers; BM, biomass weight; Yield, grain yield; HLW, hectoliter weight, CV, coefficient of variation; FAF, fungicide application frequency; CV, coefficient of variation; LSD, least significant difference. *, significant difference at $p<0.05$; **, significant differences at $p<0.01$; ns, non-significant difference; Means with the same letter are not significantly different.

A significant difference ($P<0.01$) was observed in the main factor which is fungicide spray frequencies on all yield related parameters except on tiller numbers. The lowest days for heading (70.66 days), for maturity (126.88 days), and the lowest plant height (93.71cm) were obtained from unsprayed treatments. There were statistically significant ($P<0.05$) difference in the main factor fungicide application in spike length.

The lowest spike length was found on the unsprayed treatment while the highest spike length on three times fungicide application. There was no significant difference between two and three times fungicide application for spikelet per spike but there was significant difference between unsprayed with two and three times application. The highest spike length (11.23cm) was recorded in the Alidoro variety which is moderately resistant to SLB (Table 1). The analysis of variance (ANOVA) on the number of kernels indicates there was a significant difference on both main factors among varieties and fungicide spray frequency. But there was no significant difference between Alidoro and Danda'a varieties. However; the highest NKPS (61.07) was obtained on the Alidoro variety while the lowest was recorded in Gambo variety.

The highest biomass weight (11.93 t/ha) was recorded from the variety Alidoro and the lowest (10.16t/ha) from the susceptible variety (Gambo). Among fungicide spray frequencies the lowest biomass weight (9.93 t ha^{-1}) was recorded on the unsprayed plots while the highest (12.84t/ha) was from three times sprayed plots.

Table 2. Relative losses of grain yield and yield components of three bread wheat varieties due to Septoria leaf blotch under different fungicide spray frequencies at Debre Tabor during 2017 cropping season

Variety	FAF	SL (cm)	Loss (%)	NSPS	Loss (%)	NKPS	Loss (%)	BM (t ha^{-1})	Loss (%)	TKW (g)	Loss (%)	Yield (kg ha^{-1})	Loss (%)
Alidoro	**Control**	10.5	10.25	19.8	2.46	58.5	5.03	11.2	11.81	29.5	18.28	3964.0	26
	1times	11.0	5.98	20.0	1.47	60.7	1.46	11.4	10.24	33.0	8.58	4332.3	19.74
	2times	11.3	3.41	20.0	1.47	63.5	+3.08	12.4	2.36	35.0	3.04	5063.7	6.19
	3times	11.7	0	20.3	0	61.6	0	12.7	0	36.1	0	5398.0	0
Danda'a	**Control**	8.7	3.33	17.7	5.85	53.0	13.96	10.2	25	26.2	29.94	3407.3	39.09
	1times	8.7	3.33	18.6	1.06	56.1	8.92	11.4	16.12	31.5	15.77	4487.3	19.78
	2times	8.9	1.11	18.9	+0.5	61.0	0.97	11.6	14.71	36.3	2.9	4922.3	12.00
	3times	9.0	0	18.8	0	61.6	0	13.6	0	37.4	0	5594.0	0
Gambo	**Control**	6.5	20.73	14.0	13.58	40.1	24.33	8.4	31.14	25.0	32.06	3153.0	46.42
	1times	7.0	14.63	14.5	10.5	42.0	20.75	9.5	22.13	31.1	15.4	4126.3	29.8
	2times	7.4	9.75	15.5	4.3	49.2	7.10	10.6	13.11	35.0	4.89	5025.3	14.6
	3times	8.2	0	16.2	0	53.0	0	12.2	0	36.8	0	5885.3	0

Means with the same letter are not significantly different. FAF=fungicide application frequency, SL=Spike length; NSPS=number of spikelet per spike; NKPS=number of kernels per spike; BM=biomass weight; Yield =grain yield; TKW=1000 kernel weight.

Table 3. Correlation coefficients between septoria leaf blotch severities assessed on all leaves on different days after planting (DAP) on yield and yield components of bread wheat during 2017 cropping season

Parameters	SLB severity at different days after planting (DAP)									
	46DAP	53DAP	60DAP	67DAP	74DAP	81DAP	88DAP	95DAP	102DAP	109DAP
SL	-0.734**	-0.891**	-0.882**	-0.853**	-0.860**	-0.801**	-0.808**	-0.821**	-0.808**	-0.798**
NSPS	-0.678**	-0.929**	-0.926**	-0.928**	-0.937**	-0.887**	-0.878**	-0.845**	-0.824**	-0.825**
NKPS	-0.593**	-0.817**	-0.797**	-0.865**	-0.884**	-0.869**	-0.871**	-0.850**	-0.844**	-0.839**
BM	-0.328	-0.412*	-0.477**	-0.618**	-0.652**	-0.680**	-0.714**	-0.686**	-0.728**	-0.736**
YLD	-0.123	-0.098	-0.167	-0.345*	-0.370*	-0.456**	-0.516**	-0.520**	-0.577**	-0.597**
TKW	-0.128	-0.190	-0.282	-0.441**	-0.453**	-0.561**	-0.616**	-0.597**	-0.648**	-0.662**

*=significant at 0.05 probability level **=significant at 0.01 probability level; DAP, days after planting; SL, Spike length; NSPS, number of spikelet per spike; NKPS, number of kernels per spike; NT, number of tillers; BM, biomass weight; YLD, grain yield; TKW, 1000kernel weight.

Thousand grain weights is also affected by resistance level and the highest 1000 grain weight (33.5g) was obtained from Alidoro variety and the lowest from susceptible variety. It is also consistent with fungicide application that the minimum weight (26.88g) recorded on the unsprayed plot while the maximum grain weight 36.78g) on three times sprayed treatments. It agreed with Hershman, (2012) kernels from severely SLB diseased wheat heads are usually shriveled and lightweight and also pushes the plant to mature early and it makes unable to accumulate dry matter. Similarly, Hampton and Close, (1975) prove that a spraying regime which included three sprays of benomyl or two of mancozeb significantly increased (P<0.05) l000-grain weight.

3.3. Relative loss in grain yield components

At study area on the untreated bread wheat plots, relative grain yield losses were notably higher on the three varieties. Relative grain yield loss was reduced by all combination of varieties by chemical spray frequencies. There were losses in yield components of all varieties. The highest loss in spike length, number of spikelet per spike, number of kernels per spike, biomass weight, thousand kernel weight and hectoliter weight were recorded on the unsprayed plots of all varieties. The highest losses on the above mention yield related parameters were recorded on the susceptible variety (Gambo) (Table 2).

The highest relative grain yield loss was recorded on unsprayed plots of Gambo, with loss percentage of 46.42% and unsprayed plots of Danda'a (39.9%) followed by one times sprayed plot (29.80%) of Gambo. The result of this study is in agreement with Abera et al. (2015), 41% yield loss was obtained on the susceptible varieties at Holeta, Ethiopia. Among unsprayed treatments, the lowest yield loss (26%) was recorded from Alidoro; which was moderately resistant to septoria leaf blotch. On this variety the minimum grain yield loss obtained from two times fungicide spray (6.19%), while 19.74% yield loss was incurred on a single fungicide application. On the variety Danda'a which is moderately susceptible to SLB, minimum yield loss was obtained on two time sprayed plots (12.00%) and the highest on the unsprayed plots. Similarly, Alemar, (2013) had reported in susceptible varieties about 40.6% yield loss had been occurred in Hadya Kembata areas of Ethiopia. On the moderately resistant variety, Alidoro at Debre Tabor minimum yield loss was obtained from the two times fungicide sprays while the maximum yield loss obtained from the unsprayed plots (Table 2). Similarly, Ponomarenko, (2011) reported that sever epidemics of SLB can reduce wheat yields by 35 to 50%. Similarly, Eyal, (1987) reported that the infections on the flag leaves can cause the most severe losses by reducing grain weight.

Table 3. Correlation coefficients between septoria leaf blotch severities assessed on all leaves on different days after planting (DAP) on yield and yield components at bread wheat cultivar Adet during 2017 cropping season

Parameters	SLB severity at different days after planting (DAP)					
	65DAP	72DAP	79DAP	86DAP	93DAP	100DAP
SL	-0.295	-0.388*	-0.369*	-0.228	-0.197	-0.333*
NSPS	-0.564**	-0.570**	-0.611**	-0.479**	-0.454**	-0.544**
NKPS	0.194	0.231	0.196	0.119	0.058	0.101
BM	-0.073	-0.065	-0.073	-0.019	0.006	0.029
YLD	0.232	0.208	0.067	0.086	-0.192	-0.161
TKW	-0.443**	-0.419*	-0.475**	-0.387*	-0.309	-0.394*

*=significant at 0.05 probability level **=significant at 0.01 probability level; DAP, days after planting; SL, Spike length; NSPS, number of spikelet per spike; NKPS, number of kernels per spike; NT, number of tillers; BM, biomass weight; YLD, grain yield; TKW, 1000kernel weight.

Generally, on this study the grain yield loss under natural epidemics ranges from 26.0% (Alidoro) to 46.2% (Gambo) on the study area under natural infestation, where there was a high Septoria leaf blotch severity. This agreed with (Agrios, 1997 and Bockus et al., 2010) that SLB can cause the grain yield loss up to 50%. But, it could not reach up to 82% yield loss (Abreham, 2008). The overall loss on grain yield of Gambo, susceptible variety was highest compared with the other two varieties under this experiment. It confirmed the idea of Ahmad et al. (2010) that susceptible genotypes showed higher yield losses as compared to resistant genotypes. In general; in this study, the pattern of grain yield loss was consistent with both fungicide spray frequencies and crop resistant levels. The loss on grain yield of the three varieties was high at Debre Tabor where the epidemic of SLB was high. The result of this study is consistent with Ponomarenko, (2011) reported that severe epidemics of SLB can reduce wheat yields. In wheat and other crops photosynthetic activity is the main physiological process responsible of increments in yield. This is in line with Shtienberg, (1990) reported that in plants infected with pathogens, there is a decline in photosynthetic activity because of a decrease in photosynthesizing leaf area or a reduction in the efficiency of the process affecting indirectly the rate and duration of grain weight accumulation.

3.4. Correlation between septoria leaf blotch with grain yield and yield components

Correlation analysis showed that, septoria leaf blotch severity and yield and most agronomic parameters on both all and flag leaves of all varieties were negatively correlated (Table 3 and 4). This is in agreement with the study of Vrapi et al. (2012) "there was high negative correlations between wheat crop yield and *Septoria tritici* blotch". The correlation between spike lengths, number of spikelet per spike, number of kernels per spike and biomass weight with disease severity on all leaves and flag leaves at the study area showed that there was a significant negative correlation in all assessment dates (Table 3 and 4). Similarly, Trottet, (1982) indicated that there was a negative and highly significant correlation between flag leaf and thousand kernel weight.

At the study area the correlation between disease on all leaves and yield showed that there was negative correlation except on the first assessment dates. On the first three assessment dates 46, 53, and 60DAP there was no correlation at $P<0.05$ between disease severity and yield with correlation values r= -0.123, -0.098 and -0.167 respectively. However, after the fourth and fifth assessment dates 67 and 74 DAP there was a moderate negative correlation (r= -0.345 and -0.370). Starting from the sixth assessment dates grain yield was significantly correlated with disease severity on all leaves with the highest correlation coefficient r=-0.597 at the final assessment date 109 DAP (Table 3). Similarly, the severity scored on flag leaves throughout the assessment dates was highly correlated with yield. This agrees with AHDB (2016) that flag leaf contribute approximately 65% of yield. Similarly, Marroni et al. (2006) had reported that the most serious yield loss occurs when the flag leaf which are responsible for providing photosynthetic products for grain filling are severely infected with septoria leaf blotch. In conclusion, correlation analysis of Septoria leaf blotch severity recorded at later growth stage showed significantly negative correlation with yield and yield components than it was recorded at early growth stage of the crop. This agreed with Jenkins et al. (1969) stating that *Septoria tritici* blotch occurs after ear emergence the disease becomes quite severe on the upper leaves and causes significant yield loss.

4. Conclusion

The disease severity at study area was very aggressive and initiated infection at early growth stages and there was a continuation of rainfall and relative humidity until harvesting which was conducive for disease development. Varieties were responding to Septoria leaf blotch differently. However, the moderately resistant variety (Alidoro) was also highly affected by the pathogen. This was due to resistance level can be changed through time and biological activity of the race. Most of the yield components were negatively correlated with the severity. Therefore, the current study revealed that fungicide application will minimize the loss incurred by the pathogen. The effect of this pathogen on quality of bread wheat should also be studied further.

List of Abbreviations: BAP: Benzyl amino purine. SLB: Septoria Leaf Blotch

Competing Interest Statement: All the authors declare that they have no competing interest.

Author's Contribution: The authors declare that they have no competing interests.

Acknowledgments: All authors contributed equally to the conception and design of the study. Their great gratitude also goes to the Delivering Genetic Gain in

Wheat (DGGW) project and Amhara Agricultural Research Institute (ARARI) for funding this study.

References

Abera, M. 2017. Agriculture in Lake Tana sub-basin of Ethiopia. In: Stave K., Goshu G., Aynalem S. (eds) Social and Ecological System Dynamics. AESS Interdisciplinary Environmental Studies and Sciences Series. Springer, Cham, p. 375-397.

Abreham, T. 2008. Increasing crop production through improved plant protection-volume I. Proceedings of the 14th annual conference of the plant protection society of Ethiopia (PPSE). December 2006. p: 19-22.

Agrios, G.N. 1997. Plant Pathology, 4th ed., Academic Press, New York. p: 244-256

AHDB. 2016. Agricultural and Horticultural Development Board. Cereals and oilseeds division. *cereals.ahdb.org.uk/publications.*

Ahmad, S., M. Afzal, I.R. Noorka, V. Iqbal, N. Akhtar, Y. Iftkhar and M. Kamran. 2010. Prediction of yield yosses in wheat (*Triticum aestivum* L.) caused by yellow rust in relation to epidemiological factors: in Faisalabad University College of Agriculture, University of Sargodha, Pakistan. Pakistan J. Bot. 42(1): 401-407.

Alemar, S. 2013. Temporal development of septoria blotch (*Septoria tritici*) and its effect on grain yield and yield components of bread wheat in Haddiya-Kambata area Southern Ethiopia. M.Sc. Thesis. Haremaya University. Ethiopia.

Alemu, A., T. Feyissa, R. Tuberosa, M. Maccaferri, G. Sciara, T. Lettaa and B. Abeyo. 2020. Genome-wide association mapping for grain shape and color traits in Ethiopian durum wheat (*Triticum turgidum* ssp. *durum*). Crop J. https://doi.org/10.1016/j.cj.2020.01.001.

Allioui, N., A. Siah, L. Brinis, P. Reignault and P. Halama. 2016. Identification of QoI fungicide-resistant genotypes of the wheat pathogen *Zymoseptoria tritici* in Algeria. Phytopathol Mediterr. 55(1): 89-97

ATA (Agricultural Transformation agency). 2015. Transforming Agriculture in Ethiopia:

Ayele, B., B. Abeyo and V. Akulumuka. 2015. Wheat research and development in the eastern and central Africa: past, present and future outlook. p: 60-70. *In*: F. Wander, V. Akulumuka, J. Maina, J. Otiang, J. F. Mubiru, D. Mbugua, and R. Muinga (eds.). Regional specialization for enhanced agricultural productivity and transformation. Proceedings of the Eastern Africa Agricultural Productivity Program End-of-Phase One Project Conference and Exhibition. [ASARECA] Association for strengthening Agricultural Research in Eastern and Central Africa.

Bhathal, J.S., R. Loughman and J. Speijers. 2003. Yield reduction in wheat in relation to leaf disease from yellow (tan) spot and septoria nodorum blotch. Eur. J. Plant Pathol. 109 (5): 435-443.

Bockus, W.W., R.L. Bowden, R.M. Hunger, W.L. Morrill, T.D. Murray and R.W. Smiley. 2010 Compendium of wheat diseases and pests, 3rd ed. American Phytopathol. Soc. St. 43-44.

Boukef, S., B.A. McDonald, A. Yahyaoui, S. Rezgui and P.C. Brunner. 2012. The frequency of mutations associated with fungicide resistance and population structure of *Mycosphaerella graminicola* in Tunisia. Eur. J. Plant Pathol. 132(1): 111-122.

CIMMYT (International Wheat and Maize Improving Center). 2015. Wheat Atlas. Retrieved from http://wheatatlas.org/country/production/ETH/0 May 29/2017.

Dean, R., J.V. Kan, Z. Pretorius, K.H. Kosack, A.D. Pietro, P. Spanu, J. Rudd, M. Dickman, R. Kahmann, J. Ellis and G. Foster2012. The top 10 fungal pathogens in molecular plant pathology. Mol. Plant Pathol. 13(4): 414-430.

Eyal, Z., A.L. Scharen, J.M. Prescott and M. Ginkel. 1987. The septoria diseases of wheat: concepts and methods of disease management. CIMMYT, Mexico.63: 1087-1091.

Gebreselassie, S., M. Haile and M. Kalkuhl. 2017. The wheat sector in Ethiopia: Current status and key challenges for future value chain development. ZEF Working Paper No. 160. http://dx.doi.org/10.2139/ssrn.3013041.

Gomez, K.A. and A.A. Gomez. 1984. Statistical procedure for agricultural research. Second edition. Wiley-Intercedence Publications. New York. USA

Guush, B., Z. Paulos, K. Tafere and S. Tamru. 2011. Food grain consumption and calorie intake patterns in Ethiopia. ESSP II Working Paper No. 23.

Hampton, J.G. and R.C. Close. 1975. Effect of septoria leaf spot in spring wheat. New Zealand J. Exp. Agric. 4(1): 89-92.

Jenkins, J.E.E. and W.A. Morgan. 1969. The effect of septoria diseases on the yield of winter wheat. Plant Pathol. 18(4): 152-156.

KARC. 2005. Progress report for/2005 In Abreham Tadesse (ed.). Increasing crop production through improved plant protection. 1: 381-385.

Loughman, R. and G.J. Thomas. 1991. Fungicide and cultivar control of septoria disease of wheat. Crop Prot. 11(4): 349-354.

Mann, M.L. and J.M. Warner. 2017. Ethiopian wheat yield and yield gap estimation: A spatially explicit small area integrated data approach. Field Crops Res. 201: 60-74.

Marroni, M.V., R. Viljanen, R. Butler and Y. Deng. 2006. Fungicide timing for the control of *septoria tritici* blotch of wheat. New Zealand Plant Prot. 59: 160-165.

Mengistu, H., W. Getaneh, A. Yeshi, D. Rebeka and A. Badebo. 1991. Wheat pathology research in Ethiopia. Int. J. Agron. Plant Prod. 173-180.

Neumann, K., P.H. Verburg, E. Stehfest and C. Müller. 2010. The yield gap of global grain production: A spatial analysis. Agric. Syst. 103(5): 316-326.

Ponomarenko, A., S.B. Goodwin and G.H.J. Kema. 2011. *Septoria tritici* blotch (STB) of wheat. *Plant Health. Department of Botany and Plant Pathology*, Purdue University, West Lafayette, IN USDA-ARS, Crop Production and Pest Control Research Unit, Purdue University, West Lafayette, IN Plant Research International, Wageningen, The Netherlands 2012. The American Phytopathological Society.

Saari E.E. and L.M.A. Prescott. 1975. Scale for appraising the foliar intensity of wheat diseases. Plant Dis. Rep. 59: 377-380.

Sall, A.T., T. Chiari, W. Legesse, K. Seid-Ahmed, R. Ortiz, M. van Ginkel and F.M. Bassi. 2019. Durum wheat (Triticum durum Desf.): Origin, cultivation and potential expansion in Sub-Saharan Africa. Agronomy. 9(5): 263.

Shaw, M.W. 1990. Effects of temperature, leaf wetness and cultivar on the latent period of *Mycosphaerella graminicola* on winter wheat. Plant Pathol. 39(2): 255-268.

Shivadditya, G. 2010. Biocontrol of cereal pathogens. Dissertation.com, Boka Raton, USA.

Singh, R.P., P.K. Singh, J. Rutkoski, D.P. Hodson, X. He, L.N. Jørgensen, M.S. Hovmøller and J. Huerta-Espino. 2016. Disease Impact on Wheat Yield Potential and Prospects of Genetic Control. Annu. Rev. Phytopathol. 54(1): 303-322.

Tadesse, W., Z. Bishaw and S. Assefa. 2019. Wheat production and breeding in Sub-Saharan Africa. Int. J. Clim. Chang. Strateg. Manag. 11(5): 696-715.

Teklay, A., M. Mehari and M. Legesse. 2015. Field response of wheat genotypes to *Septoria Tritici* blotch in Tigray, Ethiopia. J. Nat. Sci. Res. 5(1): 10-19.

Temesgen, K., T. Hussien and T.S. Payne. 2000. Field response of bread wheat genotypes to *septoria tritici* blotch. *In*: Proceedings of the eleventh regional Workshop for Eastern, Central, and Southern Africa. Addis Ababa, Ethiopia. 169-182.

Trotter, M. 1982. Problems poses par l'tude du comportment de lignees de ble vis-à-vis-de la septoriose par causes septoria nodorum Berk.

Vrapi, H., G. Belul, K. Foto, S. Halit and R. Thanas. 2012. The relationship between diseases index of septoria leaf blotch, leaf rust and yield losses in bread wheat cultivar in Albania. J. En. Sci. and Eng. 1: 957-965.

Wallelign, Z. 2015. Importance and management of loose smut [*Ustilago nuda* (Jensen) Rostrup] of barley (*Hordeum vulgare* L.) through seed dressing and coating materials on barley in Western Amhara, Ethiopia. A Thesis submitted to the School of Plant sciences, School of Graduate Studies Haremaya University, Ethiopia.