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Influence of Meteorological Parameters on the Development of Exerohilum Turcicum (Pass.) Leonard and Suggs. on Maize in Tanzania

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Abstract

Twenty maize varieties and inbred lines were used to determine the effect of weather parameters on the development of *Exserohilumturcicum*incitant of northern leaf blight disease in Tanzania. Artificially inoculated field experiments were conducted in Morogoro. Arusha and Mbeya Regions in 2013 and 2014 in a 15 m^2 plot size, replicated three times in Randomized Complete Block Design. The disease severity indexes were recorded at weekly interval from 65 Days after Sowing and subsequently for five weeks, while weather reports were obtained from Tanzania Meteorological Agency. Data were subjected to ANOVA, correlation coefficient and coefficient of determination ®²), while means were separated using LSD ($P \leq 0.05$). Results on disease severity index indicated high significant ($P \leq 0.05$) differences in the region, year, and interaction between region and year. Rainfall, relative humidity and temperature significantly favoured maize infection by *E. turcicum* in Mbeya, Arusha and Morogoro to 76.1 %, 58.3 % and 41.8 %, respectively. Negative significant ($P \leq 0.05$) correlation coefficients were found between minimum temperature and severity index in Morogoro ($r = -0.694$) and Arusha ($r = -0.748$) Regions while significantly positive correlation existed between relative humidity and severity index ($r = 0.739$) in Mbeya Region. Although the weather parameters encouraged prevalence of northern leaf blight disease in all the regions, relative humidity (69 %) in Mbeya favoured high development of the pathogen while minimum temperatures encouraged infection in Morogoro (18.6 °C) and Arusha(14.2°C) Regions.

Keywords: *Maize, Exserohilumturcicum, rainfall, relative humidity and temperature, Tanzania.*

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Background to the Study

Northern leaf blight caused by *Exserohilumturcicum* (Pass.) Leonard and Suggs.is very severe in cool humid regions characterized by heavy dew during the growing season (Shurtieff, 1980; Dorothea *et al*., 1998; Juliana *et al*., 2005). Jordan *et al*. (1983) reported that heavy dews, cool temperatures and frequent rains created environmental conditions conducive for disease development. A temperature range of 20-27°C, relative humidity from 90-100 % and low luminosity, the presence of large amount of inocula and long dew periods favour NLB epiphytotics (Hennessy *et al*., 1990; Bentolila*et al*., 1991; Gregory, 2004; Levic *et al*., 2008). Ullstrup (1970) reported that mild temperatures and humidity are paramount for epidemics of *Turcicum* blight. The pathogen was favoured by temperatures ranging between 17 to 27ºC (Shurtleff, 1980; Esteve, 1989). Khatri (1993) reported that in Georgia and Russia, the most favourable conditions for development of maize leaf blight were 22 to 25°C and 75 to 90 % relative humidity.

The aggressiveness of *E. turcicum* is based on the crop phenology, however, aggression is more on young seedlings (plants) at an optimum temperature of 20°C. With extended dew period and leaf wetness, lesion number, lesion size and inoculum concentration were reported to increase (Levy and Cohen, 1983; Bentolila, 1991). Furthermore, spread of NLB within and between fields occurs by conidia produced abundantly on leaf lesions. However, the disease is sporadic in occurrence depending on the environment and resistance of varieties grown (Degefu, 1990 and Perkins and Pedesen, 1987). Northern leaf blight of maize caused by *E. turcicum* is almost ubinquitous in all the countries where maize is grown and is a threat to maize production in many areas of the world (Muiru*et al*. 2010; Pandurangegowd., 1993; Kachapur, 1988; Harlapur*et al*., 2000).

In Tanzania, the disease is an important fungal foliar disease affecting several maize hybrids and composites (Nkonya, 1998). Among the diseases adversely affecting productivity, ubinquitous incidence of leaf blight in the pre-harvest stage is prominent. The disease is responsible for premature death of blighted leaves and results in significant yield reductions (Nwanosike, 2015a). Northern leaf blight severity of 40-70 % on susceptible and yield loss of 60 % have been reported in the neighbouring countries of Zambia, Uganda, Kenya, Ethiopia and South Africa (Simelane, 2007; Kloppers and Tweer, 2009; Haasbroek, 2014). However, there is no information on the pathogen epidemiology caused by this important disease of maize in Tanzania.

Seed treatment and application of fungicides have been recommended for management of NLB (Anon, 2004). Despite these management approaches, NLB continues to be a major constraint in maize production in Tanzania and other maize growing countries in Africa. Previous reports have shown variations among genetic background of different maize varieties and weather conditions in different regions and countries(Pandurangegowda, 1993; Harlapur, 2007; Nwanosike, 2015b; Nwanosike, 2016). Consequently, the variation has impeded the development of common strategies to combat northern leaf blight disease. Therefore, there is a need to study the disease development and weather factors associated with such development to facilitate suitable design for effective management practices.

It is quite necessary to conduct epidemiological studies to further sustain the relationship between maize and Tanzanian wide agro-ecological environment, such information on the disease outbreak is lacking currently. This will initiate systematic studies on NLB outbreak in Tanzania. Epidemiological studies play a vital role in developing prediction and forecasting models of the disease progress in relation to disease incidence and environmental factors. Therefore, this study determined disease development in relation to rainfall, temperature and relative humidity in Tanzania.

Materials and Methods

Study Area

Mbeya Region is a major maize producing area in the Southern Highlands (latitudes 7° and 11.5°S and longitudes 30° and 38°E), with both tropical and temperate. Temperatures are warm in the lowlands and cool in the highlands while rainfall pattern is unimodal (November to May), usually between 750 to 3,500 mm annually. Arusha Region is part of the Northern Highlands and covers about 9.3 % of the area of Tanzania (Nkonya, 1998). It has a diverse climate and as such produces a wide range of crops with maize as the second largest crop after wheat (Nkonya, 1991). Morogoro Region is in the Eastern zone with relatively low altitude, low to moderate unimodal (December to May) rainfall, however few bimodal rainfall areas benefit from the short rains which normally occur between October and November (Kaliba *et al.*, 1998).

Field Management

Field experiments were carried out in three locations, in the Crop Museum at Sokoine University of Agriculture, Morogoro, Agricultural Research Institute, Selian, Arusha and Agricultural Research Institute,Uyole, Mbeya. The 20 maize varieties and inbred lines(Bora, H208, H308, Kilima, Kito, PAN 63, PAN 67, Situka-1, Situka M1, Staha, Tan 222, TAN 250, TAN 254, TANH 600, TMV-1, TMV-2, UH 615, UH 6303, UHS5210 and ZM 309)were sown in a randomized complete block design (RCBD), replicated three times with plot size of 5 m x 3 m at a spacing of 75 cm x 30 cm inter and intra-rows, respectively. Each plot consisted of four rows and a one meter boarder separated treatments and replicates. Such plots were maintained in the same location of the same field for the two seasons of 2013 and 2014.

Planting was done in December in Mbeya and March in Arusha and Morogoro in the two seasons of 2013 and 2014. Basal application of Diamonium phosphate (DAP) was done on planting and top dressed with urea (46 % N) at 90 kg N ha^{-1} (Adipala*et al.*, 1993), three weeks after germination. To avoid insect infestation, dimethioate insecticide was applied twice in each location at 30 and 45 days after sowing based on commercial recommendation. Ten stands per plot were randomly selected from the two middle rows, tagged before inoculation and used for disease evaluation. Pure conidia of *E. turcicum*were counted with a haemocytometer, and the suspensions were adjusted to 10^5conidia/ml concentration (Levy, 1991; Xiaoming, 2014), into such suspension, 0.1 % of Tween 20 (polyoxythylenesorbitanmonolaurate) a surfactant was added at one drop per 100 ml for uniform spread of inoculum (Carson, 1995; Muiru*et al.*, 2007) and used for leaf inoculation. Field inoculation of plants with *E. turcicum*was done at 35 and 45 DAS, concentrating on the two middle rows of each plot using a hand plastic atomizer (Muiru*et al.*, 2007). The inoculation was done in the evening (1600 h).

Data on NLB disease severity were recorded at weekly interval for six weeks beginning from 65 DAS. Such stages of growth have been reported as the most important infection period of northern leaf blight of maize (Nwanosike, 2016). A visual scale of 0-5 base on leaf area infected in the whole plant basis was used to determine disease severity (CIMMYT, 1985; Durrishahwar, 2008), where 0 represented no lesion and 5 represented heavily blighted leaves (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 %), 5 = several coalesced lesions, leaf showing wilting, tearing and blotching typical blight symptoms).The arbitrary graduation of 10 class scale of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, and 5.0 were used for accurate measurement of the NLB disease severity (Jenkins and Robert, 1961).

The severity scores were converted into percent disease index (PDI) to determine the severity index(Wheeler, 1969) as shown below.

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

Weather reports on minimum and maximum temperatures, relative humidity and rainfall for 2013 and 2014 were obtained from Tanzania Meteorological Agency and used to determine the development of NLB disease.

Results and Discussion

Results (Table 1)indicated significantly (P ≤ 0.05) high disease severity index of northern leaf blight of maize in Regions, year and within interaction between Region and year, influenced by climatic factors that prevailed during the 2013 and 2014 growing seasons in Tanzania. However, the mean disease severity index was endemic in Mbeya (76.1 %) and Arusha (58.5 %) regions than Morogoro region which recorded 41.8 % (Table 2).

Table 1: Combined analysis of variance of *Exserohilumturcicum* on maize during the 2013and 2014 growing seasons.

Source of variation	DF	SS	MS	F	F pr.
Replication	2	189.1	94.6	0.33	
Region	2	422913.5	211456.7	739.49	<.001
Year	1	4101.9	4101.9	14.34	<.001
Region*Year	2	85697.4	42848.7	149.85	<.001
Residual	2152	615363.8	285.9		
Total	2159	1128265.7			

Statistical significant difference at p ≤ 0.05, DF = degree of freedom, SS = Sum of squares, MS = Mean squares

Table 2: Disease severity index of *Exserohilumturcicum*on maize varieties in Morogoro, Arushe and Mbeya Regions, Tanzania.

Region	2013	2014	Pooled
	PDI	PDI	PDI
Morogoro	32.8a	50.8a	41.8a
Arusha	64.7b	51.9a	58.3b
Mbeya	74.6c	77.6b	76.1c
SED±	0.89	0.73	1.26
LSD($P \leq 0.05$)	1.75	1.43	2.47
CV (%)	33.3	23.9	28.8

Means followed by the same letter in the same column are not significantly different according to Least Significant Difference ($P \leq 0.05$). PDI = Percent Disease index

On the bases of meteorological reports, relatively low minimum temperature (13.9°C) and maximum temperature (23.7°C), relative humidity (67 %) and cumulative rainfall (386.1 mm) in MbeyaRegion induced high disease severity index of 72.4 %. In Arusha Region,average minimum temperature (14.2°C) and maximum (22.6°C), relative humidity (91.1%) and rainfall (35 mm) recorded in 2013/2014 resulted todisease severity index of 59 %. Thecomparatively highminimum temperature (18.6°C), maximum temperature (28.9°C) coupled withlow relative humidity of 56.8 % and cumulative rainfall (62.6 mm)in Morogoro Region was associated to the low disease severity index (41.8 %) for 2013 and 2014growing seasons (Table 3).

Table 3: Mean weather data recorded during 2013 and 2014 growing seasons in Morogoro, Arusha and Mbeya Regions, Tanzania

	Max temp(°C)	**Min temp(°C)**	**RH(%)**	**RF(mm)**
Morogoro	28.9±1.0	18.6±1.6	56.8±7.7	62.6±11.8
Arusha	22.6±0.6	14.2±1.0	91.1±6.0	35±6.4
Mbeya	23.7±0.5	13.9±0.5	67±6.3	386.1±19.2

± = Standard deviation. Max and Min temp. = maximum and minimum temperatures, RH = Relative humidity, RF = Rainfall,

The pooled data during the period of disease evaluation (65-100 DAS) showed negative significant ($P \leq 0.05$) correlation coefficient (-0.694) between minimum temperature and disease severity index (Table 4). The study also indicated that of 49 % ($R^2 = 0.49$) disease index associated with weather condition, minimum temperature was significantly ($P \leq 0.05$)the most contributing factor, as it increase with a decreased in severity index. Maximum temperature, relative humidity and rainfall were negatively but non-significantly correlated with disease index (Table 4).

Table 4: Correlation coefficients between weather parameters and northern leaf blight disease severity index in Morogoro in 2013 and 2014 growing seasons.

S/no	Weather parameter	Disease index (%)		
		2013	2014	Pooled
1	Maximum temperature	-0.155	-0.365	-0.451
2	Minimum temperature	-0.939**	-0.862*	-0.694*
3	Relative humidity	-0.822*	-0.132	-0.086
4	Rainfall	-0.594	-0.645	-0.316
	R^2			0.492

***Significant at ≤ 0.01, *significant at ≤ 0.05, max., min. temp. (°C), RH and PDI (%), Rainfall (mm)*

High negatively significant ($P \leq 0.05$) correlation coefficient existed between minimum temperature and NLB disease severity index (-0.748) in Arusha, indicating that northern leaf blight infection increased with decreased maximum and minimum temperatures and increased relative humidity. Results also showed that maximum temperature, relative humidity and rainfall were not significantly different but negatively correlated with northern leaf blight disease severity index (Table 5). Coefficient of determination (R^2) associated 56 % of infection to weather condition in Arusha between 2013/2014. Similar to Morogoro, minimum temperature was the major contributing factor, however high correlation coefficient.

Table 5: Correlation coefficients between weather parameters and northern leaf blight disease severity index in Arusha in 2013 and 2014 growing seasons

S/no	Weather parameter	Disease index (%)		
		2013	2014	Pooled
1	Maximum temperature	-0.459	-0.524	-0.266
2	Minimum temperature	-0.776	-0.430	-0.748**
3	Relative humidity	-0.380	-0.638	-0.430
4	Rainfall	-0.559	-0.532	-0.432
	R^2			0.560

***Significant at ≤ 0.01, maximum, minimum temperatures (°C), relative humidity and disease index (%), Rainfall (mm).*

In Mbeya, results (Table 6) indicated significantly high positive ($P \leq 0.05$) relationship between northern leaf blight disease severity index and relative humidity (0.739) during the two growing seasons. The study also showed that maximum and minimum temperatures and cumulative rainfall were negatively but not significantly correlated with NLB disease index. This implied that, although 68 % ($R^2 = 0.677$) infection was associated to the weather parameters, relative humidity influenced the disease development compared to other factors.

Table 6: Correlation coefficients between weather parameters and northern leaf blight disease severity index in Mbeya in 2013 and 2014 growing seasons

S/no	Weather parameter	Disease index (%)		
		2013	2014	Pooled
1	Maximum temperature	-0.805	-0.653	-0.123
2	Minimum temperature	0.280	-0.609	-0.265
3	Relative humidity	0.733	0.609	0.739**
4	Rainfall	-0.282	0.369	-0.151
	R^2			0.677

***Significant at ≤ 0.01, max., min. temp. = °C, RH and PDI =%, Rainfall=mm.*

Discussion

The investigation clearly indicated temperature, relative humidity and rainfall in Mbeya (December-May) and Arusha (March-June) in 2013/2014 favoured high development of northern leaf blight disease in the maize varieties compared to Morogoro. This was evident in the average disease severity index recorded in Mbeya (76.1 %), Arusha (58.3 %) and Morogoro (41.8 %). High NLB disease levels occurred in late May for Morogoro and Arusha, but in Mbeya, the NLB disease was high in March. Such periods corresponded to when the climatic conditions were favourable for secondary infection by *E. turcicum*. In a survey report of NLB, Nwanosike*et al*., (2015b) also reported high incidence and severity in the humid Highlands of Mbeya and Arusha districts compared to the lowland dry Coastal and Morogoro districts. Northern leaf blight disease of maize have been reported as disease of highland agro-ecological and wet areas (Ramathani2010; Ramathani, 2011)

The high disease development in Mbeya was associated with low minimum and maximum temperatures (13.9°C), moderate relative humidity (67 %) and 386.1 mm cumulative rainfall which prevailed during the period of data collection for the two growing seasons. In Arusha, NLB disease index was directly related to temperatures (14.2°C) and high relative humidity (91.1 %), while relatively high minimum and maximum temperatures (18.6-28.9°C) and moderate relative humidity of 56.8 % may have reduced infection of maize by *E. turcicum* in Morogoro. Earlier, reports have shown that intermittent rains, low air temperature and high relative humidity, cloudy weather and long leaf wetness predisposed maize genotypes to NLB disease infection and spread, such was the case in Mbeya. Incidence of NLB disease may have been reduced with less rainfall, high temperature and low relative humidity as found in Morogoro (Sharma and Mishra, 1988; Khatri, 1993; Rai and Kummar, 2002; Pandurangegowda, 1994; Harlapur, 2000).

The negatively significant correlation between minimum temperature and disease severity index in Morogoro and Arusha indicated that minimum temperature was strongly and directly related to NLB disease development. However, the maximum temperature (28.9°C) in Morogoro and low cumulative rainfall in Arusha (35 mm) did not restrict NLB spread but may have been responsible for the moderate disease severity, particularly in Morogoro. The positively significant ($P \leq 0.05$) correlation between relative humidity and NLB severity index and the negative relationship with temperatures and cumulative rainfall in Mbeya, indicated favourable conditions for development of NLB disease. Previous reports have shown negative significant correlation coefficient between NLB disease of maize and minimum temperature and positive relationship with relative humidity and rainfall (Harlapur, 2000; Harlapur, 2005; Nwanosike, 2015b; Nwanosike, 2016). The coefficient of determination (R^2) associated 49.3 %, 56 % and 67.7 % infection to the weather parameters in Morogoro, Arusha and Mbeya, respectively. Earlier, Nwanosike, (2015b) reported that weather records were responsible for 38.2 %, infection of *E. turcicum* base on districts survey of NLB disease in Tanzania.

The study confirmed that the climatic factors were more conducive in Mbeya and Arusha regions for development NLB disease than in Morogoro Region. It is therefore, evident that temperatures, relative humidity and cumulative rainfall confirmed strong relationship with the development of northern leaf blight on maize during the 2013 and 2014 growing season. Being the first report on field epidemic study of *E. turcicum* in Tanzania, there is a need for extensive research in all maize growing regions to understand the pathogen behaviour overtime and to enable the disease forecast for sustainable management of the disease and maize production.

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