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Field assessment of disease resistance status of some newly-developed early and extra-early maize varieties under humid rainforest conditions of Nigeria

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Periodic assessment of resistant status of genetic materials in a breeding program is an important activity to ensure its continued progress. Forty newly-developed early and extra-early maize varieties were evaluated under natural field infection conditions for two years to assess their resistance status to some common diseases prevalent in the humid rainforest agro-ecology, and to determine effect of the diseases on grain yield and other agronomic characters. The experiment was laid out using a 5 x 8 alpha lattice design with three replications. Data were recorded on flowering traits, disease scores as well as yield and yield components. Data collected were subjected to analysis of variance, correlation and regression analyses. Results revealed that the varieties were significantly different for flowering traits, as well as yield and yield components except ears per plant, ear aspect and plant aspect. For disease scores, the varieties were not significantly different except for *Helminthosporum maydis*. There was a differential response of the early and extra-early maize varieties under the field evaluation conditions. However, all varieties maintained their resistance level against streak, northern leaf blight, southern leaf blight and smut. Although, none of these diseases significantly reduced yield, scores for *Curvularia* leaf spot and rust disease significantly exceeded the resistance threshold, suggesting an urgent attention is needed for the management of the diseases before the damages reach economic threshold.

Key words: Blight, *Curvularia*, maize, rainforest, streak.

INTRODUCTION

Maize (*Zea mays* L.) is an important staple cereal in sub-Saharan Africa because of its great economic value and wide adaptation to all agro-ecological zones in the region. It plays a critical nutritional role in human and animal diet. However, maize production in tropical Africa is constrained by a number of stress factors which could be biotic and abiotic. Important biotic stress in maize production is a complex of pests and diseases that significantly reduce the quantity and quality of production. Grain yield loses ranging from 1 to 70% have been reported due to some of the major diseases, which depend on factors such as genetic constitution of the cultivars, stage of growth at the time of infection, and environmental conditions (Bua and Chelimo, 2010).

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The maize plant is susceptible to many diseases that affect yield and quality of the crop. These diseases are caused by both infectious and non-infectious causal agents. Infectious causal agents are biological organisms that increase their population on diseased plants and then are spread to healthy plants, causing disease. They include fungi, bacteria, viruses, nematodes, and other organisms that are commonly thought of as plant pathogens. The losses due to diseases cannot be adequately estimated because disease symptoms are found on virtually all maize plants, and it is rather very difficult, if not impossible to create conditions where the plant is completely free from disease. The greatest losses caused by disease are probably from those diseases that occur annually.

Among the diseases of economic importance in maize production in the humid tropics of Nigeria is streak. The disease is caused by a geminivirus that is transmitted by viruliferous leafhoppers of the genus *Cicadulina mbila*. Incidence of maize streak is estimated at 60% across all African agro ecosystems where maize is grown (De Vries and Toenniessen, 2001) and it is considered as the most widespread biotic constraint to maize production. Rusts is another important maize disease caused by a fungus (*Puccinia polysora*). The pathogen has distinctive reproductive structures called pustules that erupt through the surface of leaves, stalks, or husks and produce spores called urediniospores which are round and red-brick in colour scattered on the leaf surface and occur on both leaf surfaces. Severe infections can lead to defoliation and premature senescence (CIMMYT, 2004).

Northern corn leaf blight (NCLB*)* is caused by a fungus *Helminthosporium turcicum.* Its symptom is typified by long (length: 2 to15 cm) lesions with tapered ends that is gray-green to tan lesions in colour on lower leaves at the beginning, but can spread to all leaves and husks with secondary infections. The disease is prevalent in areas of high altitude and cold regions but its incidence has been noticed among some inbred lines in the humid rainforest locations in Nigeria lately. Southern corn leaf blight is another disease of notable economic importance caused by a fungus *Helminthosporium maydis.* It is favoured by warm temperature, high rainfall and high humidity. Typically, it is more of a problem in the south-western region of Nigeria than northern corn leaf blight (CIMMYT, 2004). Other important diseases of maize in this region are *Curvularia* leaf spot (CLS): caused by the fungus *Curvularia lunata* (Wakker) Boedijn which results in yield losses up to 20 to 30% (Dai et al., 1996; Lui et al., 1997) and corn smut caused by *Ustilago maydis*.

Southwestern zone of Nigeria is characterized by high temperature, rainfall, and relative humidity, conditions, which favour high disease incidence and build-up. It is therefore a hotspot for testing resistance status of newly developed maize varieties and hybrids in the sub-region.

Although, the incidence and severity of most of these diseases can be reduced by chemical control methods ranging from seed dressing to foliar spraying, host plant resistance provides the most economical management option to farmers, which is also environmentally friendly. The scientists at the International Institute of Tropical Agriculture (IITA) and national agricultural research stations in Nigeria had, in time past, worked hard to develop maize germplasm sources that are resistant to most maize diseases of economic importance in the region and routinely generate new maize genetic materials from these germplasm sources so that, resistance to those common diseases are automatically acquired by the new materials.

However, most times, resistance breakdown due to segregation of genes for resistance, mutation of the pathogens or introduction of new morphotypes or ecotypes of the pathogens cause disease. Therefore, it is important to periodically examine the level of resistance of the newly developed maize genetic materials to these common diseases. This could be carried out in a screenhouse facility where, the inoculum of the diseases is artificially applied and the symptoms recorded. Another alternative is the use of natural field screening at hot spot where such disease is endemic.

The objectives of the study were to (i) assess resistance status of early and extra-early maize varieties to some common disease conditions, prevalent in the humid rainforest agro-ecology, and (ii) determine effect of the diseases on grain yield and other agronomic characters of the varieties.

MATERIALS AND METHODS

Location

The study was carried out at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife (7°28'N, 4°33'E, rainfall 1150 mm, altitude 224 m above sea level) which is located in the humid rainforest ecology of southwestern Nigeria. The experiment was conducted during the cropping seasons of 2014 and 2015, when disease incidence is usual maximum.

Plant materials and field layout

Forty early and extra-early maize varieties with divergent reactions to biotic and abiotic stresses developed for the mid-altitude and sub-humid agro-ecologies of west and central Africa by the Maize Improvement Unit of the (IITA) were used for this study. Brief description of the characteristics of 40 maize varieties was given in Table 1. The experimental field had been left to fallow for a year. The land was ploughed twice, and harrowed two weeks before the layout and planting was done. A 5 x 8 alpha lattice design with four replications was used for the evaluation of the genetic materials. Each plot consisted of a two-row, 5 m long, spaced 0.75 m apart with, within row spacing of 0.5 m.

The planting was done manually on the 25th July, 2014 and 13th June, 2015. Three seeds were sown per hill. Atrazine was sprayed as a pre-emergence herbicide, immediately after planting at the rate of 1.5 litres per ha. Two weeks after planting, the three seedlings per stand were thinned to two to maintain plant population of 66,666 plants per hectare. Three days later, a compound fertilizer,

Table 1. Description of the genetic materials evaluated at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. Nigeria and their reactions under stress.

S/N	Pedigree	Maturity	Endosperm colour	Endosperm type	Reaction to drought	Reaction to *Striga* infestation
1	TZEE-W STR BC_5	Extra-early	White	Normal	Susceptible	Highly resistant
2	TZE-WPOP DT STR C_4	Early	White	Normal	Resistant	Resistant
3	2009 TZE-WDT STR	Early	White	Normal	Resistant	Resistant
4	2000 SYN EE-W STR	Extra-early	White	Normal	Susceptible	Resistant
5	EVDT-Y 2000 STR	Early	Yellow	Normal	Susceptible	Resistant
6	DTE STR-Y SYN 2000 POP C_2	Early	Yellow	Normal	Resistant	Resistant
7	2008 DTMA-Y STR	Early	Yellow	Normal	Resistant	Resistant
8	2009 DTE-Y STR	Early	Yellow	Normal	Resistant	Resistant
9	EVDT-Y 2000 STR QPM	Early	Yellow	QPM	Susceptible	Resistant
10	DTE-W STR SYN	Early	White	Normal	Resistant	Resistant
11	2008 TZEE-Y STR	Extra-early	Yellow	Normal	Susceptible	Resistant
12	2009 TZEE-OR_2 STR QPM	Extra-early	Orange	QPM	Susceptible	Resistant
13	2009 TZEE-OR_1 STR	Extra-early	Orange	Normal	Susceptible	Resistant
14	2000 SYN EE-W STR QPM	Extra-early	White	QPM	Susceptible	Resistant
15	99 TZEE-Y STR QPM	Extra-early	Yellow	QPM	Susceptible	Resistant
16	2008 SYN EE-W DT STR	Extra-early	White	Normal	Resistant	Resistant
17	TZEE-W POP STR C_5	Extra-early	White	Normal	Susceptible	Resistant
18	TZEE-WPOP STR 104 BC_2	Extra-early	White	Normal	Susceptible	Resistant
19	DTSTR-Y SYN POP C_3 F_1	Early	Yellow	Normal	Resistant	Resistant
20	SYN DTE STR-Y	Early	Yellow	Normal	Resistant	Resistant
21	EVDT-Y 2000 STR QPM	Early	Yellow	QPM	Resistant	Resistant
22	2011 TZE-Y DT STR	Early	Yellow	Normal	Resistant	Resistant
23	TZE-Y POP DT STR QPM	Early	Yellow	QPM	Resistant	Resistant
24	EVDT-W 2008 STR	Early	White	Normal	Resistant	Resistant
25	2009 TZEE-OR_1 DT STR QPM	Extra-early	Orange	QPM	Resistant	Resistant
26	2004 TZEE-W POP STR C_4	Extra-early	White	Normal	Resistant	Resistant
27	SYN DTE STR-W	Early	White	Normal	Resistant	Resistant
28	DT-W STR SYN	Early	White	Normal	Resistant	Resistant
29	2011 TZE-W DT STR SYN	Early	White	Normal	Resistant	Resistant
30	2008 DTMA-Y STR	Early	Yellow	Normal	Resistant	Resistant
31	EV DT-Y 2008 STR	Early	Yellow	Normal	Resistant	Resistant
32	DTE STR-W SYN POP C_3F_1	Early	White	Normal	Resistant	Resistant
33	2004 TZEE-YPOP STR C_4	Extra-early	Yellow	Normal	Resistant	Resistant
34	2013 DTE STR-W SYN F_1	Early	White	Normal	Resistant	Resistant

Table 1. Contd.

35	2011 DTE Y STR SYN	Early	Yellow	Normal	Resistant	Resistant
36	2013 DTE STR-Y SYN F_1	Early	Yellow	Normal	Resistant	Resistant
37	2012 TZE-W POP DT C_4 STR C_5	Early	White	Normal	Resistant	Resistant
38	TZEE-Y POP STR C_2	Extra-early	Yellow	Normal	Moderately resistant	Moderately resistant
39	TZEE-W POP STR QPM C_2	Extra-early	White	QPM	Moderately resistant	Moderately resistant
40	TZEE-Y POP STR C_2 QPM	Extra-early	Yellow	QPM	Moderately resistant	Moderately resistant

NPK 15-15-15, was applied by side placement method at the rate of 60 kg per ha and 5 weeks after planting, additional 30 kg N per ha was applied as top dressing using urea fertilizer. Weed control at this stage was carried out by hand weeding. No disease control measure was applied throughout the period of the experiment except seed dressing with Apron-plus to prevent rodents and birds from picking the seeds before and during germination.

Data collection

Data were recorded on emergence percentage, number of days to 50% silking and 50% anthesis and anthesis-silking interval was calculated as the difference between the days to silking and anthesis. Plant height was recorded as the average heights of 10 plants per plot from the soil level to the first tassel branch. The mean height per maize plant was determined during leaf stage seven.

Five common foliar diseases were scored on plot basis. The diseases included *Curvularia* leaf spot, southern leaf blight caused by *H. maydis*, northern leaf blight caused by *H. turcicum*, maize rust caused by *P. polysora*, corn smut caused by *U. maydis* and streak caused by maize streak virus. In identifying the disease symptoms, a handbook of diseases published by the International Maize and Wheat Centre (CIMMYT) was used (CIMMYT, 2004). Severity of each of the five diseases was evaluated using rating scale of 1 to 5 according to the breeder's scale International Institute for Tropical Agriculture's standard (IITA) and Blight *H. maydis, H. turcicum* are scored on plot basis on a scale of 1 to 5 as given as follows; 1 = slight infection very few lesions on leaves, usually only on the lower leaves of the plant; 2 = light infection few to moderate lesions on leaves below top ear, no lesions on leaves above the top ear; 3 = moderate infection, moderate to large number of lesions on leaves below the top ear, few lesions on leaves above the top ear; 4 = heavy infection, large number of lesions on leaves below the top ear, moderate to large number of lesions on leaves above the top ear; 5 = very heavy infection, all leaves with large number of lesions leading to premature death of the plant and light ears (Badu-Apraku et al., 2012).

Similarly, *Curvularia* leaf spot, rust (*P. polysora*), and streak were scored on plot basis using a 1 to 5 rating scale based on the proportion of the ear leaf that is covered with lesions. The scale is as follows: 1 = slight infection: less than 10% of the ear-leaf covered by lesions. 2 = light infection: 10 to 25% of the ear-leaf covered by lesions; 3 = moderate infection 26 to 50% of the ear-leaf covered by lesions; 4 = heavy infection: 51 to 75% of the ear-leaf covered by lesions, leading to premature death of the plant and light cobs; 5 = very heavy infection: 76 to 100% of the ear-leaf covered by lesions, leading to premature death of the plant and light cobs (Badu-Apraku et al., 2012).

In all cases, scores < 3 signified resistance of genotype to the disease while any score greater than 3 indicate susceptibility of the genotypes to the disease (Badu-Apraku et al., 2012). Plant aspect was scored on a plot basis using a scale of 1 to 5 based on the plant's general appeal and architecture with features such as uniform medium-height plants standing erect, strong stalk, uniformly big ears, well covered with husk and uniformly placed at the middle of the plant, no visible symptoms of any common tropical diseases on leaves, stems, and ears, on the scale, 1 = excellent plant architecture; 2 = very good plant architecture: 3 = satisfactory plant architecture: 4 = poor plant architecture and 5 = very poor plant architecture (Akinwale and Adewopo 2016). When the cobs were fully developed, the varieties were assessed for their susceptibility to root and stem lodging based on scale 1 to 5, where, 1= excellent (no lodging), 2 = very good, 3 = good, 4 = fair and 5 = poor.

Husk cover as well ear aspects were rated visually on a scale of 1 to 5, where 1 = clean, uniform, well covered husk, deep greenish plant appearance, large and well-filled ears, and 5 = opened husk with rotten, small and partially filled ears (Badu-Apraku et al., 2012). Sixteen weeks after planting, harvesting was done. Data were recorded on the number of ears per plot. Ear aspect was measured on a plot basis using a scale of 1 to 5, where 1 = excellent ears: uniformly big ears, well filled with grains, no ear rot or other ear disease symptoms, 2 = very good ears: uniform moderate-sized ears, well filled with grains, no ear rot or other ear disease symptom; 3 = satisfactory ears: less uniform moderate-sized ears, well filled with grains, no ear rot or other ear disease symptom; 4 = poor ears: small-sized ears, poorly filled with grains, slight symptoms of ear rot and other diseases; and 5 = very poor ears: very small-sized ears, ears poorly filled with grains and severe symptoms of ear rot and other ear diseases (Badu-Apraku et al., 2012).

Cobs were harvested on plot basis and ear weight was taken using a weighing balance. Grain yield per hectare was computed on the basis of ear weight per plot, and the weight was adjusted to 80% shelling percentage (800 g grain kg^{-1} ear weight) and 15% (150 g kg^{-1}) moisture content (Badu-Apraku et al., 2012).

Statistical analyses

Data collected were subjected to analyses of variance (ANOVA) to test for significant differences among genotypes for the traits measured for each year. Having tested for homogeneity of variance using Levene's test, combined ANOVA was carried out to test the effect of year, variety and variety × year interaction of the agronomic performance

Table 2. Means squares from analysis of variance for emergence and flowering traits of 40 maize varieties belonging to two maturity groups evaluated under field conditions at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. Nigeria

Source	DF	Emergence (%)	Days to tasseling	Days to anthesis	Days to silking	ASI
Year (Y)	1	89.01	2.10	3.69	2.01	4.01*
Block/Rep*Y	24	169.93	1.21	2.08	1.15	1.41
Rep/Y	4	11.75*	8.01*	26.29**	26.85**	0.08
Variety (G)	39	1291.74**	3.28*	5.39**	11.28**	7.22**
Extra-early (EE)	15	435.63**	2.72	5.19**	11.12**	0.32
Early (E)	23	589.19**	3.40**	5.18**	1.90**	4.84*
E vs EE	1	144.92	5.67	16.37**	2.42	6.19*
G x Y	39	103.01	2.20	2.18	1.65	1.97
Error	69	222.15	2.01	2.37	1.27	2.25
R-square (%)		78	53	63	85	66
CV (%)		24.27	2.78	2.91	2.04	64.88

*, ** Significant and highly significant at p<0.05 and p<0.01 levels, respectively, DF: degree of freedom, S V: source of variation, C V: coefficient of variation, ASI: anthesis-silking interval.

Table 3. Means squares from analysis of variance for grain yield and yield component traits of 40 maize varieties belonging to two maturity groups evaluated under field conditions at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife Nigeria in 2014 and 2015.

Source of variation	DF	EPP	Number of ears per plot	Ear aspect	Plant aspect	Plant height, cm	Grain yield,kg ha $^{-1}$
Year (Y)	1	0.34	10.24	0.19	0.22	0.031	1154334**
Block/Rep*Y	24	0.65	33.02	0.1	0.71*	0.024	156748.2
Rep/Y	4	0.43	390.21**	0.83**	0.53	0.071*	954093.3
Variety (G)	39	0.39	167.14**	0.20	0.27	0.023*	1012167.9**
Extra-early (EE)	*15*	*0.27*	49.11	0.23	0.45	0.02	278276.0
Early (E)	*23*	*0.47*	97.01**	0.10	0.19	0.02	561603.6**
E vs EE	*1*	*0.22*	9.06	1.01**	0.005	0.01	86051.4
G x Y	39	0.33	51.06*	0.25	0.002	0.021	1002471.5*
Error	69	0.44	62.4	0.14	0.32	0.02	335135.5
R-square (%)		67	65	53	46	57	69
C.V (%)		26.53	29.18	13.03	18.9	7.51	23.51

*, ** Significant and highly significant at p <0.05 and p <0.01 levels, respectively.

and disease scores.

Significant means were separated using Least Significant Difference (LSD). Correlation and regression analyses were also done to assess relationship among traits. All analyses were carried out using Statistical Analysis Software (SAS) version 9.2 (SAS Institute, 2002).

RESULTS AND DISCUSSION

Field performance of the 40 early and extra-early maize varieties

Results of analysis of variance on the response of the 40 newly developed varieties of maize to some common tropical diseases revealed that, the 40 varieties were significantly different from flowering traits (Table 2), as well as for yield and yield components except EPP ear aspect and plant aspect (Table 3). For disease scores, the varieties were not significantly different except for *Helminthosporum maydis* (Table 4). Partitioning the variety effect into variation within varieties in each maturity group and variation between the two maturity groups revealed that significant variation among the 40 varieties for emergence and days to silking was due to the variation in varieties within each maturity group rather than variation between maturity groups. Furthermore,

Table 4. Mean squares from analysis of variance for disease severity scores of the 40 maize varieties belong to early and extra-early maize maturity groups tested under field conditions at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife in 2014 and 2015.

Source of variation	DF	*Curvularia* Leaf spot	*Exserohilium turcicum*	Maize streak	*Helminthosporum maydis*	*Puccinia polysora* RUST	*Ustilago maydis* (SMUT)
Year (Y)	1	0.11	0.06	0.21	0.12	2.12	0.0021*
Block/Rep*Y	24	0.1	0.70*	0.27	0.47	0.72**	0.0002
Rep/Y	4	1.28**	4.83**	0.13	0.47	9.64**	0.0001
Variety (G)	39	0.09	0.21	0.27	0.53*	0.21	0.0010
Extra-early (EE)	15	0.10	0.22	0.14	0.57	0.18	0.0053
Early (E)	23	0.17	0.27	0.33	0.54*	0.44	0.0030
E vs EE	1	0.02	0.31	0.02	1.19	0.02	0.0021
G × Y	39	0.05	0.23	0.27	0.73*	0.21	0.0030
Error	69	0.08	0.23	0.31	0.3	0.26	0.0003
R-square (%)		55	60	43	54	66	42
CV (%)		8.25	20.36	43.00	24.37	16.13	6.38

*, ** Significant and highly significant at p<0.05 and p<0.01 levels respectively, S V: source of variation, DF: degree of freedom.
CV: coefficient of variation.

variation in the 40 genotypes was accounted for by significant variation among varieties within early maturity group alone, for anthesis-silking interval (ASI) was as a result of variation within early varieties and between the two maturity groups while for days to anthesis, the difference among the 40 genotypes was due to variation among varieties within each and between maturity groups (Table 2). Forty maize varieties exhibited resistance to smut (*U. maydis*), southern leaf blight (*H. maydis*), northern leaf blight (*Exserohilium turcicum*) and streak disease as indicated by their low maximum severity scores but susceptible to *Curvularia* leaf spot (*C. lunata*) and leaf rust (*P. polysora*).

The result of this study on the response of 40 maize varieties to *H. maydis was* contrary to findings in earlier studies where, the organism caused negative effect on maize genotypes having male sterility inducing T cytoplasm (Gengenbach et al., 1973; Earle et al., 1978). In these studies, trace of the pathogen caused epiphytoty on maize hybrids which have been produced on the basis of Texas type of sterile cytoplasm. The result stimulated further studies on developing alternative types of male sterility inducing cytoplasms in different crops. However, in this study, experimental varieties were used, not cytoplasmic male sterility (CMS) hybrids and this may explain differences in the response of the genetic materials to the pathogen.

The varieties were significantly different for most traits measured. All varieties had desirable scores (maximum scores < 3.0) for streak and smut, indicating that all varieties showed resistance to both diseases. In contrast, the maximum scores for the varieties were greater than 3.0 for *E. turcicum, Curvularia* leaf spot, *H. maydis* and rust fungus, indicating that at least one variety was susceptible to the fungal diseases (Table 5).
DTE STR-W SYN POP C_3F and 2013 DTE STR-Y SYN F_1 had the highest yield, 2840 and 2832 kg ha^{-1}, respectively (Table 5). The two varieties had desirable scores for most diseases (<3.0) except for *Curvularia* and rust (Table 5). This implied that even though the two varieties had high symptoms of *Curvularia* leaf spot and leaf rust fungi, the fungi infection did not affect the yielding ability of the two highest yielding varieties. However, it is not advisable for breeders to wait until these two diseases get beyond the economic threshold before attention is paid to upgrade tolerance of the newly developed varieties.

For streak and smut, 100% of the varieties were

Table 5. Means for disease severity scores and other agronomic traits of the top 10 yielding varieties and 5 worst yielding varieties at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. Nigeria.

Variety	Maturity	Emergence	Days to tasseling	Days to anthesis	Days to silk	ASI	*E. turcicum*	*Curvularia*	Streak	*H. maydis*	Smut	Rust	Ear aspect	Plant aspect	Ears per plot	Ears per plant	Grain yield
DTE STR-W syn POP C_3F	Early	60	53	55	58	2	3.0	3.3	1.2	2.2	1.0	3.5	2.8	3.3	33.6	1.5	2840
2013 DTE STR-Y syn F_1	Early	55	53	56	60	4	2.8	3.1	1.0	2.4	1.0	3.0	2.8	3.2	27.1	1.0	2832
TZEE-WPOP STR QPM C_2	Extra-early	46	53	56	61	5	3.2	3.3	1.0	2.5	1.0	3.2	3.2	2.8	32.5	1.2	2703
TZE-W POP DT STR C_4	Early	20	56	58	59	1	3.0	3.6	1.6	2.7	1.0	3.1	3.0	2.4	34.5	2.3	2669
TZEE-W POP STR 104 BC_2	Extra-early	56	54	56	59	3	3.1	3.5	1.0	2.8	1.2	3.5	2.9	2.9	29.3	1.0	2637
2004 TZEE W POP STR C_4	Extra-early	52	53	55	58	3	2.5	3.2	1.1	3.1	1.0	3.4	3.2	2.7	22.0	1.2	2629
DT-W STR syn	Early	38	54	55	60	4	2.8	3.5	1.1	2.4	1.0	3.3	3.0	2.8	34.5	1.2	2598
syn DTE STR-W	Early	37	54	56	61	5	2.7	3.5	1.1	2.7	1.0	3.0	2.7	3.0	27.9	1.7	2555
2009 DTE-Y STR	Early	35	54	58	59	1	3.2	3.4	1.3	2.3	1.0	3.2	2.7	3.3	28.5	0.9	2530
syn DTE STR-Y	Early	43	53	55	59	5	2.8	3.8	1.5	2.1	1.0	2.6	3.0	2.6	35.9	1.3	2491
2008 DTMA-Y STR	Early	54	55	59	61	2	3.3	3.3	1.7	2.9	1.0	2.9	3.1	3.3	24.6	1.1	1542
EVDT-Y 2000 STR	Early	35	53	56	60	4	3.4	3.5	1.2	2.3	1.0	3.0	2.9	2.8	25.4	1.4	1489
TZEY Pop DT STR QPM	Early	14	54	56	60	3	2.9	3.8	1.1	2.7	1.0	2.7	2.7	3.3	19.4	0.8	1427
EVDT-W 2008 STR	Early	40	54	55	60	4	2.8	3.2	1.4	2.3	1.0	3.0	3.0	3.0	29.2	1.3	1414
2008 TZEE Y STR	Extra-early	57	53	54	56	2	2.7	3.4	2.2	1.9	1.0	3.3	3.0	2.4	26.4	1.0	1373
Mean		41	54	56	60	3	2.9	3.3	1.3	2.3	1.0	3.0	2.9	3.0	27.3	1.2	2113
SE		2.25	0.17	0.23	0.22	0.19	0.05	0.04	0.06	0.07	0.01	0.06	0.04	0.05	0.80	0.05	65.0
Minimum		10	53	54	56	1	2.1	2.7	0.9	1.2	1.0	2.1	2.4	2.4	16.1	0.6	1373
Maximum		61	57	61	64	5	3.4	3.8	2.4	3.1	1.2	3.7	3.6	3.6	35.9	2.3	2840

tolerant (Table 6). Disease with highest percentage of susceptible varieties was *Curvularia* leaf spot (90%), followed by rust (82.5%) Northern corn blight (22.5%) and Southern corn blight (2.5%). It is important to note that Northern corn blight, which is known as a common disease in higher altitude and colder regions is becoming prominent in the hotter and humid climate. The reason for this is yet to be fully investigated. However, the scenario could be attributed to climate change. Furthermore, it was observed that 90 % of the 40 varieties were susceptible to *Curvularia* leaf spot. Of these 40 varieties, 100% of the extra-early maize varieties were susceptiblewhile 83% of the early varieties showed susceptibility to *Curvularia* (Table 6). This suggests that more of the extra-early varieties were susceptible to *Curvularia*. Similarly, more of the extra-early varieties showed susceptibility to leaf rust (69%) than the early varieties (54%). In contrast, the early maize had more varieties that were susceptible to Northern corn blight (25%) than the early maize (19%) (Table 6).

Relationship among traits

Across maturity groups, northern corn blight, southern corn blight, streak and smut had no significant relationship with any agronomic traits including grain yield (Table 7). This result may suggest that even though there were visible symptoms of these diseases on the plants, they did not significantly affect the performance and productivity of the maize varieties, thus most of the varieties evaluated, by and large, showed tolerance to most common diseases. This result is in agreement with Olakojo et al. (2005), who reported tolerance of newly developed QPM and normal-endosperm maize to some diseases in south-western Nigeria. The result on the effect of streak is in contrast with the findings of Bosque et

Table 6. Proportion of tolerant and susceptible varieties for different diseases at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. Nigeria.

Disease	All varieties		Early varieties		Extra-early varieties	
	Tolerant (%)	Susceptible (%)	Tolerant (%)	Susceptible (%)	Tolerant (%)	Susceptible (%)
Curvularia leaf spot	10.0	90.0	17	83	0	100
Northern corn blight	77.5	22.5	75	25	81	19
Maize streak	100.0	0.0	100	0	100	0
Southern corn blight	97.5	2.5	100	0	94	6
Corn smut	100.0	0.0	100	0	100	0
Leaf rust	17.5	82.5	46	54	31	69

Table 7. Correlation between agronomic traits and severity scores of common diseases across 40 early and extra-early maturing maize varieties and for each maturity group at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. Nigeria.

Variables	Combined						Early						Extra-early					
	TUR	MAYDIS	CUR	SR	RUST	SMUT	TUR	MAYDIS	CUR	SR	RUST	SMUT	TUR	MAYDIS	CUR	SR	RUST	SMUT
TASSEL	-0.04	0.14	-0.59**	-0.13	-0.33*	0.17	-0.17	0.22	-0.46*	-0.12	-0.35	0.08	0.19	0.06	-0.77**	-0.31	-0.42	0.33
ANTH	-0.04	0.14	-0.67**	-0.22	-0.10	0.06	-0.25	0.20	-0.56**	-0.30	-0.13	0.12	0.28	0.15	-0.82**	-0.29	-0.20	0.08
SILK	0.09	0.04	-0.52**	-0.10	-0.28	-0.02	-0.14	-0.06	-0.23	-0.05	-0.60**	-0.12	0.25	0.16	-0.67**	-0.27	-0.17	0.04
EASP	-0.04	0.03	0.00	-0.18	-0.05	-0.11	-0.21	0.03	0.30	-0.14	0.04	-0.18	0.07	-0.05	-0.21	-0.14	0.00	-0.15
PASP	-0.07	-0.05	-0.13	-0.28	0.09	-0.14	-0.15	-0.02	-0.23	-0.51**	0.20	-0.23	0.00	-0.12	-0.08	0.07	0.03	-0.09
EARNO	-0.07	-0.08	0.31*	0.05	0.01	-0.06	-0.24	0.21	0.27	0.01	0.29	-0.20	0.21	-0.68**	0.38	0.18	-0.48*	0.12
MC	-0.05	0.09	0.28	-0.04	-0.03	-0.19	0.20	0.15	0.63**	0.01	-0.02	-0.01	-0.33	-0.02	0.01	-0.08	0.02	-0.37
ASI1	0.15	-0.11	0.19	0.15	-0.21	-0.10	0.17	-0.24	0.44*	0.28	-0.24	-0.19	0.09	0.09	-0.13	-0.10	-0.04	-0.04
EPP	-0.09	0.16	0.19	-0.12	-0.15	-0.03	0.01	0.43*	0.23	-0.18	-0.07	-0.07	-0.25	-0.38	0.16	-0.02	-0.37	0.07
YIELD	-0.04	0.04	-0.06	-0.08	0.12	0.10	0.01	-0.06	-0.06	0.04	0.20	-0.07	-0.10	0.29	-0.05	-0.52*	-0.07	0.36

al. (1998), who reported that streak mosaic virus disease was negatively correlated with plant height, dry weight, grain weight per plot, 1000-grain weight, ear length and diameter. This confirms that, maize breeders in this sub-region routinely incorporate tolerance/resistance to some common diseases into newly developed varieties even when the breeding target is not on disease resistances. More so, the result on *E. turcicum* was contrary to the findings of Nwanosike et al. (2015) who reported in their work on 5 varieties of maize that, Northern corn blight was negatively correlated with yield grain.

Contrary to the response of the maize plants to the diseases mentioned above, *Curvularia* had significant correlation with days to tasseling (r = - 0.59 **), days to anthesis (r = - 0.67 **), days to silk (r = - 0.52 **) and number of ears per plot (r = 0.31 *). This result indicates that as scores for *Curvularia* increased (indicating susceptibility) the days to flower decreased (earliness). In other words, *Curvularia* infection resulted in earliness to flower or the early maturing varieties which is more susceptible to *Curvularia* infection than the

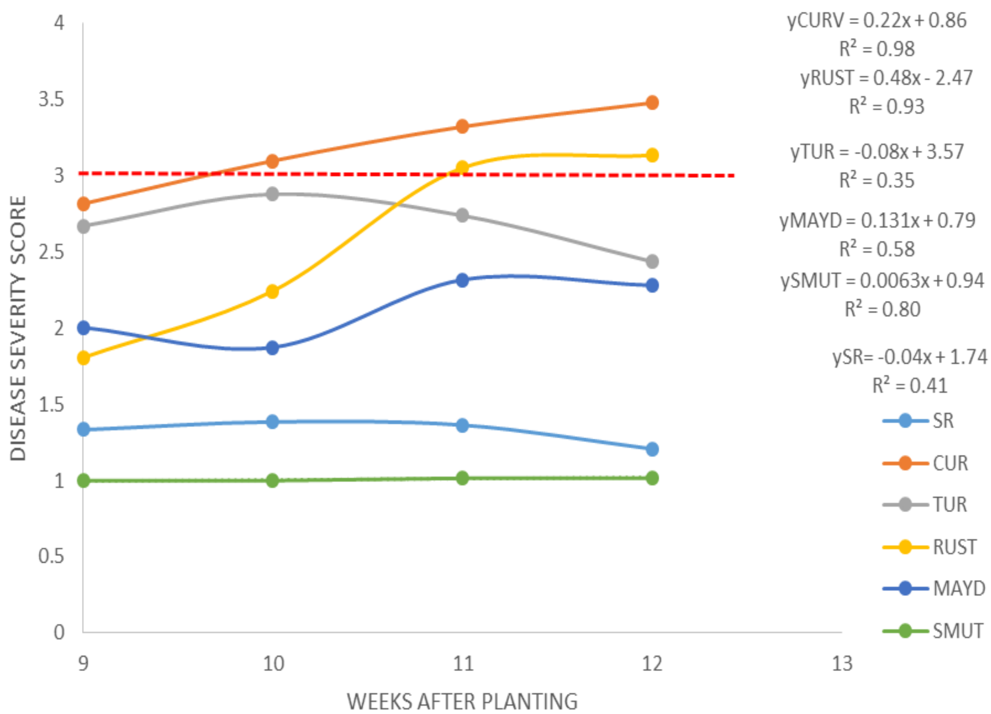

Figure 1. Response of extra-early maize varieties to common diseases in the humid rainforest agro-ecological conditions at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. Nigeria. SR = Maize streak; CUR= Curvularia leaf spot; TUR = Northern corn blight by *Exserohilium turcicum*; RUST= Rust fungi; corn smut *Ustilago maydis*. MAYD= Southern corn blight caused by *Helminthosporium maydis*

late maturing ones. Varieties that were susceptible to *Curvularia* flowered earlier than the tolerant varieties. In a study on incidence and severity of some common diseases of maize, Akonda et al. (2015) reported that *Curvularia* leaf spot was one of the two most virulent diseases in the region negatively affecting plant's health and yield. In addition, leaf rust also had significant correlation with days to tasseling (r = - 0.33*), although the r^2 of 10.89% indicates that the relationship is very weak.

Furthermore, results of correlation between agronomic traits and diseases severity scores showed differential pattern in the response of the the different maturity groups to the different diseases. No agronomic traits had significant correlation with severity scores for *E. turcicum* and smut, indicating that these diseases had no significant effect on the performance and productivity of both maturity classes of maize. Among phenological traits, *Curvularia* leaf spot had significant relationship with days to tassel (r = - 0.46 *), days to anthesis (r = - 0.56 *) and ASI (r = - 0.44 *) for early maize but for extra-early maize, *Curvularia* score had significant correlation with days to tassel (r = - 0.77 **), days to anthesis (r = - 0.82 **) and days to silk (r = - 0.67 **). This result implies that *Curvularia* significantly increase days to flowering of maize. Since the correlation coefficient and resulting R-squares between *Curvularia* and flowering traits were higher for extra-early maize than those of early maize, it indicates that *Curvularia* had higher effect on flowering traits of extra-early than early maize varieties. Moreover, *H. maydis* had significant relationship with number of ears per plant (EPP) among early maize varieties but had significant relationship with number of ears per plot among extra-early maize varieties.

Results of the regression analysis revealed that only rust and *Curvularia* leaf spot scores got beyond the susceptibility threshold (>3.0) for extra-early maize varieties (Figure 1). This implies that proper management practices are necessary to bring these diseases under control when extra-early maize varieties are produced. In addition, the results further showed that rust had the highest rate of disease progression per week (b-value = 0.48) followed by *Curvularia* leaf spot (b-value = 0.22). In contrast, other diseases were below the susceptibility threshold with smut and streak being the lowest. This implied that extra-early maize varieties are still largely resistant to diseases such as smut, streak, Northern and Southern leaf blight and therefore no need for control measures.

The pattern of response of early maize varieties to the common diseases under field conditions was similar to that of extra-early varieties. For the early, only *Curvularia*

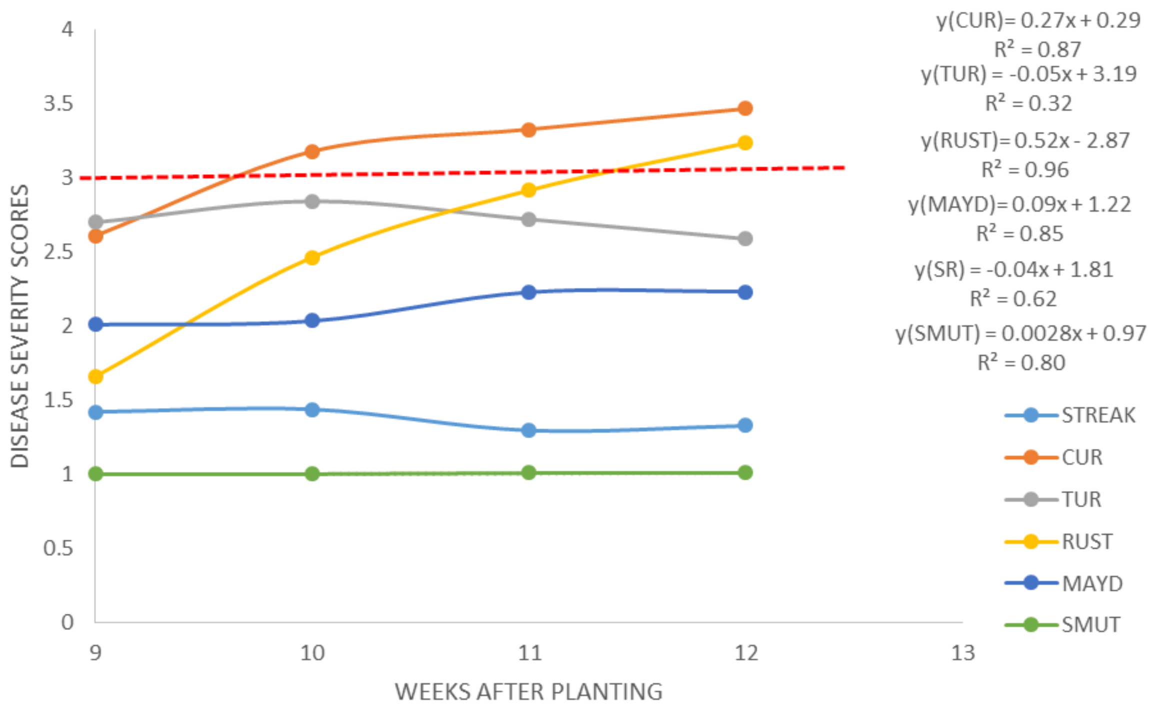

Figure 2. Response of early maize varieties to common diseases in the humid rainforest agro-ecological conditions at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. Nigeria. SR = Maize streak; CUR= Curvularia leaf spot; TUR = Northern corn blight by *Exserohilium turcicum*; RUST= Rust fungi; corn smut *Ustilago maydis*. MAYD= Southern corn blight caused by *Helminthosporium maydis.*

leaf spot and leaf rust exceeded the susceptibility threshold, leaf rust had highest value for disease progression (b-value = 0.52), followed by *Curvularia* leaf spot (b-value = 0.27) (Figure 2), a trend similar to that of the extra-early varieties. This result implies that the early maturing maize varieties were also sensitive to these two diseases and attention should be given to manage them. Apart from the two diseases, *E. turcicum* incidence was the next disease, fast approaching the threshold line. This disease has been reported to be a serious one, which causes huge economic damage in the high altitude regions (Yeshitila, 2003). It is therefore note-worthy to find out in this study that its incidence in low altitude climate was higher than that of Southern blight.

There is limited information on the appropriate time toward score diseases for the purpose of selecting tolerant genotypes under field conditions. The result also revealed that different diseases reached their peak at different time, suggesting that for extra-early maize, different diseases should be recorded at different times. *Curvularia* leaf spot and leaf rust, which were the diseases that reached the threshold, touched the line at different time. *Curvularia* leaf spot curve touched the threshold line shortly before 10 weeks after planting (WAP), suggesting that tolerance to *Curvularia* leaf spot among extra-early maize is better detected as from 10 WAP while tolerance to rust is best scored as from 11 WAP (Figure 1). For early maize, the two diseases which reached threshold touched the threshold line at different time, suggesting that scoring the diseases should be at different times. Following from this, *Curvularia* leaf reached the threshold line before 10 WAP and that the disease should be scored for early maize anytime from 10 WAP. For rust score, curve touched the threshold between 11 and 12 WAP, implying that the disease scoring should be scored at that time (Figure 2). The result which revealed the best time to score leaf rust under field conditions was not in agreement with that recommended by CIMMYT Maize Program (2004), who reported that the best time to score *Puccinia sorghi* is before tasseling. The extra-early maize in this study started tasseling at 6-7 WAP while early maize started tasseling at 7-8 WAP.

Due to the fact that the evaluation in this study was conducted under field condition, spread of inoculation might not be even and this may affect the result. Thus, a screenhouse study where artificial inoculation of the genetic materials is carried out might be necessary to ascertain the level of resistance/tolerance present in the new germplasm.

Furthermore, when studying the resistance of a crop to pathogen(s), it would be very useful to present information on race composition of the pathogens on a given territory. This information is not available in the rain-forest agro-ecological zone of Nigeria. Therefore, subsequent studies should be conducted to provide this information.

Conclusion

The disease progression became severe at eight weeks after planting with visible symptoms. These symptoms increased drastically with time but all forty maize varieties still maintained their tolerance level against streak, Northern leaf blight, Southern leaf blight and smut. Although, none of these diseases significantly reduced yield, scores for *Curvularia* leaf spot and rust disease significantly exceed the resistance threshold suggesting that management of the two diseases need attention to control them before they start causing economic damage.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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