Effect of Northern Leaf Blight (*Exserohilum Turcicum*) Severity on Yield of Maize (*Zea Mays* L.) in Morogoro, Tanzania

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Abstract: ***Grain yield losses of five varieties of maize due to northern leaf blight (NLB) were evaluated in the Sokoine University of Agriculture, Morogoro crop museum using artificial inoculation. The experiment was laid out in two blocks of E.turcicum inoculated and mancozeb treatment plots, arranged in randomized complete block design in three replicates. Data on disease severity base on percent leaf area affected and yields were subjected to analysis of variance while significant means were separated using Turkeys. Correlations and coefficient of determination analysis were used to determine the relationship and reliability of the critical point models. Results showed that the maize varieties Bora, Kilima, Situka-1, Staha and Tmv-1 were highly susceptible to NLB. Percent disease index (PDI) varied from 63.3 % in Kilima to 87 % in Staha. Consequently, proportional grain yield losses of 23.9 - 40.4 % and 11.2 - 36.1 % were recorded for grain yields (tons/ha) and 1000 grain weight (g/plot), respectively. It was also found that mancozeb sprays completely protected and increased yield of the maize varieties. The average PDI estimated at silk dry significantly ($p \leq 0.05$) and negatively correlated with yields while coefficient determination values $R^2 = 0.35 - 0.97$ and $R^2 = 0.54 - 0.99$ for yield measured in tons/ha and g/plot, respectively, confirmed the reliability of the crop models. Although the critical point model indicated good fit for the two years, yield loss models varied within varieties for the two years.***

Keyword: Maize, northern leaf blight, *Exserohilim turcicum*, yield loss, Morogoro.

1. Introduction

Maize is a crop of strategic national interest and contributed 46 % GDP of the agricultural products in Tanzania (Gabagambi, 2009). However maize is mostly produced by resource limited small-scale farmers in Tanzania (Rowhani *et al*., 2011). Despite farmers' effort to increase production through increase of arable land, application of fertilizers, pesticides and other inputs, yield of maize have remained low, between 1.3-1.5 tons/ha (Moshi *et al*., 1990; Rowhani *et al*., 2011). *Inter alia,* northern leaf blight (NLB) caused by *Exserohilum turcicum* is the most important limiting fungal disease hampering maize production in East Africa (Adipala *et al*., 1993a) and the world in general (Chandrashekara *et al*., 2014).

Average losses of 60% have been reported in Kenya, Uganda, Ethiopia South Africa and Zambia (Simelane and Kapooria 2007). In Uganda, overlapping of growing seasons and presence of off-season maize resulted in infection before tasseling stage, consequently resulting to higher yield loss (Adipala *et al*., 1993b). Yield loss is caused predominantly through loss of photosynthetic leaf area due to blighting (De Vries and Toenniessen, 2001). Under severe infestation, sugars can be diverted from the stalks for grain filling leading to crop lodging (Ferguson and Carson, 2004). When disease caused by NLB is established before silking and spreads to upper leaves during grain filling, severe yield losses can occur (Ullstrup and Miles, 1957; Raymundo and Hooker, 1981). Yield losses as high as 98% have been recorded (Kachapur and Hegde, 1988) but typically ranged from 15-50 % (CIMMYT, 1985; Perkins and Hooker, 1981). However, magnitude of yield loss depends on the stage of plant when infection occurred, severity of disease and the maize genotype resistance. Yield loss model have shown that the most favourable time to estimate potential yield losses in maize resistance to northern leaf blight was during the period 3-6 week after silking (Raymundo and Hooker, 1981; Perkins and Pedersen, 1987). They explained that critical point (CP) and area under disease progress curve (AUDPC) models gave relatively good fit $r^2 = 0.68$ and $r^2 = 0.66$.

In maize and other cereals, upper leaves contributed significantly to yield (Bowen *et al*., 1991). Hooker (1979) reported that the top, middle and bottom leaves contributed approximately 10:5:1 %, respectively to grain yield. The first and second leaves above the ear contributed significantly to yield and their mechanical removal reduced yield by 32 % (Levy and Leonard 1990). Campbell and Madden (1990) reported that disease assessment must be reproducible and highly correlated to yield loss. Harlapur *et al*. (2009) reported negative significant correlation and a range of 2.9 to 51.9 % yield loss in maize due northern leaf blight.

Information on the general relationship between yield of maize and severity of NLB are available (Kachapur and Hegde, 1988; Pataky *et al*., 1988; Krasuz, *et al*., 1993; Babu *et al*., 2004; Harlapur *et al*., 2007; Reddy *et al*., 2013) but not in Tanzania. Although Nkonya *et al*. (1998) identified *E. turcicum* as important disease and estimated economic injury level of 45%.

Several agro-ecological zones exist in Tanzania among the tropical (Coastal and Morogoro regions) to temperate (Highlands) weather of the country. Maize is cultivated in almost all the regions of Tanzania, but no empirical evidence on the relationship between yield losses and northern leaf blight. This investigation aimed at determining the level of yield losses associated with northern leaf blight on five common maize varieties and to develop yield loss models using critical point to for estimating potential losses caused by *E. turcicum* in maize.

2. Materials and Methods

Study area and field management

Five maize varieties Bora, Kilima, Situka-1, Shaha, and Tmv-1 were evaluated for yield losses in the Sokoine University of Agriculture, Morogoro crop museum using artificial inoculation. Plots were established on land under maize production and maintained for two growing seasons in an identical manner in 2013 and 2014.

Field experiments were laid out in randomized complete block design (RCBD) with three replicates. The trial was conducted in paired blocks with *E. turcicum* inoculated and mancozeb fungicide treatments (Harlapur, 2005). Plots were planted and thinned to stand density of about 68000 per hectare, in a plot size of 15 m^2, separated by 0.75 m, 0.3 m and 1.0 m inter row, intra row and inter plot/replicates respectively. Before inoculation, ten stands were randomly selected at the two middle rows of each plot and tagged. Such stands were used for disease assessment.

The protected block was sprayed with 0.25 % mancozeb (Dithane M45, 80 % WP) at 1.68 kg/ha^{-1} (Pataky *et al.*, 1998 and Harlapur, 2005) using 15 liter knapsack sprayer while the other block was inoculated with pure culture of *E.turcicum i*solate. Five fungicide sprays were observed beginning from 35 days after planting and subsequently at interval 7 days.

Pure culture of *E. turcicum* was mass produced on sorghum seeds and used for inoculation after air dring in a sterile plastic tray for two days under room temperature following Adipala, *et al*., (1993). Plants in the two centre rows were inoculated by placing about 10 infected sorghum seeds into five whorls of each stand (50 seeds per stand). Inoculation was made after 1600 hours and spread with water using a knapsack sprayer (Harlapur, 2005) to induce infection. Disease inoculation was done twice at 35 and 45 days after planting.

To reduce inter-plot dispersal of inoculum and drift of the fungicide, three rows of tall and late maturing local variety of maize presumed to be resistant to northern leaf blight were planted between the protected and inoculated blocks, 10 days before trail establishment. Blanket application of dimethioate insecticide was applied at 30 and 45 DAS in both treatments to reduce insect infestation. Agronomic recommendations for maize production were observed.

Northern leaf blight assessment

Data on disease severity based on percent leaf area infected was recorded at silk dry stage using visual scales of 0-5 (CIMMYT, 1985; Muiru *et al*., 2007; Durrishahwar *et al*., 2008) with little modification. Disease severity rating was as follows; 0 = leaves free from infection, 1 = a few restricted lesions on the lower leaves (≤ 5 %), 2 = several small and large lesions on many leaves (5.1-10 %), 3 = numerous small and large lesions on many leaves (10.1-25 %), 4 = many enlarged and coalesced lesions on many leaves above the cob (25.1-50 %) and 5 = several coalesced lesions, leaf showing wilting, tearing and blotching typical blight symptoms (> 50%). Severity scores were converted to percent disease index (PDI) as described by Wheeler *et al*., (1969) using the formula below;

$$\text{PDI} = \frac{\text{Sum of numerical grading}}{\text{Leaves examined} \times \text{maximum disease grade}} \times 100$$

Grain yield and 1000 grain weight was calculated from weight of hand threshed maize and converted to tons/ha and g/plot after adjusting to 15.5 % moisture content with a hand moisture meter.

Data analysis

Combined analysis of variance (ANOVA) was used to analyze data while means with significant differences were compared using Turkey (Turkey's-kramer) simultaneous test for data at P≤ 0.05 (Steel *et al*., 1997) for treated and inoculated treatments. Data on grain yield and 1000 grain weight of the varieties were used to determine yield loss of *E. turcicum* inoculated treatments as a percentage of mancozeb treated plots as described by Harlapur (2005) using formula below;

$$Percent\ yield\ loss = \frac{Vp - Vu}{Vp} \times 100$$

Where, Vp = Value of protected plot, Vu = Value of unprotected plot

Crop Loss Assessment Model

Crop loss assessment model was developed for varieties Bora, Kilima, Situka-1, Staha and TMV1 for both grain yield and 1000 grain weight for 2013 and 2014. The observed grain yield and 1000 grain weight values of the treatments and the corresponding percent disease index (PDI) values were used to identify the relationship between northern leaf blight severity and losses in the maize varieties. Critical point models for northern leaf blight of maize were developed using simple linear regression functions;

$$Y = a + bx,$$

Where; Y = the yield loss, 'a' = constant, 'b' slope and 'x' = per cent disease index. Yield expressed as a percentage of the average yield of uninoculated was used as the dependent variable. Criteria for selection of best fitting models for estimating yield losses were based on; 1) correlation coefficient (r), which showed the relationship between dependent and independent variables, 2) coefficient of determination (R^2), which indicated the proportion of the total variation explained by the model ($R^2 > 0.05$).The graphs of grain yield and 1000 grain weight per plots verses per cent disease index values were plotted to identify the relationship between the two variables and 3) F-statistics, which tests the significance of the regression model (p <

0.05) as described by Perkins and Pedersen (1987). Genstat 14th edition (PC/window7, 2013), IBM SPSS statistics 20 and XLSTAT 2015 version software statistical packages were used for analysis of data.

3. Results

Results (Table 1) showed that the five maize varieties differed significantly (p≤ 0.05) in response to *Exserohilum turcicum*. Consequently, disease index ranged from 63.3 % to 89 % with mean of 74.3 %. Although the five maize varieties were susceptible to NLB, varieties Staha and Bora were significantly highly susceptible to NLB compared to the others. Results also indicated that mancozeb sprays completely protected the varieties against northern leaf blight. This was evident in the significant increase in grain yield of the maize varieties in mancozeb treated plots over *E. turcicum* inoculated treatments (Table 2).

Table 1: Effect of Mancozeb and *Exserohilum turcicum* inoculation on development of northern leaf blight of maize in Morogoro during 2013 and 2014 growing seasons

Percent disease index (%)						
S/no	Variety	Mancozeb treated		*E. turcicum* inoculated plots		
		2013	2014	2013	2014	Pooled
1	Bora	0.0	0.0	83.3a	90.0a	86.7a
2	Kilima	0.0	0.0	60.0b	66.7b	63.3b
3	Situka-1	0.0	0.0	64.0b	70.7b	67.3b
4	Staha	0.0	0.0	88.0a	90.0a	89.0a
5	Tmv-1	0.0	0.0	60.0b	70.0b	65.0b
	Mean	0.0	0.0	71.1	77.5	74.3
	Cv (%)	0.0	0.0	8.6	4.9	6.6

Means followed by the same letter in the same column are not significantly different according to Turkey's 95 % level of confidence.

Maize grain yield losses ranged from 23.9 % to 40.4 % (Table 2). The least grain yield losses of 23.9 % and 26.1 % were observed in the varieties Kilima and Sikuta-1, respectively while Staha and Tmv-1 varieties recorded 39.6 % and 36.6 % grain yield losses. The highest grain yield loss of 40.4 % was found Bora. Results indicated that grain yield losses were directly proportional to percent disease index (PDI) of northern leaf blight (Fig.1). Early inoculation (35-45 DAS) of *E.turcicum* may have encouraged secondary spread for the severe infection and consequently resulted to grain yield losses observed in this study.

Table 2: Grain yield losses of maize due to northern leaf blight in Morogoro during 2013 and 2014 growing seasons.

Grain Yield (Tons/ha^{-1})							
Variety	Mancozeb treated plots			*E. turcicum* inoculated plots			% Yield loss (ha^{-1})
	2013	2014	pooled	2013	2014	pooled	
Bora	7.57	6.27a	6.92a	3.90	4.27	4.08	40.4
Kilima	6.34	4.49b	5.41b	4.44	3.51	3.98	23.9
Situka-1	6.26	4.96ab	5.61ab	4.25	3.96	4.10	26.1
Staha	6.01	5.22ab	5.61ab	3.51	3.19	3.35	39.6
Tmv-1	7.14	6.05a	6.60ab	4.21	4.04	4.13	36.6
Mean	6.66ns	5.40	6.03	4.06ns	3.79ns	3.93ns	33.3
Cv (%)	14.1	9.8	12.9	14.9	11.5	13.1	-

Means followed by the same letter in the same column are not significantly different according to Turkey's 95 % level of confidence, ns = not significant

Yield losses measured in 1000 grain weight ranged from 11.2 % to 36.1 % (Table 3), however were not were proportional to the disease index except for Bora and Staha varieties (Fig. 1). The variety Situka-1 recorded higher yield depression (36.1%) followed by Bora (32.7 %) and Staha (24.9 %). Varieties Kilima and Tmv-1 recorded the least weight losses (1000 grain weight) of 11.2 % and 24 % respectively (Table 1). Such variation in grain yield losses measured in 1000 grain weight suggested that the maize varieties were affected by level or proportionality of disease and level of tolerance to northern leaf blight. Evidence of tolerance to NLB was observed in the variety Staha with higher PDI (Table 1) and relatively low grain weight loss 24.9 % (Table 3).

Table 3: Losses in 1000 grain weight due to northern leaf blight in Morogoro during 2013 and 2014 growing seasons.

Grain Yield (tons/ha^{-1})							
Variety	Mancozeb treated plots			*E. turcicum* Inoculated plots			% Grain wt loss/plot
	2013	2014	pooled	2013	2014	pooled	
Bora	319.9c	318.3c	319.1cd	214.0a	214.0b	214.0b	32.7
Kilima	332.8c	334.3bc	333.6c	302.2a	290.6a	296.4a	11.2
Situka-1	364.4b	359.9b	362.2b	227.1b	235.7bc	231.4b	36.1
Staha	387.0a	388.1a	387.6a	294.1a	288.1a	291.1a	24.9

Tmv-1	323.8c	308.7c	316.2d	240.4b	239.7b	240.0b	24.0
Mean	345.6	341.9	343.7	255.8	253.7	254.7	25.8
Cv (%)	2.3	2.8	2.5	6.1	6.4	6.5	-

Means followed by the same letter in the same column are not significantly different according to Turkey's 95 % level of confidence.

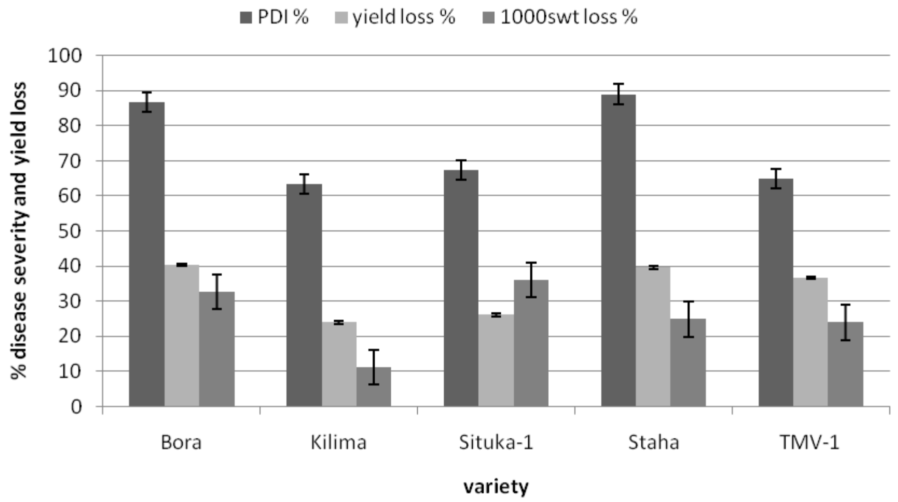

Figure 1: The relationship between percent disease severity and grain yield losess (tons/ha and 1000 grain weight g/plot) for five varieties maize in Morogoro in 2013/2014 growing seasons.

High negative correlation coefficients (Table 4) were observed between grain yields and disease index of varieties Bora, Kilima, Situka-1, Staha and Tmv-1 in 2013 and 2014. The 'r' between grain yield (tons/ha) and NLB ranged from – 0.66 (Kilima) to – 0.99 (Tmv-1) in 2013 and – 0.60 (kilima) to -0.98 (Situka-1) in 2014. Yield measured in 1000 grain weight indicated similar results and ranged from -0.78 (Kilima) to -0.99 (Bora) in 2013 and -0.74 (Kilima) to -0.99 (Situka-1) in 2014. The cumulative effect of disease epidemic in the study suggested that yields decreased as disease index increased in all the varieties and also confirmed that the maize varieties exhibited different tolerant levels to NLB.

Table 4: Correlation coefficients (r) between percent disease index of northern leaf blight and grain yield of five maize varieties during 2013 and 2014 growing season in Morogoro

		Grain yield		1000 seed weight	
S/No	Variety	2013	2014	2013	2014
1	Bora	r = - 0.9559 (0.003)	r = - 0.9513 (0.003)	r = - 0.9901 (< .001)	r = - 0.9826 (< .001)
2	Kilima	r = - 0.6639 (0.15)	r = - 0.5995 (0.21)	r = - 0.7840 (0.07)	r = - 0.7407 (0.09)
3	Situka-1	r = - 0.9802 (<.001)	r = - 0.9807 (< .001)	r = -0.9741 (< .001)	r = - 0.9992 (< .001)
4	Staha	r = - 0.9378 (0.006)	r = - 0.9663 (0.002)	r = - 0.9689 (< .001)	r = - 0.9887 (< .001)
5	Tmv-1	r = - 0.9892 (< .001)	r = - 0.8903 (0.017)	r = - 0.9675 (0.002)	r = - 0.9445 (0.005)

Figures in bracket are the t- test F-probability

Linear or quadratic regression model revealed 44 – 97 % variation in yield (tons/ha) as a function of NLB severity index in 2013 and 36-96 % in 2014 (Table 5). Yield measured in 1000 grain weight recorded variation of 61-98 % and 55-99 % in 2013 and 2014, respectively. The variety Kilima was the least affected with 44 % and 36 % for grain yield (tons/ha) and 61-55 % (1000 g/plot) for 2013 and 2014 respectively. Although the variation was significant from zero, grain yield of the variety Kilima indicated relatively low fitness (R^2 = 0.44 and R^2 =0.36) and 1000 grain weight (R^2 = 0.61 and R^2 = 0.51) compared to other varieties. Varieties Bora, Situka-1, Staha and Tmv-1 were highly fitted for grain yield (tons/ha) and yield measured in 1000 grain weight in the two seasons (Table 5). The study therefore suggested that, the predicted grain yield (tons/ha) and 1000 grain weight losses in the varieties showed good fit by using variable PDI.

Table 5: Regression coefficients (R^2) between percent disease index of northern leaf blight and grain yield of five maize varieties during 2013 and 2014 growing season in Morogoro

		Grain yield		1000 Grain weight	
S/No	Variety	2013	2014	2013	2014
1	Bora	R^2 = 0.9138	R^2 = 0.9050	R^2 = 0.9811	R^2 = 0.9655
2	Kilima	R^2 = 0.4408	R^2 = 0.3594	R^2 = 0.6147	R^2 = 0.5487
3	Situka-1	R^2 = 0.9782	R^2 = 0.9618	R^2 = 0.9488	R^2 = 0.9985
4	Staha	R^2 = 0.8794	R^2 = 0.9338	R^2 = 0.9388	R^2 = 0.9776
5	Tmv-1	R^2 = 0.9786	R^2 = 0.7926	R^2 = 0.9360	R^2 = 0.8921

The relationship between losses in grain yields (tons/ha and 1000 grain wt.) and disease index assessed at silk dry were expressed by the simple linear regression model (Table 6). The regression line and coefficient of determination (R^2) were presented in figures 1-5. Results revealed negative slope coefficients. The slope coefficient from the regression model ranged from – 0.03 to -0.05 (2013) and -0.01 to -0.03 (2014) for grain yield and -0.5 to -2.1 (2013) and -0.7 to -1.8 in 2014 for 1000 grain weight. Variation in slope coefficients also indicated that the varieties were susceptible to NLB, however higher in varieties Bora and Staha.

Table 6: Crop loss models between percent disease index of northern leaf blight and grain yield of five maize varieties during 2013 and 2014 growing season in Morogoro

		Grain yield		**1000 seed weight**	
S/No	**Variety**	**2013**	**2014**	**2013**	**2014**
1	BORA	y = 7.57 – 0.044 PDI	y = 6.27 – 0.022 PDI	y = 319.72 –1.256 PDI	y = 318.3-1.154PDI
2	KILIMA	y = 6.40 – 0.034 PDI	y = 4.47 – 0.014 PDI	y = 332.17 –0.488 PDI	y = 334.15 –0.651 PDI
3	SITUKA-1	y = 6.24 – 0.031PDI	y =4.95 – 0.014PDI	y =362.58 –2.088 PDI	y = 359.91 -1.758 PDI
4	STAHA	y = 6.01 – 0.028 PDI	y = 5.22 – 0.023 PDI	y =387.04 – 1.056 PDI	y = 388.13 –1.112 PDI
5	TMV-1	y = 7.15 – 0.049PDI	y = 6.05 – 0.029 PDI	y = 323.77 –1.389 PDI	y = 308.67 – 0.9860PDI

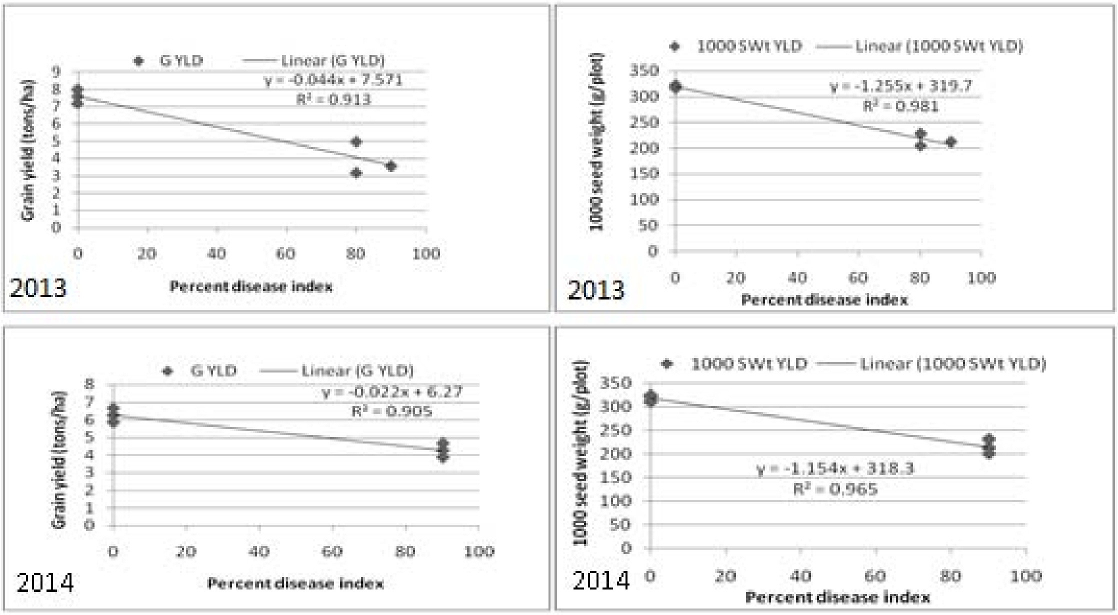

Figure 1: Relationship between grain yield and percent disease index in the variety Bora, 2013 and 2014 in Morogoro

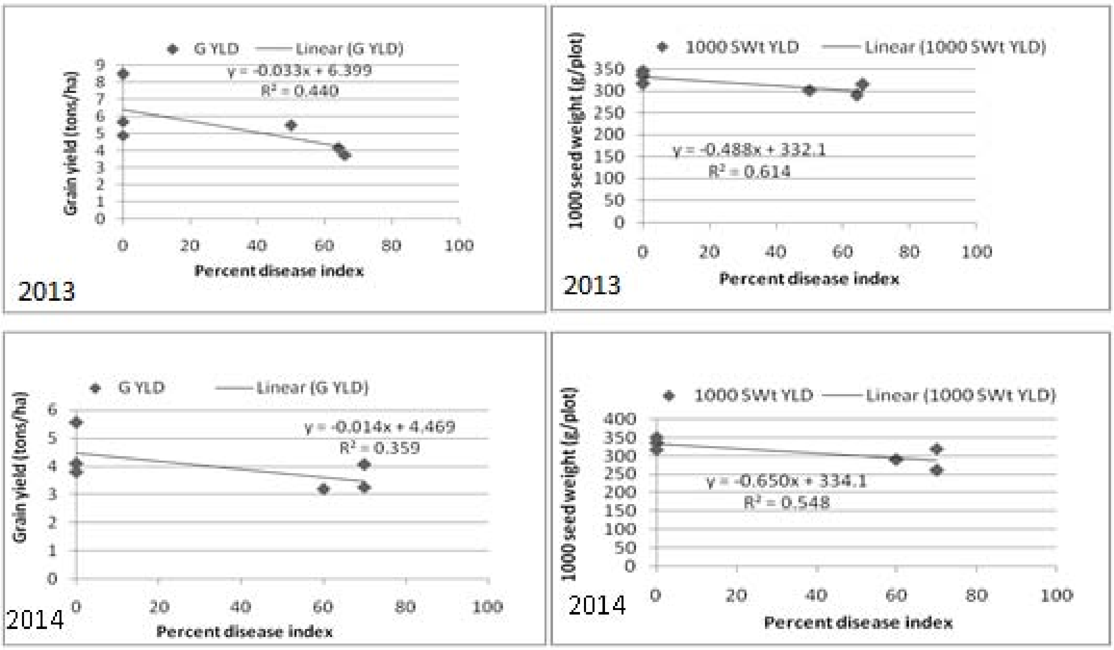

Figure 2: Relationship between grain yield and percent disease index in the variety Kilima, 2013 and 2014 in Morogoro

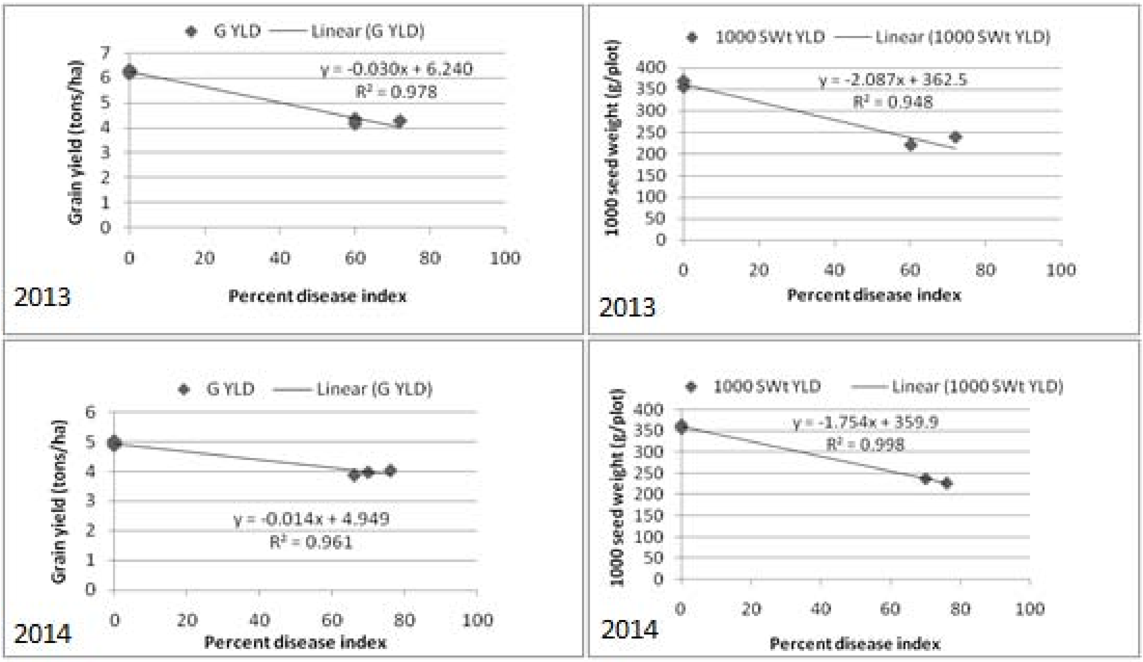

Figure 3: Relationship between grains yield and percent disease index in the variety Situka-1, 2013 and 2014 in Morogoro

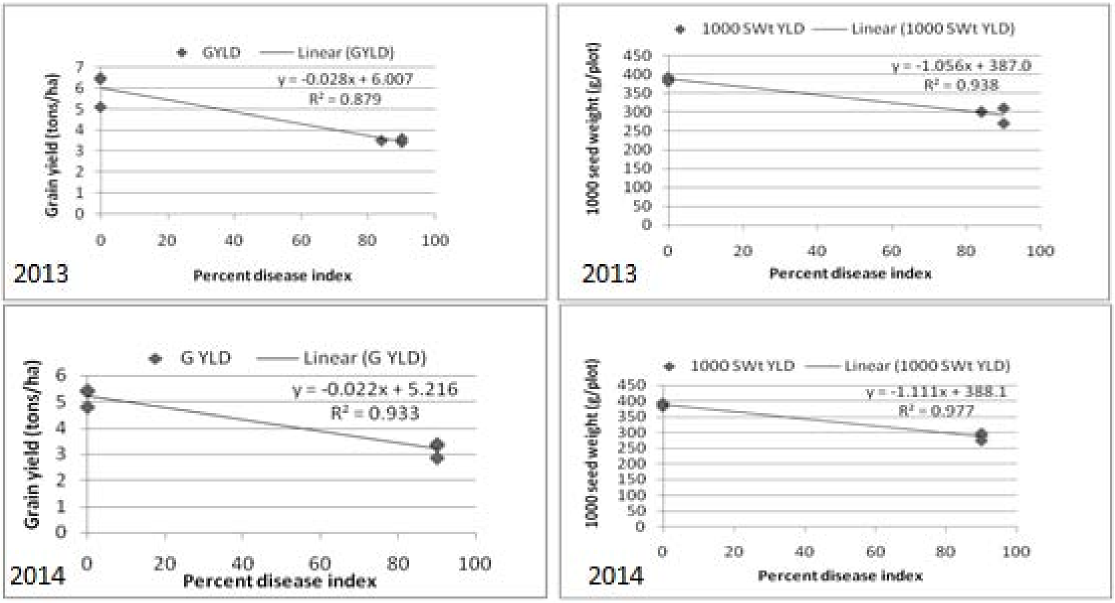

Figure 4: Relationship between grain yields and percent disease index in the variety Staha, 2013 and 2014 in Morogoro

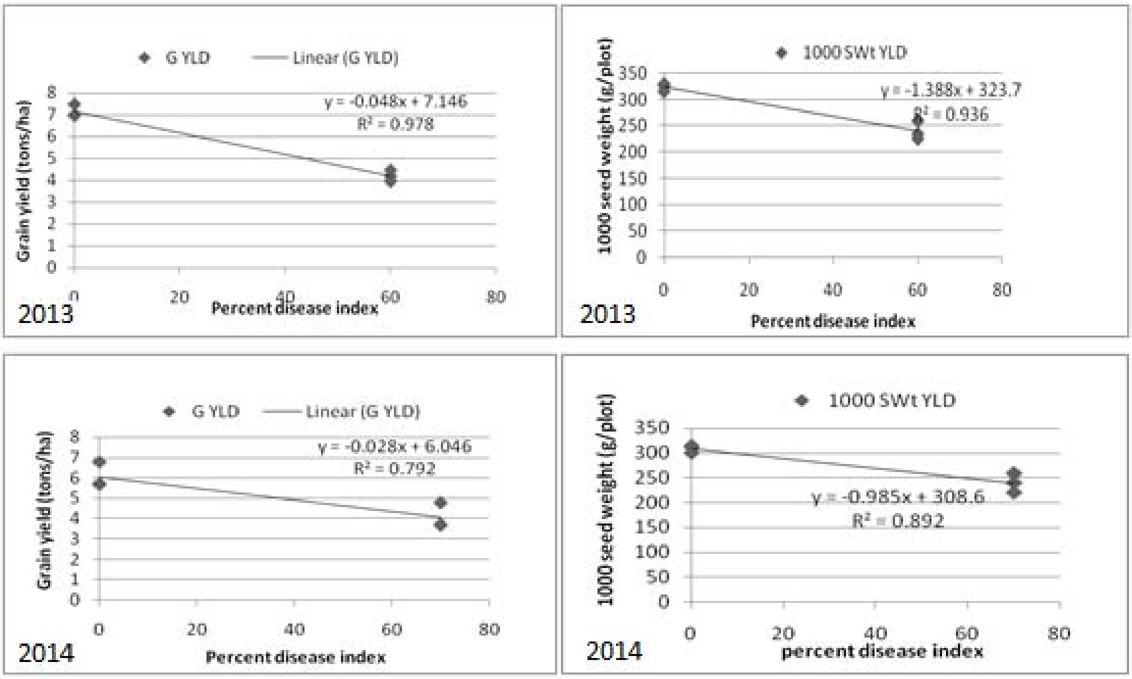

Figure 5: Relationship between grain yields and percent disease index in the variety TMV-1, 2013 and 2014 in Morogoro

4. Discussion

The five maize varieties Bora, Kilima, Situka-1, Staha and TMV-1 were very severely infected by northern leaf blight in the *E turcicum* inoculated plots, however level of infection varied significantly. Earlier, Adipala *et al*., (1993) reported that under severe field infection of NLB, maize cultivars reacted differently in Uganda. The effect of NLB on yield was dependent on resistance or susceptibility of hybrids (Pataky, 1992; Pataky *et al*., 1998) and varied from genotype to genotype (Shivankar and Shivankar 2000). Consequently, mancozeb treated plots recorded higher grain yield (tons/ha and 1000 grain weight). Results of the study agreed with Sharma and Mishra (1988) who reported that infection due to NLB on maize was effectively suppressed by sprays of mancozeb fungicide.

The relationships between maize grain yields of varieties and northern leaf blight varied significantly and the disease adversely affected yield. Similar observation has been reported previously (Adipala *et al*., 1993; Pataky, 1992; Solomonovish *et al*., 1992; Harlapur, 2005). The losses in maize grain yield ranged from 23.9 % to 40.4 % with a mean of 33.3 %. Yield depression of 39.6 (Staha) % and 40.4 % (Bora) were proportional to disease severity of 89 % and 86.7 %, respectively. Grain losses of 2.9 – 51.9 %, directly proportional to NLB disease on different maize hybrids have been reported (Pandurangegowda, 1991; Patil *et al*., 2000; Harlapur 2005). Early inoculation (35-45 DAS) of *E.turcicum* may have encouraged secondary spread for the severe infection and consequently resulted to grain yield losses observed in this study. Similar observation was made by Raymundo and Hooker (1981) who reported that early onset of NLB, caused severe losses in grain yield of 63 % when severity was 97% in maize.

Besides losses in grain yield, considerable losses were observed in 1000 grain weight which varied among varieties. Reduction in yield of 1000 grain weight ranged from 11.2 to 36.1 % with average of 25.8. The inconsistency between PDI and grain yield loss in suggested that although the varieties were susceptible to NLB, the level tolerance to northern leaf blight differs. The present study therefore showed that varieties Bora and Staha were recorded higher infection and greater yield depression compared to Kilima, Tmv-1 and Situka-1. Earlier, Perkins and Pedersen (1987) reported that reduction in 500 grain weights of maize contributed to yield loss probably due to loss of active leaf area. They explained that loss of active leaf area resulted in less photosythate during grain filling period thereby resulting to production of small grains. In a related work, Pataky *et al* (1998) reported that yield measured as weight of ears and number of marketable ears decreased as NLB severity increased.

Crop loss model is an important tool in the prediction and forecasting of losses due to NLB disease. It is a prerequisite for determining decision in threshold and deployment of cost effective management practices (Harlapur, 2005). Results of this investigation revealed high significant correlation coefficient (‘r’) and coefficient of determination (R^2) between grain yields (tons/ha and 1000 grain weight in g/plot) predictions with input variable PDI. High negative correlation coefficients between yield and PDI at silk drying showed cumulative effect of disease epidemic and explained that grain yield of the varieties decreased with increased PDI, depending on level of tolerance. Earlier reports have shown that late assessment of northern leaf blight were more correlated using critical point models than tasseling and silking stages (Campbell and Madden 1990; Adipala *et al*., 1993; Harlapur, 2005) as observed in this study. Pataky *et al.* (1998) also reported high correlation coefficient of 0.76 to 0.98 due NLB on susceptible varieties of maize.

The simple linear regression crop models explained 36 to 98 % variation in yield (tons/ha) and 54 to 98 % variation in 1000 grain weight as a function of disease severity at harvest in 2013 and 2014, respectively. In this study, the predicted grain yield (tons/ha) and 1000 grain weigh loss values in all varieties showed fitness by using variable PDI, thus confirmed that critical point model is appropriate for prediction of grain yields losses due to NLB of maize. The results agreed with Pataky *et al*. (1998) who reported 31-70 % variation in yield as a function of NLB severity on maize at harvest. The study also conformed to Bowen and Pedersen (1988) who reported that using critical point models to determine relationship between yield and northern leaf blight severity on susceptible genotypes indicated better prediction on the reduction of individual grain yield components.

The significant coefficient of determination clearly indicated the validity of the developed models. The simple linear regression equations of grain yield on disease index resulted in high R^2 in the two years indicating that much of the variation in yield could be attributed to northern leaf blight. The relatively lower R^2 values in grain yield (R^2 = 0.3594) and 1000 grain weight (R^2 = 0.44) recorded in Kilima was associated with influence of environmental and physiological characters of the variety. Kilima plots were affected by flooding and logging particularly in 2014 and may have contributed to low fitness. However, the values are significant from zero. Earlier, Adipala, *et al*. (1993) reported that critical point models, using percentage leaf area affected at GS 9.1 on a619xA632 gave good fit (R^2 = 0.53). They further explained based on interaction from ANOVA and regression coefficients that models must be separately constructed for each variety. Perkins and Pedersen (1987) also reported good fitness (R^2 = 0.66) using critical models at 3, 5, and 6 week after midsilk.

Negative variation in slope coefficients from the regression model also indicated that for every unit change in NLB, grain yields in ton/ha and 1000 grain weight was affected. Earlier, Pataky, (1992) reported that slope coefficient of -0.44 to -0.75 from the regression of percentage of yield on severity of NLB in the entire leaf canopy while Chenulu and Hora (1962) revealed that for every unit increase in the NLB intensity, loss in grain yield increased by17.3 % in maize. Slope coefficients from linear regression of percentage yield on NLB severity have been reported to range from -0.2 to -0.8, indicating 2 to 8 % reduction in yield for each 10 % NLB severity (Bowen and Pedersen, 1988; Fisher *et al*., 1976; Pataky, 1987; Pataky, 1994).

The present investigation established that maize varieties Bora, Kilima, Situka-1, Staha and Tmv-1were highly susceptible to northern leaf blight under artificial inoculation. This resulted to considerable yield losses in the maize varieties in Morogoro. It was also found that mancozeb sprays protected and increased yield of maize. Although the critical point model indicated good fit for the two years, differences in yield loss models were found in varieties and years. This explained the difficulties in estimating yield loss relationships. This study is the first report on the relationship between maize yield and northern leaf blight in Tanzania, therefore is imperative to estimate yield loss caused by NLB over years and many locations (James and Teng, 1979; Adipala *et al*., 1993) to compliment the finding of this study.

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