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Modelling Septoria Tritici Blotch (Septoria tritici) Disease-Yield Loss Relationship and Determining the Crop Growth Stag Provides Considerable Yield Return for Disease Management

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Abstract
Septoria tritici blotch (Septoria tritici) (STB) is one of the important problems of wheat production in the Ethiopia; including Haddiya-Kambata areas of SNNPR. A field experiment was conducted at Hossana and Angecha in 2012 main cropping season to quantify the relationship between septoria tritici blotch and yield and yield components of bread wheat varieties. Three different spray intervals of propiconazole (Tilt 250 EC) and one unsprayed plot for each of the three varieties (Alidoro, Galama and Gambo) were used to create different STB epidemic levels. Treatments were arranged in randomized complete block design (RCBD) with factorial arrangement in three replications. Severity on all leaves (i.e. the leaves except flag leaf) and on flag leaf was recorded independently at weakly interval since the onset of disease. The respective host growth stage at the time of disease assessment was used to describe the weekly disease assessment included in the model, so that yield loss was associated with disease severity at particular plant growth stages. The F- statistics was used to test the significance of the overall relationship ($p<0.05$) and the coefficient of determination (R^2) was computed to determine the proportion of the variation in yield loss explained by the disease variables (predictors) in the model. As the result this study, Yield and yield components negatively correlated with severity recorded on different plant growth stage at weekly intervals. On all tested varieties, STB developed after growth stage (GS) of 70 was strongly related with yield losses. After this growth stage, the grain yield loss of 12.35 to 23kg per hectare incurred for each of 1% increase of Septoria tritici blotch severity. Therefore, managing STB development before GS 70 provides better yield return.
Keywords: wheat, Septoria tritice blotch, severity, loss

1. INTRODUCTION

Wheat is an important cereal crop in Ethiopia. It is widely cultivated in altitude ranging from 1500 to 3000 m.a.s.l. The most suitable area, however, falls between 1700 and 2800 m.a.s.l (Hailu, 1991; Bekele *et al*., 1994; Ethiopan ATA, 2013). Its production and productivity has increased from time to time in Ethiopia. But, national productivity is less than the world average productivity (FAOSTAT, 2009).

This low average productivity is because of the frequent abiotic and biotic stresses that are occurring during critical growth stages of the crop. Among the most biotic stresses, *Septoria tritici blotch (*STB) caused by *Septoria tritici* (teleomorph: *Mycosphaerella graminicola*) is one of the major leaf disease (Eshetu, 1986; Mengistu *et al*., 1991: as cited in Abreham, 2008; Ethiopian ATA, 2013). It is widely distributed over all wheat growing areas. Its severity reaches up to 78% with fastest progress rate (0.074gompit/day) on susceptible variety (Alemar and Temam, 2016). Based on survey result the yield loss of wheat at hot spot areas on susceptible varieties due to this disease reach up to 82% (Eshetu, 1986; Mengistu *et al*., 1991: in Abreham, 2008).

With this problem, the relationship between *Septoria tritici* blotch development and its effect on grain yield is not well known. To determine critical wheat growth stage at which *Septoria tritici* blotch management return considerable yield return, understanding the relationship between disease development and its yield effect need to be known precisely. Therefore, the objective of this study was to modeling disease- yield loss relation and to determine the crop growth stag at which disease management strategy give considerable yield return.

2. MATERIALS AND METHODS

2.1. Experimental Site

The experiment was conducted at two research sites; Angecha and Hossana. Both of which represent the high lands of major wheat production areas of Southern Nations Nationalities and peoples Region (SNNPR) of Ethiopia with high rainfall and are expected to be the suitable environment (hot spot) of the disease (Fikre, 2010). Hosanna site is found in Haddiya Zone which is located at 7°34’ 04’’ N and 37°51’22’’ E at about 2306 meters above sea level (m.a.s.l). It receives an average annual rainfall of 1153 mm. The monthly average minimum and maximum temperatures are 10.3^{0}C and 23ºC, respectively.

The dominant soil type is nitosol and slightly acidic. It belongs to the sub humid agro climatic zone (http://mapcarta.com/ April, 2012). Angecha site is found in Kambata Tembaro Zone which is located at 7^{o}20' N and 37^{o}51'E at about 2320 m.a.s.l. It belongs to the sub-humid agro-climatic zone. Its average annual rainfall ranges from 1000-1200 mm. The dominant soil type is luvisol (ArARC, 2006).

2.2. Experimental Materials and Treatments

The experiment was conducted using three bread wheat varieties (Alidoro,Galama and Gambo) that are moderately resistant, moderately susceptible and susceptible to *Septoria tritici* blotch and relatively resistant to other diseases like wheat rusts (Ethiopian crop registration directory of 1995, 2005 and 2011). Multiple levels of *Septoria tritici* blotch epidemics had been created in experimental plots through the application of propiconazole (Tilt 250 E.C.) at different intervals of time. Tilt is a systemic fungicide effective against almost all cereal fungal diseases. The fungicide was applied at a rate of 0.5 l/ha (125 g a.i. ha^{-1}) in three different spray schedules viz., every 10, 20 and 30 days. The base for selection of 10 days intervals was relatively long latent period (14-21 days) of STB (Eyal *et al*., 1987; Shaw, 1990). The ten-day sprayed treatment had been started immediately as *Septoria tritici* leaf blotch symptom appeared; on 03 and 17 of September 2012 at Hossana and Angecha, respectively. The 20 and 30-day spray interval treatments started two and three weeks after onset of disease, respectively. Then spraying continued at the specified intervals until the crop attained its physiological maturity. Unsprayed plots were included for each variety to allow maximum *Septoria tritici* blotch development for comparison of the effect of disease levels on different parameters.

2.3. Experimental Design and Treatment Management

The experiment was laid out using Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. There were a total of 12 treatments of combinations of three levels of varieties and four levels of fungicide spraying frequencies. Each plot was consisted of 6 rows of 5 m length. The space between rows, plots and replications had been 0.2 m, 1 m and 2 m wide, respectively. Seed rate of 150 kg/ha, which is recommended for the area, had been used. Fertilizers at a rate of 23 kg/ha N and 46 kg/ha P_2O_5 were applied during planting and weeds controlled by hand weeding. Planting was done in July 20 and 23 / 2012 at Hossana and Angecha, respectively on previous year wheat cultivated field to increase inoculum potential. At both locations the land was ploughed four times by oxen.

To ensure uniform spread of inoculum and sufficient disease development, infector plants consisting of a mixture of different susceptible bread wheat varieties (Gambo and Galama) were bordered the plots perpendicular to rows of the plot by spreading row on both ends of the plots. During fungicide sprays, plastic sheet was used to separate the sprayed plots from the adjacent plots in order to prevent inter-plot interference due to spray drift. This was achieved by covering the adjacent plots using plastic sheet fitted on the wooden poles at the time of spraying.

2.4. Data Collection

2.4.1. Disease data

Septoria tritici blotch severity was assessed on 10 randomly selected pre-tagged plants per plot at weekly interval from the time of disease appeared until the crop attained its physiological maturity. Severity on flag leaf was recorded independently. The average severity from the 10 plants per plot was used for analysis. During disease assessment, the growth stage of the crop was recorded to correlate the level of disease severity at a particular growth stage with yield loss in kg/ha. Crop growth stage was assessed based on the decimalized key developed by Zadocks *et al.* (1974). STB severity was scored visually using a double-digit (00 to 99), modified version of Saari and Prescott's scale (Eyal *et al*. 1987; Saari and Prescott, 1975.) 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. In addition to disease data yield and yield component data was collected at appropriate time. For each score, percentage of disease severity was estimated based on the following formula:

% Severity = $(D1/9) \times (D2/9) \times 100$ (Saari and Prescott, 1975)

2.5. Data Analysis

2.5.1. Modelling disease-yield loss relationships

Disease severity scored at weekly intervals (independent variables) and all yield and yield components data (dependent variables) were subjected to stepwise regression analysis to identify severity scored at which particular growth stages (GS) can significantly contribute in yield losses and determine the model. Again, severity scored at weekly intervals and grain yield & yield components data were subjected to Pearson correlation to explain the degree of their relationship based on correlation coefficient (r) value. Based on the results of stepwise regression analysis, to predict grain yield loss on Alidor and Galama critical point (CP) model was developed using disease severities recorded at growth stages of 75 on all leaf and 73 on flag leaf, respectively. But, to predict grain yield loss on variety Gambo multiple points (MP) model was developed using disease severities recorded at growth stage of 70.8 on all leaf and 71 on flag leaf. The respective host growth stage at the time of disease assessment was used to describe the weekly disease assessment included in the model, so that yield loss was associated with disease severity at particular plant growth stages. The F- statistics was used to test the significance of the overall relationship ($p<0.05$) and the coefficient of determination (R^2) was computed to determine the proportion of the variation in yield loss explained by the disease variables (predictors) in the model.

3. RESULTS AND DISCUSSION

The experiment was planted in July 20, and 23 2012, at Hossans and Aangecha, respectively. It was harvested at the beginning of December 2012 at both locations. During the cropping season, intensity of the rainy was high up to the end of September and then it became very low at the latter growth stage of the crop. At both locations in the experimental field early leaves maturity was observed. This is might be the combined effect of shortage of rain fall and STB infestation of the field by STB.

3.1. Correlation Among Severity at Different Day After Planting and Grain Yield And Yield Components

Correlation analysis showed that, *Septoria tritici* blotch severity and most agronomic parameters at both locations on all varieties were negatively correlated (Table 1-6). This is agreed with idea of "there is high negative correlations between wheat crop yield and *Septoria tritici* blotch (Tamar, 1981; Vrapi, 2012).

At Hossana on variety Alidoro, days to maturity was negatively correlated with severity scored on flag leaf after 80 DAP with correlation coefficient ranging from -0.248 to -0.337. But, on all leaves it showed negative correlation with severity scored on 87, 94 and 101 DAPs having correlation coefficient of -0.006, -0.039 and -0.375 respectively (Table 1). On this variety, correlation of days to maturity with severity assessment made from all leaves at weekly interval was non-significant at both Angecha and Hossana (Table 1 & 4).

On variety Alidoro, *Septoria tritici* blotch assessment made on all leaves on 87, 94, and 101 DAPs were significantly negatively correlated with spike length with correlation coefficient (*r)* of -0.641, -0.679, and -0.697 respectively at Hossana. Number of kernels per spike also showed significantly negative correlation with severity scored on DAP 73 ($r = -0.575$) on all leaves and beginning from 80 to 101 DAPs on flag leaves (Table 6). This showed that number of kernels per spike can largely affected by *Septoria tritici* blotch severity at later stage. Severity recoded at the whole DAPs at weekly interval, except 45 and 52 showed significantly negative correlations with biomass weight. However, the test weight of this variety showed negative correlation with severity recorded onwards 52 DAP, it was less significant. Again although it was non significant; at $p \leq 0.05$, severity recorded on wards 73 DAP showed negative correlation with harvest index (Table 1). *Septoria tritici* blotch Severity recorded on all dates at weekly intervals showed negative correlation with grain yield. But, significant negative correlation was been with severity recorded beginning from 73 DAP for the whole scoring dates on both all and flag leaves. The maximum correlation coefficient $r = -0.747$ for DAP 101 on all leaves (Table 1).

On Galama at Hossana, severity recorded on the whole recording dates beginning from 73 DAP on all leaves and flag leaf showed significant negative correlation with days to maturity; with the range of -0.655 to -0.765 correlation coefficient (Table 2). Spike length showed negative correlation with *Septoria tritici* blotch severity scored on all scoring dates, except the first three on all leaves, but it was non significant at $p \leq 0.05$. STB Severity scored on all DAPs showed non significant negative correlation with number of tillers per meter square. Number of spike per meter square of Galama showed significantly negative correlation with severity scored starting from 59 up to 101 DAPs on all leaves, except 66 DAP. Most probably severity on 59 and 79 DAPs was the most important ones for this parameter. Number of kernels per spike showed significantly negative correlation for the severity scored on 80 ($r = -0.633$), 87 ($r = -0.684$) & 94 ($r = -0.648$) DAPs on flag. On this variety biomass weight also showed significantly strong negative correlation with STB severity scored beginning from 59 DAP for the whole scoring dates on both all and on flag leaves with the highest correlation coefficient of $r = -0.970$ on 101 DAP (GS 73) on all leaves. Thousand kernel weight of Galama showed significantly negative correlation with severity recorded from 59 to 101 DAPs on all leaves and with severity scored on 101 DAP ($r = -0.709$) on flag leaf. Here the highest correlation coefficient was $r = -0.788$ on 101 DAP on all leaves (Table 2).

Also grain yield showed significant and negative correlation with severity scored starting from 59 DAP for the whole scoring dates (DAPs), except 66 DAP. Here also the highest correlation coefficient was $r = -0.889$ on 101 DAP on flag leaf. Harvest index of Galama showed non significant negative correlation with severity through out the scoring dates (DAPs), but its test weight showed significantly negative correlation with severity scored beginning from 59 DAP, except 66 DAP and the largest correlation coefficient was $r = -0.836$ on 80 DAP (GS 60) on flag leaf (Table 2).

On variety Gambo at Hosanna, all *Septoria tritici* blotch severity recorded at weekly interval since 73 DAP showed significant negative correlation with spike length. *Septoria tritici* severity recorded on 52 DAP (GS 17, 30) (r = -0.656) showed significant correlation with number of tillers per meter square. In addition the correlation between days to maturity of Gambo and *Septoria tritici* blotch severity recorded on 87 (r = -0.807), 94 (r = -0.825) & 101 (r = -0.727) DAPs on flag leaf showed significantly negative relation. Again it showed significant negative correlation with severity on 73, 80 and 87 DAPs on all leaves (Table 3). Number of spikes per meter square and kernels per spike showed significantly negative correlation with severity recorded at weekly intervals since 73 DAP (GS 60) on all and flag leaves. *Septoria tritici* blotch severity recorded since 66 DAP (GS 45) both on all and flag leaves in weekly intervals revealed significantly negative correlation with biomass weight of this variety. Relatively the highest correlation coefficient(r) between severity and this parameter was -0. 938 on 80 DAP (GS 69). Thousand kernel weight of Gambo showed significantly negative correlation with severity recorded in weekly intervals since 59 DAP on all leaves and severity recorded on 80, 87, 94 & 101 DAPs on flag leaf with correlation coefficient of -0.862, -0.897, -0.859,& -0.888, respectively (for flag leaf) (Table 3). Also its grain yield exhibited significantly negative correlation with severity scored on 73 (r = -0.890), 80 (r = -0.953), 87 (r = -0.950), 96 (r = -0.908) & 101 (r = 825) DAPs on all leaves and severity scored after 87 DAP on flag leaf with the highest correlation coefficient of -0.966 (94 DAP) on flag leaf. Test weight of variety Gambo also showed significantly negative correlation with severity scored on 73 and 80 DAPs on all leaves with correlation coefficient of -0.803 and -0.726 respectively. Moreover that it showed significantly negative correlation with all severities recorded in weekly intervals on all DAPs on flag leaf (Table 3).

On Alidoro at Angecha, number of spikes per meter square showed significant negative correlation with severity recorded after 75 DAP and number of kernels per spike showed significantly negative correlation with severity scored on all DAPs after 68 DAP, on all leaves with maximum correlation coefficient of r = -0.734 at75 DAP. Severity recorded on all leaves on 75 (r = -0.611), 89 (r = -0.625), 96 (r = -0.792) and 103 (r = -0.767) DAPs showed significantly negative correlation with biomass weight of this variety. Here the highest correlation coefficient was -0.792 on 96 DAP (GS 70.8) (Table 4). Thousand kernel weight of Alidoro was significantly negatively correlated with severity scored on all leaves on 89 (r=-0.625) and 96 (r = -0.625) DAPs and 103 DAP(r = -0.771) on flag leaf. Moreover that grain yield of this variety showed negative significant correlation with severity scored on all leaves on 75 (r = -0.595), 89 (r = -0.574), 96(r = -0.725 and 103 (r = -0.731) DAPs. Also it showed significant negative correlation with severity scored on flag leaf on 89 DAP (r = -0.642); however severity level was low on flag leaf. Test weight of this variety showed strong correlation with severity recoded starting from 75 to 103 DAPs on all leaves with maximum correlation coefficient of r = -0.761 with severity on 103 DAP (Table 4).

At Angecha, number of spike per meter square, number of kernels per spike and biomass weight of Galama showed significantly negative correlation with severity scored starting from 75 DAP on all and flag leaves, except 89 DAP which was nonsignificant for number of spikes per meter square. The highest correlation coefficient (r = -0.795) for number of spikes per meter square shown on 75 DAP. It was r = -0.884 on 103 DAP on all leaves for number of kernels per spike and r = -0.727 on 96 DAP on flag leaf for biomass weight (Table 5). *Septoria tritici* blotch severity scored after 68 DAP both on all and flag leaves showed significant negative correlation with thousand kernel weight; with relatively highest coefficient of r = -0.880 on DAP 96 on flag leaf (Table 5).

Also its grain yield showed significantly negative correlation with severity scored on 75 (r = -0.790), 82 (r = -0.828), 89 (r = -0.842), 96 (r = -0.852) & 103 (r = -0.837) DAPs on all leaves and severity scored on 89 (r = -0.693), 96 (r = -0.832) & 103 (r = -0.894) DAPs on flag leaf. The maximum correlation coefficient (r = -0.894) between grain yield and *Septoria tritici* blotch severity was shown on 103 DAP (GS 73) on flag leaf (Table 5). Again its test weight showed significantly negative correlation with severity scored after 75 DAP on all and flag leaves. Relatively the highest correlation coefficient (r) between them was -0.790 on 103 DAP on all leaves (Table 5).

At Angecha, thousand kernel weight of Gambo showed significantly negative correlation with severity recorded in weekly intervals beginning from 75 DAP, on all leaves and on 96 DAP on flag leaf. Again grain yield of this variety revealed significant negative correlation with severity scored at weekly intervals since 75 DAP on all and flag leaves with the maximum correlation coefficient of -0.852 on 89 DAP on flag leaf. The correlation coefficient between grain yield and *Septoria tritici* blotch severity showed relatively high on flag leaf than all leaves (Table 6). In concluding, as the result of correlation analysis STB 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 *Septoria tritici* blotch occur after ear emergence the disease becomes quit severe on the upper leaves and cause significant yield loss (Jenkins *et al*., 1969).

Table 1. Correlation coefficients between *Septoria tritici* blotch severities assessed on all and flag leaves on different days after planting (DAP) and yield and yield components of Alidoro variety in 2012 at Hosanna

parameters	*Septoria tritici* severity on all leaves									On flag leaf			
	DAP									DAP			
	45 52 59 66 73 80 87 94 101									80	87	94	101
DM	0.222	0.349	0.269	0.244	0.335	0.259	-0.006	-0.039	-0.375	-0.248	-0.326	-0.337	-0.320
SL(cm)	-0.116	-0.187	-0.485	-0.309	-0.477	-0.533	-0.641*	-0.679*	-0.697*	-0.683*	-0.623*	-0.683*	-0.703*
NT/m^2	-0.302	-0.519	-0.661*	-0.379	-0.666*	-0.732**	-0.572*	-0.603*	-0.599*	-0.367	-0.430	-0.414	-0.410
NS/m^2	-0.224	-0.413	-0.662*	-0.506	-0.707*	-0.773**	-0.796**	-0.780**	-0.768**	-0.589*	-0.669*	-0.637*	-0.637*
NKPS	0.021	-0.109	-0.241	-0.223	-0.575*	-0.560	-0.545	-574	-0.574	-0.661*	-0.662*	-0.621*	-0.643*
BMW(t/ha)	-0.304	-0.372	-0.705*	-0.629*	-0.707*	-0.612*	-0.694*	-0.680*	-0.674*	-0.635*	-0.635*	-0.648*	-0.713**
TKW(g)	0.057	-0.049	-0.377	-0.225	-0.520	-0.632*	-0.840**	-0.834**	-0.842**	-0.899**	-0.915**	-0.907**	-0.895**
GY(kg/ha)	-0.012	-0.149	-0.449	-0.240	-0.614*	-0.723**	-0.705*	-0.744**	-0.747**	-0.644*	-0.623*	-0.649*	-0.632*
HI	0.382	0.206	0.180	0.321	-0.005	-0.230	-0.304	-0.332	-0.341	-0.304	-0.351	-0.321	-0.246
TW(kg/hl)	0.115	-0.015	-0.176	-0.161	-0.166	-0.117	-0.127	-0.196	-0.194	-0.299	-0.205	-0.265	-0.349

Here:- DM= days to maturity, SL= spike length, NT= number of tillers, NS=number of spikes, NKPS=number of kernels per spike, BMW= biomass weight, TKW= thousand kernels weight, GY= Grain yield, HI= harvest index, TW= test weight, DAP = days after planting

Table 2. Correlation coefficients between *Septoria tritici* blotch severities assessed on all and flag leaves on different days after planting (DAP) and yield and yield components of Galama variety in 2012 at Hosanna

parameters	*Septoria tritici* severity on all leaves									On flag leaf			
	DAP									DAP			
	45 52 59 66 73 80 87									80	87	94	101
DM	-0.025	-0.109	-0.535	-0.257	-0.655*	-0.669**	-0.755**	-0.792**	-0.801**	-0.751**	-0.741**	-0.740**	-0.765**
SL(cm)	0.102	0.231	0.146	-0.238	-0.233	-0.268	-0.150	-0.145	-0.263	-0.126	-0.201	-0.225	-0.199
NT/m^2	-0.283	-0.203	-0.141	-0.161	-0.027	-0.303	-0.214	-0.198	-0.255	-0.250	-0.235	-0.268	-0.288
NS/m^2	-0.338	-0.323	-0.694*	-0.501	-0.762**	-0.890**	-0.941**	-0.940**	-0.906**	-0.805**	-0.736**	-0.823**	-0.954**
NKPS	0.020	0.368	-0.183	-0.143	-0.305	-0.460	-0.485	-0.504	-0.516	-0.633*	-0.684*	-0.648*	-0.514
BMW(t/ha)	-0.385	-0.301	-0.748**	-0.608*	-0.865**	-0.910**	-0.947**	-0.960**	-0.970**	-0.795**	-0.749**	-0.824**	-0.960**
TKW(g)	-0.406	-0.307	-0.782**	-0.559*	-0.757**	-0.660*	-0.718**	-0.755**	-0.788**	-0.493	-0.455	-0.504	-0.709**
GY(kg/ha)	-0.318	-0.074	-0.623*	-0.354	-0.662*	-0.794**	-0.851**	-0.870**	-0.874**	-0.814**	-0.812**	-0.841**	-0.889**
HI	-0.102	-0.253	-0.486	-0.010	-0.296	-0.156	-0.222	-0.233	-0.166	-0.273	-0.256	-0.244	-0.226
TW(kg/hl)	-0.362	-0.216	-0.612*	-0.324	-0.683*	-0.670*	-0.696*	-0.668*	-0.586*	-0.836**	-0.769**	-0.830**	-0.745**

Here:- DM= days to maturity, SL= spike length, NT= number of tillers, NS=number of spikes, NKPS=number of kernels per spike, BMW= biomass weight, TKW= thousand kernels weight, GY= Grain yield, HI= harvest index, TW= test weight, DAP = days after planting, DAP = days after planting

Table 3. Correlation coefficients between *Septoria tritici* blotch severities assessed on all leaves on different days after planting (DAP) and yield and yield components of Gambo variety in 2012 at Hosanna

parameters	*Septoria tritici* blotch severity on all leaves									On flag leaves			
	DAP									DAP			
	45 52 59 66 73 80 87 94 101									80	87	94	101
DM	0.102	-0.398	-0.395	-0.081	-0.700*	-0.697*	-0.615*	-0.511	-0.409	-0.552	-0.807**	-0.825**	-0.727**
SL(cm)	0.411	-0.071	-0.537	-0.428	-0.709**	-0.845**	-0.793**	-0.809**	-0.761**	-0.559	-0.788**	-0.786**	-0.715**
NT/m^2	- 0.099	-0.656*	-0.456	-0.382	-0.431	-0.378	-0.541	-0.450	-0.420	-0.513	-0.510	-0.515	-0.594*
NS/m^2	0.129	-0.184	-0.233	-0.241	-0.761**	-0.802**	-0.835**	-0.765**	-0.674*	-0.877**	-0.863**	-0.870**	-0.903**
NKPS	0.079	-0.166	-0.370	-0.373	-0.789**	-0.869**	-0.875**	-0.812**	-0.698*	-0.927**	-0.928**	-0.924**	-0.950**
BMW(t/ha)	0.287	-0.131	-0.521	-0.577*	-0.882**	-0.938**	-0.909**	-0.908**	-0.851**	-0.818**	-0.876**	-0.908**	-0.895**
TKW(g)	0.222	-0.339	-0.584*	-0.660*	-0.658*	-0.822**	-0.873**	-0.811**	-0.686*	-0.862**	-0.897**	-0.859**	-0.888**
GY(kg/ha)	0.295	-0.210	-0.462	-0.458	-0.890**	-0.953**	-0.950**	-0.908**	-0.825**	-0.887**	-0.948**	-0.966**	-0.961**
HI	0.434	-0.008	-0.225	-0.228	-0.521	-0.652*	-0.550	-0.530	-0.431	-0.486	-0.608*	-0.590*	-0.531
TW(kg/hl)	0.160	-0.129	-0.188	-0.003	-0.803**	-0.726**	-0.539	-0.470	-0.365	-0.639*	-0.692*	-0.762**	-0.686*

Here:- DM= days to maturity, SL= spike length, NT= number of tillers, NS=number of spikes, NKPS=number of kernels per spike, BMW= biomass weight, TKW= thousand kernels weight, GY= Grain yield, HI= harvest index, TW= test weight, DAP = days after planting

Table 4. Correlation coefficients between *Septoria tritici* blotch severities assessed on all and flag leaves on different days after planting (DAP) and yield and yield components of Alidoro variety in 2012 at Angecha

parameters	Severity on all leaves								Severity on flag leaves		
	DAP 54 61 68 75 82 89								DAP 89 96 103		
DM	-0.148	-0.003	0.176	0.064	0.002	-0.062	-0.290	-0.338	-0.359	-0.081	-0.026
SL(cm)	0.258	-0.023	-0.068	0.129	0.193	0.315	0.404	0.304	0.387	-0.007	0.357
NT/m2	-0.348	-0.145	-0.485	-0.581*	-0.531	-0.680*	-0.711**	-0.677*	-0.418	-0.622*	-0.711**
NS/m2	-0.308	-0.021	-0.454	-0.665*	-0.598*	-0.735**	-0.913**	-0.899**	-0.633*	-0.619	-0.558
NKPS	-0.316	-0.357	-0.643*	-0.734**	-0.679*	-0.698*	-0.647*	-0.575*	-0.238	-0.467	-0.509
BMW(t/ha)	-0.402	-0.570	-0.470	-0.611*	-0.519	-0.627*	-0.792**	-0.767**	-0.650*	-0.352	-0.368
TKW(g)	-0.190	-0.192	-0.472	-0.563	-0.499	-0.625*	-0.625*	-0.512	-0.134	-0.440	-0.771**
GY(kg/ha	-0.318	-0.516	-0.507	-0.595*	-0.455	-0.574*	-0.725**	-0.731**	-0.642*	-0.393	-0.360
TW(kg/hl)	-0.456	-0.567	-0.469	-0.745**	-0.616*	-0.616*	-0.732**	-0.761**	-0.486	-0.316	-0.324

Here:- DM= days to maturity, SL= spike length, NT= number of tillers, NS=number of spikes, NKPS=number of kernels per spike, BMW= biomass weight, TKW= thousand kernels weight, GY= Grain yield, TW= test weight, DAP = days after planting

Table 5. Correlation coefficients between *Septoria tritici* blotch severities assessed on all and flag leaves on different days after planting (DAP) and yield and yield components of Galama variety in 2012 at Angecha

parameters	Severity on all leaves								Severity on flag leaves		
	DAP								DAP		
	54	61	68	75	82	89	96	103	89	96	103
DM	0.539	-0.459	-0.275	-0.673*	-0.638*	-0.638*	-0.644*	-0.587*	-0.310	-0.601*	-0.576*
SL(cm)	0.710	0.121	-0.321	-0.292	-0.273	-0.244	-0.338	-0.415	-0.338	-0.158	-0.251
NT/m2	0.309	-0.355	-0.133	-0.552	-0.501	-0.478	-0.493	-0.475	-0.383	-0.235	-0.484
NS/m2	0.292	-0.044	-0.337	-0.759**	-0.758**	-0.750**	-0.752**	-0.722**	-0.539	-0.596*	-0.737**
NKPS	0.556	0.126	-0.424	-0.735**	-0.772**	-0.777**	-0.828**	-0.884**	-0.645*	-0.722**	-0.825**
BMW(t/ha)	0.563	0.265	-0.233	-0.677*	-0.665*	-0.702*	-0.723**	-0.722**	-0.469	-0.727**	-0.721**
TKW(g)	0.112	0.516	-0.679*	-0.610*	-0.709**	-0.730**	-0.731**	-0.721**	-0.581*	-0.880**	-0.701**
GY(kg/ha	0.271	0.144	-0.414	-0.790**	-0.828**	-0.842**	-0.852**	-0.837**	-0.693*	-0.832**	-0.894**
TW(kg/hl)	0.256	0.037	-0.402	-0.712**	-0.755**	-0.749**	-0.769**	-0.790**	-0.616*	-0.638*	-0.750**

Here:- DM= days to maturity, SL= spike length, NT= number of tillers, NS=number of spikes, NKPS=number of kernels per spike, BMW= biomass weight, TKW= thousand kernels weight, GY= Grain yield, TW= test weight, DAP = days after planting

Table 6. Correlation coefficients between *Septoria tritici* blotch severities assessed on all and flag leaves on different days after planting (DAP) and yield and yield components of Gambo variety in 2012 at Angecha

parameters	Severity on all leaves								Severity on flag leaves			
	DAP								DAP			
	54	61	68	75	82	89	96		82	89	96	103
DM	-0.645	-0.606	0.143	-0.025	0.030	0.006	0.105	0.140	0.187	0.250	0.074	0.014
SL(cm)	0.401	0.159	0.235	0.242	0.207	0.141	0.152	0.139	0.025	-0.003	0.074	0.168
NT/m2	-0.159	-0.173	-0.614*	-0.709**	-0.693*	-0.737**	-0.707*	-0.671*	-0.522	-0.597*	-0.505	-0.300
NS/m2	-0.369	-0.492	-0.629*	-0.684*	-0.714**	-0.766**	-0.755**	-0.746**	-0.724**	-0.734**	-0.714**	-0.576
NKPS	-0.369	-0.492	-0.629*	-0.684*	-0.714**	-0.767**	-0.756**	-0.746**	-0.687*	-0.660*	-0.650*	-0.472
BMW(t/ha)	-0.051	-0.525	-0.577*	-0.631*	-0.627*	-0.655*	-0.676*	-0.667*	-0.836**	-0.817**	-0.812**	-0.716**
TKW(g)	-0.074	-0.329	-0.512	-0.651*	-0.636*	-0.658*	-0.655*	-0.645*	-0.511	-0.526	-0.591*	-0.491
GY(kg/ha	0.046	-0.338	-0.569	-0.709**	-0.699*	-0.687*	-0.719**	-0.721**	-0.824**	-0.852**	-0.851**	-0.761**
TW(kg/hl)	0.161	-0.178	-0.013	-0.060	-0.045	-0.178	-0.138	-0.125	0.006	-0.041	0.077	0.202

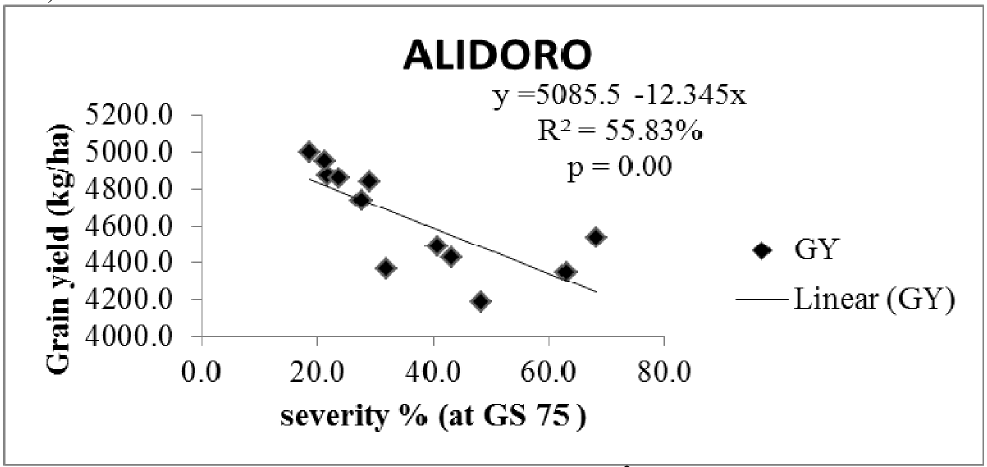
Here:- DM= days to maturity, SL= spike length, NT= number of tillers, NS=number of spikes, NKPS=number of kernels per spike, BMW= biomass weight, TKW= thousand kernels weight, GY= Grain yield, TW= test weight, DAP = days after planting

3.2. Disease - yield loss Relationships Models

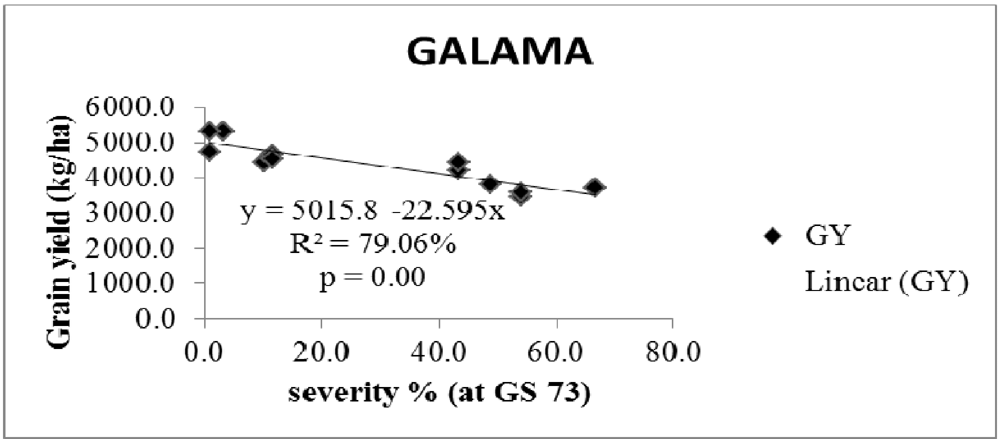
Using stepwise regression analysis the most important growth stage of the crop at which *Septoria tritici* was developed and significantly contribute to yield loss was found out. On variety Alidoro and Galama severity recorded at growth stage of 75on all leaves and 73on flag leaf was found significantly affect grain yield respectivlly. These are used to develop disease – grain yield loss relationships models (critical point model) on Alidoro and Galama,. But, severity recorded at growth stages of 70.8 on all leaves and 71 on flag leaf were found being important on grain yield variability among treatments on variety Gambo and used to develop their relationship model (multiple point model) on this variety. On all varieties, severity recorded on particular growth stage that sorted out by stepwise regression analysis as the most important on grain yield variability among treatments, again showed the highest significant negative correlation coefficient (r-value) on correlation analysis Table 1 to 6).

As the result showed, the most variability on grain yield of variety Alidoro, came due to *Septoria tritici* blotch severity recorded on all leaf on 101 DAP (GS 75). Based on this the equation showed, for every 1% of *Septoria tritici* blotch severity at this growth stage on all leaf, the grain yield can be reduced by 12.35 kg/ha (fig. 1). According the value of coefficient of determination (R^2) the equation expressed 56 % of variation on grain yield of Alidoro was as the result of *Septoria tritici* blotch at this growth stage. The probability of the equation was highly significant ($p< 0.01$). Also, the best predictor of yield loss at Hosanna on variety Galama was because of *Septoria tritici* blotch severity recorded on flag leaf at 101 DAP (GS 73). Also the equation showed that, every 1% *Septoria tritici* blotch severity increase on this particular growth stage on flag leaf can reduce the grain yield of Galama by 23kg/ha. Again the analysis result showed that 79% of variability on grain yield due to severity at this growth stage was explained by this equation and over all probability was highly significant($p = 0.00$) (fig. 1). The result on Gambo was different from the two varieties, for which *Septoria tritici* blotch severity recorded at two growth stages; which were 87 DAP (GS 70.5) on all leaf and 94 DAP (GS 70.8) on flag leaf, have been found to be the best predictors of grain yield loss with combined R^2 value of 96.22% and $p = 0.02$ (fig. 1). On this variety every 1% increase of septoria blotch at Growth stages of 70.8 on all leaves and 71on flag leaf can reduce the grain yield by 20 and 23kg/ha.

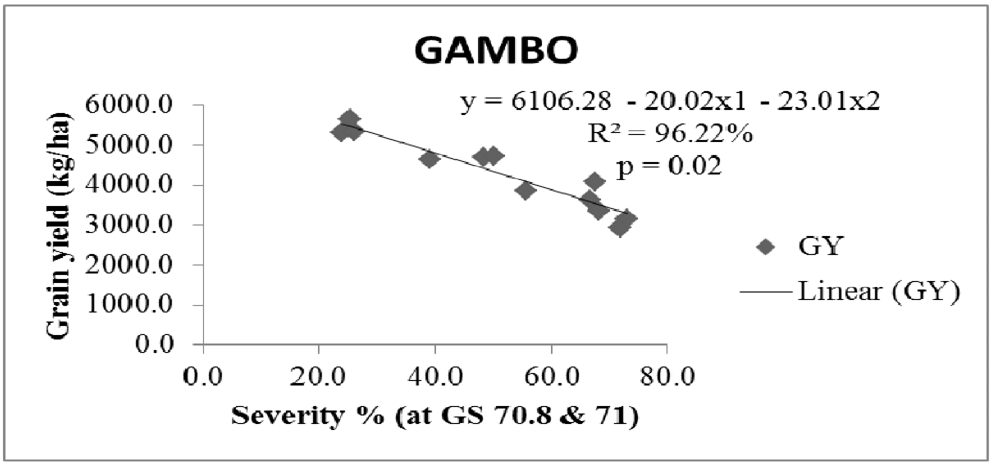
In general, on all varieties STB developed after growth stage of Z70 (kernel and milk development stage) was found to be important for grain yield loss. Therefore, however it needs more detail research with multiple year data; as the result of this study managing the disease before this growth stag provide considerable wheat grain yield recovery. This might be relate with protecting the top three leafs, especially flag leaf of the crop that contributes most to the grain yield (Ray, 1983). Due to it is activist leaf at grain filling period (Davood *et al*., 2009).



Where: Y = Grain Yield, X= severity at GS 75 on all leaf, R^2 =coefficient of determination



Where: Y = Grain Yield, X= severity at GS 73 on flag leaf, R^2 =coefficient of determination



Where: Y = Grain Yield, x1= severity at GS 70.8 on all leaf, x2 = severity at GS 71 on flag leaf,

Fig. 1. *Septoria tritici* blotch Severity-grain yield loss relationship of Alidor, Galama and Gambo at Hosanna on 2012 main cropping season.

4. SUMMERY AND CONCLUSIONS

In general, the result of the relationship of STB severity and growth stage of the crop, considerable yield loss was incurred due to STB severity after Zadock growth stage of 70. Also the model described that, every 1%

increase of septoria tritici blotch reduced the grain yield of bread wheat from 13 to 23 kg/ha. Therefore, managing the disease development before this growth stage of the wheat crop provides considerable yield recovery.

5. REFERENCES

Abreham Tadesse (ed.), 2008. Increasing crop production through improved plant protection-volume I. *Proceedings of the 14th annual conference of the plant protection society of Ethiopia* (PPSE), 19-22 December2006.

Alemar Said and Temam Hussien, 2016. Epidemics of *Septoria Tritici* Blotch and Its Development over Time; on Bread Wheat in Haddiya-Kambata Area of Southern Ethiopia; vol.6, No.1 Pp47-57.

Amsal Tarekegn, D.G. Tanner and Getinet Gebeyehu. 1995. Improvement in yield of bread wheat cultivars released in Ethiopia from 1949 to 1987. *African Crop Science J*ournal 3: Pp41-49.

ArARC, 2007 (Areka A Agricultural Research Center), Progress report.of 2007

AwARC (Awassa Agricultural Research Center), 2010. Progress report of 2010.

Bekele Geleta, Amanuel Gorfu and Getinet Gebeyehu. 1994. Wheat production and research in Ethiopia: constraints and sustainability. In: Tanner, D.G. (ed.). Developing Sustainable Wheat Production Systems. *The Eighth Regional Wheat Workshop for Eastern, Central and Southern Africa*. Addis Ababa, Ethiopia: CIMMYT.

CSA (Central Statistical Authority). 2000. Agricultural Sample Survey 1999/2000. I. Report on Area and Production for Major Crops: Private Peasant Holding 'Meher' Season. *Statistical Bulletin 227*. CSA, Addis Ababa, Ethiopia.

CSA (Central Statistical Authority). 2005. Agricultural sample survey 2004/2005, report on area and production of crops. *Statistical bulletin*. No.331, Volume I. Addis Ababa.

CSA (Central Statistical Authority). 2012. Agricultural Sample Survey 2011/2012. I. Report on Area and Production for Major Crops: Private Peasant Holding 'Meher' Season. *Statistical Bulletin* . CSA, Addis Ababa, Ethiopia.

Davood, B.T., A. Gazanchian, A.P. Hemmat and M. Nasiri, 2009. Flag leaf Morphophysiological Response to Different Agronomical Treatments in a Promising Line of Rice (Oryza sativa L.). *American-Eurasian Journal of Agriculture & Environmental Science*, 5 (3): Pp403-408.

EIAR, 2012. Report on Ethiopia and EIAR hosted International wheat conference 2012.

Eshetu Bekele, 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: Pp381-385.

Ethiopian ATA, 2013. Rusts and major wheat and barley Diseases and pests in Ethiopia.A guide for identification, scoring and management of wheat and barley diseases.

Eyal, Z., A.L.Scharen, J.M. Prescott, M.V Ginkel, 1987. The Septoria diseases of wheat*: concepts and methods of disease management.* CIMMYT, Mexico City, Mexico. P52.

FAOSTAT, 2009. International wheat production statistics

Fikre Handoro, 2010. Wheat Disease Survey. Awassa Agricultural Research Center progress report for, 2010.

Hailu Gebre-Mariam., 1991. Bread wheat breeding and genetic research in Ethiopia. In Hailu Gebre-Mariam, Tanner D.G. and Mangistu Huluka (eds). Wheat research in Ethiopia: A historical perspectives. Addis Ababa. *Ethiopian Institute of Agricultural Research* /CIMMYT Pp73-93.

Jenkins, J.E.E. and W.A. Morgan, 1969. The effect of *Septoria* diseases on the yield of winter wheat. *Plant Pathology,* 18: Pp152-156.

Mengistu Huluka*,* Getaneh W*,* Yeshi *A,* Rebeka D*,* Ayele Badebo*,* 1991.Wheat pathology research in Ethiopia. *International Journal of Agronomy and Plant Production*.

Saari, E. E., and J.M. Prescott, 1975. A scale for appraising the foliar intensity of wheat disease. *Plant disease Report* 59: Pp377-380.

Shaw, M.W., 1990. Effects of temperature, leaf wetness and cultivar on the latent period of *Mycosphaerella graminicola* on winter wheat. *Plant Pathology* 39: Pp255-268.

Tamar D., J.M. Sacks and Z. Eyal 1981. The Relationships Among plant stature, maturity class, and susceptibility to septoria leaf blotch of wheat. *Phytopathology* 72: Pp1037-1042

SNNPR Bureau of Agriculture and Rural Development, Annual Report (2006).

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. *Journal of Environmental Science and Engineering* B 1: Pp957-965.

Zadocks, J.C., T.T. Chang and C.F. Kanzak, 1974. A decimal code for the growth of stage of cereals. *Weed Res*earch 14: Pp415-421.