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Septoria Leaf Blotch (*Mycosphaerella graminicola*) Incidence on Bread Wheat (*Triticum aestivum* L.) and its Association with Biophysical Factors of Western Amhara, Ethiopia

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Abstract: Globally bread wheat (*Triticum aestivum* L.) is one of the main cereals. Despite its economic significance, wheat production and productivity is under significant threat due to abiotic and biotic stresses. Septoria leaf blotch (*Mycosphaerella graminicola*) is one of the major biotic stress, siginificantly reduce both quality and quantity of wheat, especially susceptible cultivars, in the highlands of Western Amhara, Ethiopia. However, the relative importance of this pathogen has not been well documented to develop a sound management strategy in the studied areas. The survey was conducted during the main cropping season (2017) to assess the Septoria leaf blotch incidence, severity, and management of the disease with cultural practices in nine districts of western Amhara. During the study, a total of 120 farmers' fields in nine districts were surveyed. The field survey results revealed that there was96.7% prevalence of Septoria leaf blotch on bread wheat and only four fields (3.3%) were found free of infection. Mean incidence of Septoria leaf blotch varied from 33.7% in Burie to 90.2% in Farta district. The severity also ranged from 5.31 to 30.61% in the 116 fields. Wheat variety, wheat population density, crop history, edaphic factors , weed intensity and cropping system were significantly associated with Septoria leaf blotch incidence and severity. However, the impact of altitude on the specific disease incidence remained non-significant. In general, the current study suggests that the disease has become severe and a serious constraint in most assessed fields. So, the findings of the present study indicate the need to undertake different cultural practices, including late sowing, rotating with non-cereal crops (legumes) and mixed cropping system for the integrated management of Septoria leaf blotch. However, germplasm screening and selecting tolerant varieties could be the other option for the management of the Septoria leaf blotch in the future.

Keywords: Associations, Incidence, Importance, Septoria leaf blotch, Severity, Variable.

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1. Introduction

Bread wheat (*Triticum aestivum*) is among the most important cereal food crops produced worldwide (Curtis, 2002; Miransari and Smith, 2019), which is grown on a large scale in the tropical and subtropical regions of the world (Gibson and Benson, 2002). About 75% of the world's population consumes wheat as part of the daily diet. Ethiopia is one of the largest wheat producers in sub-Saharan Africa (SSA), and the second-largest wheat producer next to South Africa in Africa (ATA, 2015). According to recent estimates, there are approximately 4.76 million farmers who are growing wheat on around 1.74 million hectares of land (CSA, 2019). This represents between 15 and 18% of total cropped areas and 20% of cereal consumption. The

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national average productivity of wheat in Ethiopia has been estimated at 0.2764 t ha^{-1} (CSA, 2019). Concerning regional contribution to wheat production, Oromia Region produces the highest (57.4%) volume of wheat grain during the main crop season, followed by Amhara Region (27%). The Amhara Region shared 570,742.91 ha of the total area under wheat cultivation, contributing 1.4 million tons of wheat grain to the national annual production while the productivity is about 0.25 t ha^{-1} (CSA, 2019).

Despite the economic and nutritional importance of wheat, its production is limited by various abiotic and biotic factors (Tesfaye et al., 2001; Merkuz, 2017). Biotic stresses include diseases, lack of improved varieties, insect pests and weeds, and abiotic constraints include drought, soil acidity, alkalinity, heat stress, soil fertility depletion and limited adoption of modern agricultural technologies (Merkuz, 2017). Septoria leaf blotch (SLB) (*Mycosphaerella graminicola*, anamorph, *Septoria tritici*) (Allioui et al., 2016), is one of the most damaging disease recently found different parts of the world, infecting bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum turgidum* L. subsp. *durum*) (Boukef et al., 2012). This pathogen is globally listed in the top ten fungal pathogens causing the most economical losses (Dean et al., 2012) and the most important disease in Ethiopia (Eshetu, 1986; Mengistu et al., 1991).

Septoria leaf blotch can cause 30 to 70% grain yield losses (Eyal et al., 1987). It has also become very severe disease resulting in up to 82% grain yield loss in all released bread wheat cultivars in Ethiopia (AARC, 2000; KARC, 2005). Similarly, at the West Shewa zone, Ethiopia estimated 41% yield losses of bread wheat have been recorded due to septoria leaf blotch (Abera et al., 2015). Although recently various methods are used for the detection and diagnosis of cop disease (Chouhan et al., 2020; Zhao et al., 2020). However, field surveys are helpful tools in studying the distribution and importance of different crops and their diseases (Ruska et al., 1997). Research information on the epidemiological factors influencing disease development is important to device its management strategies. Aange of disease management options is recommended to control Septoria leaf blotch in wheat fields. Appropriate management strategies include cultural management (restricting inoculum spread) like incorporation of non-hosts crops in rotation, deep mixing of crop residues to reducee the amount of inoculum in the soil. Knowledge of the distribution of SLB over time and across locations is essential for the further development of disease management strategies

Therefore, the present study was carried out to assess the distribution, relative importance and the intensity of Septoria leaf blotch on bread wheat, and determine the association of biophysical factors and cultural practices with the disease intensity.

2. Materials and Methods

2.1. Study area

A field survey was conducted in the field of bread wheat crop in three major wheat-producing zones of western Amhara. Disease survey was carried out in 9 districts, including two in South Gondar, three in East Gojjam and four in West Gojjam, during the main growing season of 2017. The surveyed districts namely Lay Gayint and Farta (South Gondar Zone); Yilmana Densa, Burie and Wonberima (West Gojjam Zone); and Baso Liben, Debre Elias, Goncha Siso Enese and Hulet Eju Enese (East Gojjam Zone). Roadside survey was carried out, and farmers' fields were randomly assessed depending on the availability of bread wheat fields at an interval of every 5-10 km with odometer readings. A Mixed farming system is the main occupation of the farmhouse holds. The surveyed districts are known for their high wheat yield potential.

2.2. Disease Assessment

For A total of 120 fields were assessed for Septoria leaf blotch incidence and severity. The field survey was conducted once at different growth stages of the wheat crop. In each field, data were recorded by walking along the two diagonals of wheat fields in "X" pattern. Exactly ten randomly selected plants were considered at five spots of 1m×1m (1m^2) quadrat sample area to determine the disease severity and incidence and the average of the five quadrats was used for analysis.

During the field survey several parameters, including disease prevalence, incidence, severity, and agronomic data as follows:

$$\text{Disease prevalence (\%)} = \left(\frac{\text{Fields being infected by SLB}}{\text{Total fields observed}}\right) \times 100$$

Septoria tritici blotch severity was assessed using the modified disease severity scale (double-digit, 00–99) (Saari and Prescott,1975).

Table 1. Categorization of variables used for logistic regression analysis of SLB (n=120) in western Amhara, Ethiopia, during main cropping season (2017)

Variable	Variable class	Total No. of Fields	Incidence		Severity	
			≤50%	>50%	≤25%	>25%
Variety	Local	15	8	7	10	5
	Improved	105	37	68	78	27
	Farta	14	2	12	8	6
	Lay Gayint	12	6	6	8	4
	Burie	13	12	1	13	0
District	Wonberima	13	3	10	12	1
	Yilmana Densa	15	6	9	9	6
	Hulet Eju Enese	10	4	6	10	0
	Goncha Siso Enese	13	5	8	10	3
	Baso Liben	15	2	13	6	9
	Debre Elias	15	5	10	11	4
Altitude	>2500masl	23	11	28	28	11
	1500-2500masl	97	31	50	61	20
Sowing Date	Late May	7	3	4	2	5
	Early June	16	4	12	11	5
	Late June	20	10	10	15	5
	Early July	42	10	32	29	13
	Late July	35	18	17	30	5
Soil type	Light sandy	19	12	7	16	3
	Red soil	98	31	67	70	28
	Black soil	3	3	0	3	0
Previous crop	Barley	8	2	6	4	4
	Teff	38	14	24	31	7
	Maize	32	14	18	26	6
	Wheat/Triticale	20	2	18	12	8
	Legumes	6	5	1	4	2
	Oil Crops	5	4	1	4	1
	Potato	8	3	5	5	3
	Pepper	3	2	1	3	0
Weed density	High (>61/m^2)	29	7	22	15	14
	Medium (41-60/m^2)	48	15	33	38	10
	Low (<40/m^2)	42	24	18	34	8
Population density	High (>210/m2)	71	20	51	52	19
	Medium (141-210/m^2)	39	23	16	32	7
	Low(<140/m^2)	10	4	6	5	5
Cropping system	Sole	116	43	73	86	30
	Mixed	4	3	1	4	0

Disease Severity (%)= (D1/9 ×D2/9) ×100

where D1 indicates disease progress in plant height (the relative height of the disease) and the D2 denotes as the severity of diseased leaf area.

Agronomic (cultural) practices were recorded, In addition to the disease intensity data, from each field to analyze their association with Septoria leaf blotch. Variety(ies) grown whether local or improved, previous crop (barley, maize, *tef*, wheat/triticale, legumes, oil crops, pepper and potato) and planting date (late May, early June, late June, early July, or late July) were collected through interview with farmers, filling structured questionnaires and visual assessment. The average of five quadrats (1m^2) of wheat population [high (>210 plants/m^2), medium (140-210 plants/m^{2}and low (<140 plants/m^2)] and weed density [low (<40/m^2), medium (41-60/m^2) and high(>61/m^2)] (Getaneh et al., 2006; Bogale and Amare, 2014) were taken. Altitudes: high altitude (>2500) or mid-altitude (2500-1500) m.a.s.l. of each field was measured using Global Positioning System (GPS). Soil types (whether black, light sandy or red soil) were recorded in each field and the cropping system (whether sole crop or mixed cropping) was recorded in each farmer's field..

2.3. Statistical Data Analysis

In Field survey data were analyzed using SAS 9.0 version software (SAS. 2002) for the disease intensity levels, and the incidence and severity were associated with the independent variables, using the logistic regression model by forming binomial data. The logistic regression model assesses the importance of multiple independent variables that affect the response variable. It calculates the probability of a given binary outcome as a function of the independent variables. The binary outcome was the probability that SLB severity exceeds 25% and incidence exceeds 50% (Table 1) in each wheat field based on Bogale and Amare (2014). Exponentiation of the parameter estimates of each variable class results the odds ratio, indicating the relative risk. The SAS procedures GENMOND and logistic were used to estimate the parameter estimates (McCullagh and Nelder, 1989). The chi-square test was used to detect significant differences among the treatments.

3. Results and Discussion

3.1. Prevalence and distribution of Septoria leaf botch in Western Amhara

Septoria leaf blotch infected fields attributed about 96.7% out of the total 120 fields assessed, at different crop growth stages across the nine districts. Only four fields (3.33%) were found free from Septoria leaf blotch infection. This result implicated that Septoria leaf blotch is observed to be the most distributed diseases during main cropping season of the year 2017. The reason for the high prevalence of the disease might be due to the frequent cultivation of early sown susceptible varieties, like Kakaba and local varieties, which was initial source of inocula, and favorable environmental conditions for the development and spread of disease. Similarly, Wallelign et al. (2014), indicated that Septoria leaf blotch was the most aggressive disease in all assessed bread wheat fields of South Gondar, East Gojjam, Awi and West Gojjam. These results are also in line with the observation of Endale and Getaneh (2015). They reported that there was 100% SLB distribution/prevalence in Southwest and West Shewa Zones of Oromia Regional State, Ethiopia. Similar studies in Bale wheat-producing areas, Oromia regional state, Ethiopia indicated that Septoria leaf blotch reported to be the first distributed disease across the surveyed regions (Kasa et al., 2015).

3.2. Septoria leaf botch Incidence and Severity

The incidence of Septoria leaf blotch in western Amhara ranged from 0 to 100% (Table 2). Of the surveyed 120 fields, 46 fields (38.33%) had less than or equal to 50% incidence and 74 fields (61.67%) had more significant disease incidence (> 50%). Only four fields had no infection by Septoria leaf blotch. Overall mean incidence over local and improved bread wheat varieties varied from 82.23% in the local varieties to 64.90% in improved varieties (Table 3).

In South Gondar Zone the mean incidence was 49.66%, while 90.17%) mean incidence was recorded in Farta. In Western Gojjam, the mean incidence of Septoria leaf blotch was 33.69,84.30 and 69.93%, in Burie, Wonberima, and Yilmana Densa, respectively.

Table 2. Logistic regression modeling of wheat Septoria leaf blotch incidence and severity for eight independent variables as single predictor of disease outcome

Independent Variables	Septoria leaf blotch incidence				Septoria leaf blotch severity		
	Df	Deviance	χ2	Pr>χ2	Deviance	χ2	Pr>χ2
1. Altitude	1	7150.63	2.59	0.1078	1929.74	17.46	<.0001
2. Sowing date	4	6803.23	347.4	<.0001	1779.42	150.32	<.0001
3. Variety	1	6794.72	8.51	0.0035	1767.74	11.68	0.0006
4. Soil type	2	6026.07	768.65	<.0001	1625.85	141.89	<.0001
5. Previous crop	7	5309.06	717	<.0001	1445.39	180.46	<.0001
6. Weed density	2	4772.12	536.95	<.0001	1280.68	164.71	<.0001
7. Population density	2	4226.5	545.62	<.0001	1153.03	127.65	<.0001
8. Cropping system	1	4205.07	21.43	<.0001	1148.16	4.87	0.0273

Table 3. Minimum, maximum and mean incidence (%) and severity (%) of septoria leaf blotch for different independent variables in western Amhara in 2017 cropping season

Variable	Variable class	Fields assessed	Incidence (%) Min.	Max.	Mean	SD	Severity (%) Min.	Max.	Mean	SD
Variety	Local	15	40	100	82.13	22.48	2.47	59.26	20.74	13.34
	Improved	105	0	100	64.9	33.39	0	79.01	17.85	16.07
	Farta	14	40	100	90.71	20.17	8.64	49.38	25.13	15.5
	Lay Gayint	12	0	100	49.66	33.7	0	59.26	19.85	19.37
District	Burie	13	0	100	33.69	26.84	0	18.52	5.31	5.07
	Wonberima	13	32	100	84.3	25.67	3.7	37.04	14.33	9.46
	Yilmana Densa	15	0	100	61.93	38.12	0	49.38	17.44	16.48
	Hulet Eju Enese	10	30	100	60	23.09	2.47	18.52	10.12	5.9
	Goncha Siso Enese	13	10	100	60.61	27.59	1.23	43.21	15.19	11.96
	Baso Liben	15	40	100	82.66	21.86	8.64	79.01	30.61	17.86
	Debre Elias	15	10	100	72.66	34.11	1.23	59.26	20.16	18.01
Altitude	(>2500)	39	0	100	67	31.98	0	59.26	20	15.82
	(1500-2500)	81	0	100	66.23	32.52	0	79.01	17.23	15.71
Sowing Date	Late May	7	20	100	62.28	31.46	3.7	59.26	31.04	21.27
	Early June	16	0	100	73.93	37.38	0	49.38	22.45	17.65
	Late June	20	10	100	75.7	32.58	2.47	43.21	14.25	10.95
	Early July	42	0	100	75.71	25.58	0	79.01	19.57	15.63
	Late July	35	0	100	59.82	36.55	0	59.26	13.82	14.84
Soil type	Light sandy	19	0	100	45.68	32.81	0	39.51	12.99	11.86
	Red soil	98	0	100	72.64	30.29	0	79.01	19.46	16.34
	Black soil	3	10	30	20	10	3.7	6.17	4.52	1.42
Previous crop	Barley	8	10	100	77.5	34.94	6.17	59.26	27.31	19.86
	Tef	38	0	100	67.47	29.21	0	44.44	15.2	16.61
	Maize	32	0	100	65.46	33.31	0	49.38	14.65	13.64
	Wheat/Triticale	20	20	100	85.5	23.05	2.47	79.01	26.23	17.58
	Legumes	6	0	100	34.33	37.21	0	39.51	16.25	18.23
	Oil Crops	5	10	100	46	33.61	1.23	49.38	14.07	19.87
	Potato	8	0	100	59	35.64	0	59.26	22.68	23.05
	Pepper	3	20	100	50	43.58	3.7	18.52	9.46	7.93
Weed Density	High (>61/m^2)	29	0	100	78.93	27.03	0	59.26	26.21	17.54
	Medium (41-60/m^2)	48	0	100	73.75	29.15	0	79.01	18.05	15.32
	Low (<40/m^2)	42	0	100	50.92	34.4	0	49.38	12.25	12.4
Population density	High (>210/m^2)	71	10	100	76.14	26.89	1.23	79.01	20.46	16.14
	Medium (141-210/m^2)	39	0	100	50.79	33.13	0	49.38	12.47	12.31
	Low(<140/m^2)	10	0	100	66	45.26	0	49.38	22.84	20.59
Cropping System	Sole	116	0	100	67.43	32.81	0	79.01	18.13	16.02
	Mixed	4	36	100	56	29.75	8.64	24.69	16.05	7.05

Max, Maximum; Min, Minimum; SD, Standard Deviation

The mean incidence in East Gojjam zone ranged from 60.00% in Hulet Eju Enese to 82.66% in Baso Liben. High Septoria leaf blotch incidence was recorded from Baso Liben,Farta and Wonberima districts as compared to other districts, which had lower Septoria leaf blotch incidence (Table 3). This variation could be probably due to the prevailing favorable temperature and rainfall and the use of monocultural system of wheat after wheat production without rotation, which is conducive and a source of inocula for Septoria leaf blotch development. Similarly, Shaw and Royle (1993 and Lovell et al. (2004) indicated that variable periods of rainfall are critical factors in disease initiation and development.

The highest incidence of the disease was recorded from fields at higher altitudes (>2500 masl.) than on mid altitudes (1500-2500 m.a.s.l.) (Table2). Among the wheat fields surveyed for Septoria leaf blotch, the lowest (62.8%) incidence was recorded from fields sown in late July. Bailey et al. (2001) also reported that late sowing was associated with the higher grain yield and reduced infection of Septoria leaf blotch.

Fields with red soil types, wheat/ triticale rotated fields, high weed density, high wheat population density, and sole cropping wheat fields as compared with their counter variable classes (Table 2). Similarly, Fakhfakh etal. (2009) highlighted susceptible cultivars, also climatic conditions favorable for disease spread. Moreover, certain set of cultural practices were also listed among the major factors causing significant grain yield losses due to Septoria leaf blotch. Burdon and Chilvers (1982) reported that dense stands contributed to severe Septoria leaf blotch epidemics and they argued that higher plant densities (population densities) would provide a micro-environment more conducive to the disease development than optimal planting densities.

Among the surveyed wheat fields, the lowest (17.85%) disease severity was recorded in improved bread wheat varieties and the highest (20.74%) mean severity was recorded in local or farmers' varieties. Among the surveyed districts, the minimum mean severities of 5.31 and 10.12% were recorded in Burie and Hulet Eju Enese districts, respectively. In contrast, the highest mean severities of 25.13 and 30.61% were observed in Farta and Baso Liben districts, respectively (Table 2). This might be because these districts used the same variety (Kakaba) every year without change and perhaps the variety might has lost its resistance. Similarly, the use of crop rotation with other non-cereals is poorly practised in these districts; and in Farta, the rainfall and RH conditions were optimum for SLB epidemics (Table 3).

The least (17.23%) mean Septoria leaf blotch severity was recorded in wheat fields sown at the mid (1500-2500 m.a.s.l.) altitudes and wheat fields planted in late June (14.25%) and late July (13.82). Contrarily, the highest SLB severity was recorded from fields sown in late May and early June (Table 2). Wheat crop grown in red soils, fields rotated with barley and wheat/triticale, with high weed population (>61/m^2), increased plant population (>210/m^2) and sole cropping system had the mximum disease severity as compared to their respective variable classes, observed in the surveyed districts (Table 2). Similarly, Shaner et al. (1975) and Shaw and Royle (1993) reported that early sowing gives more time for infection and multiplication or development of SLB. Gladers et al. (2001) also concluded a higher risk of Septoria leaf blotch severity periods was greatly affected by early sowing in England. Lebon et al. (2012) also reported that mixed cropping system served as a physical barrier to spore dispersal or microclimatic changes. Simón et al. (2003, 2005) reported that higher SLB incidence and severity had been attributed to an increased level of primary inoculum of SLB from previous cereal crops, mainly under prevalence of favorable conditions.

3.3. Association of Independent Variables with the Disease Intensity

The association of the independent variables, namely variety, altitude, sowing date, population density, weed density, soil type, previous crop and cropping system with incidence and severity of Septoria leaf blotch was highly significant as Pr> χ2 is <0.001. However, altitude for SLB incidence was not highly significant as Pr> χ2is >0.001for SLB incidence (Table 2), indicating independent variables as risk factors. However, different variable classes exhibited different levels of risk due to Septoria leaf blotch incidence and severity. For added variables parameter estimates, analysis of deviance, standard errors as a result of reduced regression model (Table 4 and 5). This study revealed that Septoria leaf blotch severity was highly associated with higher (>2500 m.a.s.l.) altitudes than lower elevation. As the odd ratio indicates, there were about 1.44 times higher probabilities that SLB severity exceeds 25% in higher altitudes (>2500m.a.s.l.) than lower altitudes (Table 4). The finding in this current study agrees with another investigation made by Abera et al. (2015) who indicated that the intensity of disease increased in higher altitudes than in mid altitudes.

There were also high associations of early sowing dates with Septoria leaf blotch incidence and severity. There were 9.80- and 6.89-times higher probabilities that SLB incidence exceeds 50% in late May and early June sown fields and 10.11- and 3.32-times higher probabilities that SLB severity exceeds 25% in late May and early June sown fields than other planting dates. (Table 4 and 5). The result presented here are in agreement with the findings of Shaw and Royle (1993). They concluded that early crop sowning resulted in the production of more leaves, leading to greater chances of inocula presence. Similarly, Shaneret al. (1975) and Lovell et al. (1997 2004) also confirmed that early sowing gives more time for the infection and multiplication to move between leaf layers from older to younger leaves. On the other hand, Eshetu and Zerihun (2003) also supports that late sowing significantly reduces Septoria development, though severity may not affect on kernel weight and grain yield.

Soil types also found to influence incidence of Septoria leaf blotch. The incidence and severity of

Septoria leaf blotch were positively associated with red soil types compared to light sandy and black soils (Table 4 and 5). The parameter estimates resulting from the reduced regression model, indicating high SLB incidence (>50%), had a high probability of association to red soils. There were 17.50 times more chances that SLB incidence exceed 50% (Table 4). Similarly, SLB severity was significantly associated with soil types, 1.82 times higher probabilities that the SLB severities exceeds 25% in red soils than in black and light sandy soils (Table 2). In this regard, Walters and Bingham (2007) discussed that soil factors, such as organic matter, nutrients, soil pH and similar others, have an impact on grain yield, plant disease and their interactions. It is also in line with the finding of Shaw, and Royle (1993) who reported that the availability of moisture in red soils due to high water holding capacity favors disease development.

Septoria leaf blight intensities had direct correlation with preceding or previous crops (Table 4). Disease severities were higher on wheat fields where wheat fields were preceded by cereals (such as wheat and barley). This might be due to infected stables or residues of previous wheat crops that served as source of ascospores for infection. There were 3.11- and 2.08-times higher probabilities in wheat fields that SLB severity exceeds 25% in fields rotated with barley and wheat, respectively, as compared to fields rotated with legume and oil crops (Table 4). These results were consistent with finding of Shaw and Royle (1989) who indicated that infected crop residues and volunteer wheat plants were important sources of primary inoculum pycnidiospores that survive in pycnidia on infected stubble for several months**.** Abera et al. (2015) have also reported high (100%) disease incidence and severity (70%) on wheat sown after cereals, while low (45%) severity on wheat fields sown after oil crops.

Weed population had an influence on the intensity of SLB. Septoria leaf blotch that had a high association with high (>61/m^2) weed density. This could be due to an increase of relative humidity on the crop microclimate, which favors the pathogen and their competition for available soil nutrients. This agrees with the observation of Samuel et al. (2008) who stated that higher weed density results in increased level of chocolate spot disease (*Botrytis fabae*) of faba bean. Other study also conluded that dense weed population may contribute to disease development through increased plant population density, resultant charectristics of plant canopy can favor the accumulation of inoculum, even in the absence of the susceptible host (Duczek et al., 1996).

According to the result of the present study, SLB incidence and severity had a direct association with plant population (Table 4 and 5). There were 2.61 and 1.46 times greater SLB incidence and severity that exceed 50 and 25%, respectively, as compared to the medium (optimum) population. More significant disease development at higher plant density might be due to a more favorable microclimate produced within the leaf canopy than that produced at the lower densities. This is in line with a previous observation made by Chemeda and Yuen (2008) who reported that low maize rust incidence is associated with low maize population. Similarly, Tompkins et al. (1993) reported that high seedling rates and narrow spacing creates a favorable microclimate for the development of *Stagonospora nodorum* blotch and *Septoria tritici* blotch. In contrast, Rodgers and Shaw (2000) showed that reduced plant density in the field increased nutrient availability and aggravating the disease. Similarly, Shaw and Royle (1993) reported that reduced plant density increased the dispersal ability of SLB spores by rain splash.

Table 4. Logistic regression modeling of wheat Septoria leaf blotch incidence and severity for eight independent variables as single predictor of disease outcome

Independent Variables	Df	Septoria leaf blotch incidence			Septoria leaf blotch severity		
		Deviance	χ2	Pr>χ2	Deviance	χ2	Pr>χ2
Altitude	1	7150.63	2.59	0.1078	1929.74	17.46	<.0001
Sowing date	4	6803.23	347.4	<.0001	1779.42	150.32	<.0001
Variety	1	6794.72	8.51	0.0035	1767.74	11.68	0.0006
Soil type	2	6026.07	768.65	<.0001	1625.85	141.89	<.0001
Previous crop	7	5309.06	717	<.0001	1445.39	180.46	<.0001
Weed density	2	4772.12	536.95	<.0001	1280.68	164.71	<.0001
Population density	2	4226.5	545.62	<.0001	1153.03	127.65	<.0001
Cropping system	1	4205.07	21.43	<.0001	1148.16	4.87	0.0273

The present study demonstrates the effect of cropping system on SLB disease incidence. Mixed cropping system had shown less probability of being infested by SLB (Table 4). There were 1.96- and 1.41-times higher probabilities that SLB incidence exceeds 50% and severity exceeds 25% respectively in sole cropping fields than mixed wheat fields. Inhibition of disease severity in mixed cropping systems may be attributed to either altered microclimatic conditions or barrier effect. Similarly, Lebon et al. (2012) reported that a substantial reduction of severity of SLB was assessed on wheat-pea intercrops. Similarly Malezieux et al (2009) indicated that mixed species cropping, are important tool for pest and disease management particularly row intercropping and strip intercropping, by physical barrier to spore dispersal or microclimatic changes within the intercrop canopy.

4. Conclusion

Despite the importance of bread wheat production in Ethiopia, particularly in Western Amhara, is limited by abiotic and biotic factors. Septoria leaf blotch is one of the major leaf pathogens that constrained wheat production in the study areas. This study was designed to investigate association Septoria leaf blotch with biophysical conditions and cultural practices, and to draw possible recommendations for further Septoria leaf blotch integrated management. According to the data generated by main season disease survey during 2017, revealed that Septoria leaf blotch is an important potential disease constraining rainfed wheat production in western Amhara in wheat producing areas. The disease was widely distributed in all surveyed districts of western Amhara. Different independent variables (cultural practices) were observed to influence Septoria leaf blotch incidence and severity. According to the logistic regression model, varieties, plant populations, previous crops, soil types, weed densities and cropping systems significantly affected disease incidence and severity however, altitude was not significantly associated with the disease incidence. So, the findings of the current study indicate the need to undertake different cultural practices, including late sowing, rotating with non-cereal crops (legumes) and mixed cropping system for the integrated management of Septoria leaf blotch. However, detailed field surveys and due research attention should be given to find the mechanisms of variability of the pathogen and its existing physiological races.

List of Abbreviations: CSA: Central Statistical Authority; RH: Relative Humidity; SLB: Septoria Leaf Blotch.

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References

AARC (Adet Agricultural Research Center). 2000. Progress report. Bahir Dar, Ethiopia.

Abera, T., L. Alemu, K. Bekele, W. Getaneh and H. Endale. 2015. Estimated yield loss assessment of bread wheat (*Triticum aestivum* L.) due to Septoria leaf blotch *Septoria tritici* (Roberge in Desmaz) on wheat in Holetta Agricultural Research Center, West Shewa, Ethiopia. Res. Plant Sci. 3(3): 61-67.

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

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

Bailey, K.L., B.D. Gossen, G.P. Lafond, P.R. Watson and D.A. Derksen 2001. Effect of tillage and crop rotation on root and foliar diseases of wheat and pea in Saskatchewan from 1991 to 1998: Univariate and multivariate analyses. Canadian J. Plant Sc.81: 789-803.

Bogale, N. and A. Amare. 2014. Epidemiological factors of Septoria leaf blotch (*Mycosphaerella graminicola*) on durum wheat in the highlands of Wollo, Ethiopia. *In* Tilahun Tadesse and Yeshitla Merene (Eds), 2014. Proceedings of the 6th and 7th Annual Regional Conference on Completed Crops Research Activities, Amhara Agricultural Research Institute, Bahir Dar, Ethiopia.

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: 111-122.

Burdon, J.J. and G.A. Chilvers. 1982. Host density as a factor in plant disease ecology. Ann. Rev. Phytopathol. 20: 143-166.

Chemeda, F. and J. Yuen. 2008. Associations of maize rust and leaf blight epidemics with cropping system in Hararghe highlands, Eastern Ethiopia. Crop Prot. 20: 669-678.

Chouhan, S.S., U.P. Singh and S. Jain. 2020. Applications of computer vision in plant pathology: A survey. Arch. Computat. Methods Eng. 27:611–632.

CSA (Central Statistical Agency). 2019. Agricultural sample survey 2018/2019 volume I. Report on area and production of crops (private peasant holdings, Meher season). Statistical Bulletin 589.CSA, Addis Ababa, Ethiopia.

Curtis, B.C. 2002. Wheat in the world. *In:* FAO, 2002. Bread wheat improvement and production. FAO, Rome, Italy. 554 pp.

Dean, R., Van Kan, J., Pretorius, Z., Hammond-Kosack, K., Di Pietro, A., Spanu, P., Rudd, J., Dickman, M., Kahmann, R., Ellis, J. and Foster, G. 2012. The top 10 fungal pathogens in molecular plant pathology. Mol. Plant Pathol.13: 414-430.

Duczek, L.J., L.L. Jones-Flory, S.L. Reed, K.L. Bailey and G.P. Lafond. 1996. Sporulation of *Bipolaris sorokiniana* on the crows of crop plant grown in Saskatchewan. Canadian J. Plant Sci. 76: 861-867.

Endale, H. and W. Getaneh. 2015. Survey of rust and Septoria leaf blotch diseases of wheat in central Ethiopia and virulence diversity of stem rust, *Puccinia graminis*f.sp. *tritici*. Adv. Crop Sci. Technol. 3: 166.

Eshetu, B. 1986. Review of research on diseases of barley, tef, and wheat in Ethiopia. *In*: Abreham Tadesse (ed.). Increasing crop production through improved plant protection. 1: Pp. 381-385.

Eshetu, B. and K. Zerihun. 2003. Integrated management of Septoria blotch of wheat: effects of sowing date, variety, and fungicide. Pest Manag. J. Ethiopia. 7: 11-18.

Eyal, Z., A.L. Scharen, J.M. Prescott, and M. van Ginkel. 1987. The Septoria diseases of wheat: Concepts and methods of disease management. CIMMYT, Mexico, D.F.63:1087-1091.

Fakhfakh, M.M., S. Rezgui, K. Mhedhbi, A.H. Yahyaoui and B. Nasraoui. 2009. Effect of semino therapy, fungicide-herbicide mixture foliar treatment, and cropping density on Septoria leaf blotch and durum wheat production. Tunisian J. Plant Prot. *4: 41-55.*

Getaneh, W., J. Yuenb, F. Chemeda and H. Singh. 2006. Barely leaf rust (*Puccinia hordei* Otth) in three production systems and practices in Ethiopia. Crop Protect. 26: 1193-1202

Gibson, L. and G. Benson. 2002. Origin, history, and uses of Oat (*Avena sativa*) and Wheat (*Triticum aestivum*). Iowa State University, Department of Agronomy.3p

Gladers, P., N.D. Paveley, I.A. Barrie, N.V. Hardwick, M.J. Hims, S. Langton and M.C. Taylor. 2001. Agronomic and meteorological factors affecting the severity of leaf blotch caused by *Mycosphaerella graminicola* in commercial wheat crops in England. Ann. Appl. Biol. 138: 301-311.

KARC (Kulumsa Agricultural Research Center). 2005. Progress report for/2005.pp381-385. *In*: Abreham Tadesse (ed.). Increasing Crop Production through Improved Plant Protection – Volume I. Plant Protection Society of Ethiopia (PPSE), 19-22 December 2006. Addis Ababa, Ethiopia. PPSE and EIAR, Addis Ababa, Ethiopia. 598 pp.

Kasa, D., H. Bekele and D. Worku. 2015. Distribution and occurrence of wheat rusts and septoria leaf blotch in Bale and Arsi Zones, 2014 Belg season. Glob. J. Pests Dis. Crop Protect. 3 (4) 124-130

Lebon, V., C. Gigot, M. Leconte, E. Pelzer, C. de Vallavieille-Pope, and S. Saint-Jean. 2012. Cultivar and species mixture effect on wheat *Septoria tritici* blotch spreading. Paper presented at the International Conference on Epidemiology, Canopy, Architecture, 1–5 July, Rennes, France, 44.

Lovell, D.J., S.R Parker, T. Hunter, S.J. Welham and A.R. Nichols. 2004. Position of inoculum in the canopy. Lucas, J.A. 1998. Plant Pathology and Plant Pathogens. Blackwell Science, Oxford. The risk of *Septoria tritici* blotch epidemics in winter wheat. Plant Pathol. 53: 11-21.

Lovell, D.J., S.R. Parker, T. Hunter, D.J. Royle, and R.R. Coker. 1997. Influence of crop growth and structure on the risk of epidemics by *Mycosphaerella graminicola* (*Septoria tritici)* in winter wheat. Plant Pathol. 46: 126-138.

Malezieux, E., Y. Crozat, C. Dupraz, M. Laurans, D. Makowski, H. Ozier-Lafontaine, B. Rapidel, S. de Tourdonnet, and M. Valantin-Morison. 2009. Mixing plant species in cropping systems:

concepts, tools, and models. Agron. Sustain. Dev. 29 (2009) 43–62.

McCullagh, P. and J.A Nelder. 1989. Generalized linear models (2nd ed.). Chapman and Hall, Chicago, USA. 511 pp.

Mengeistu, H., W. Getaneh, A. Yeshi, D. Rebika and B. Ayele. 1991. Wheat pathology research in Ethiopia In: Hailu Gebremariam, Tanner D.G, and MengestuHuluka (eds). Wheat research in Ethiopia. A historical prospective. Addis Ababa, IAR / CIMMYT. pp173-217.

Merkuz, A. 2017. Agriculture in Lake Tana sub-basin of Ethiopia. *In*: K.Stave, Goraw Goshu and Shimels Aynalem (Eds.).Social and ecological system dynamics, characteristics trends and integration in the Lake Tana Basin, Ethiopia, AESS Interdisciplinary Environmental Studies and Sciences Series, ISBN 978-3-319-45753-6.Springer International Publishing, Swizerland.

Miransari, M. and D. Smith. 2019. Sustainable wheat (*Triticum aestivum* L.) production in saline fields: a review, Crit. Rev. Biotechnol. 39(8): 999-1014

Rodgers, B.S. and Shaw, M.W. 2000. Substantial in winter wheat disease caused by addition of straw but not manure to soil. Plant Pathol. 49: 590-599.

Ruska, P.K., R.A. Buruchara, Gatabazi and M.A Pastor-Corrales. 1997. Occurrence and distributions in Rwanda of soilborne fungi pathogenic to the common bean. Plant Dis. 81:445-449.

Saari, E. E. and J.M. Prescott. 1975. Scale for appraising the foliar intensity of wheat diseases. Plant Dis. Report. 59: 377-380

Samuel, S., A. Seid, F. Chemeda, M.M. Abang and P.K. Sakhuja. 2008. Survey of chocolate spot (*Botrytis fabae*) disease of faba bean (*Vicia faba*L.) and assessment of factors influencing disease epidemics in northern Ethiopia. Crop Protect. 27:1457-1463.

SAS (Statistical Analysis System). 2002. Statistical Analysis System (SAS) Institute,Inc., Cary, NC, USA.

Shaner, G., R.E. Finney and F.L. Patterson. 1975. Expression and effectiveness of resistance in wheat to Septoria leaf blotch. Phytopathol. 65:761-766.

Shaw, M.W. and D.J. Royle. 1989. Airborne inoculum as a major source of *Septoria tritici* (*Mycosphaerella graminicola*) infections in winter wheat crops in the UK. Plant Pathol. 38: 35-43.

Shaw, M.W. and D.J. Royle. 1993. Factors determining the severity of epidemics of *Mycosphaerella graminicola* (*Septoria tritici*) on winter wheat in the UK. *Plant Pathol*.2: 882-899.

Simón, M.R., Cordo, C.A., Perelló, A.E. and Struick, P.C. 2003. Influence of nitrogen supply on the susceptibility of wheat to *Septoria tritici*. J. Plant Pathol. 151: 283-289.

Simón, M.R., Perello, A.E., Cordo, C.A., Larrán, S., Van der Putten, P. and Struik, P.C. 2005 Association between *Septoria tritici* blotch, plant height and heading date, in wheat. Agron. J. 97: 1072-1081.

Tesfaye, Z., T. Girma, D. Tanner, H. Verkuijl, A. Aklilu and W. Mwangi. 2001. Adoption of improved bread wheat varieties and inorganic fertilizer by small-scale farmers in Yelmana Densa, and Farta districts of Northwestern Ethiopia. Ethiopian Agricultural Research Organization (EARO) and International Maize and Wheat Improvement Center (CIMMYT). Mexico.

Tompkins, D.K., D.B. Fowler and A.T. Wright. 1993. Influence of agronomic practices on canopy microclimate and Septoria development in No-till winter-wheat produced in the Parkland region of Saskatchewan. Canadian J. Plant Sci. 73: 331-344

Wallelign Z., B. Muluken, W. Landuber and B. Dereje. 2014. Assessment of wheat disease in western Amhara. *In*: Tilahun Tadesse and Yeshitla Merene (Eds). 2014. Proceedings of the 6th and 7th Annual Regional Conference on Completed Crops Research Activities. Amhara Agricultural Research Institute, Bahir Dar, Ethiopia.

Walters, D.R. and I.J. Bingham. 2007. Influence of nutrition on disease development caused by fungal pathogens and implications on disease control. Ann. Appl. Biol. 151: 307-324.

Zhao, H., C. Yang, W. Guo, L. Zhang, and D. Zhang. 2020. Automatic estimation of crop disease severity levels based on vegetation index normalization. Remote Sens. 12*:* 1930.