Interactive Effects of Genotype X Year on Disease Reactions, Grain Yield and other Agronomic Traits of Newly Developed Quality Protein Maize in Nigeria

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Jordan Journal of Agricultural Sciences, Volume **11**, No.**2** 2015

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ABSTRACT

Experiments were conducted on six newly developed open pollinated quality protein maize (QPM) genotypes and two check entries for three years (2009-2011). The objective was to assess their yield potentials and disease tolerance/ resistance in the southern Guinea savanna agro-ecology of Nigeria. Genotype and year of evaluation were significant for ($P<0.01$ and <0.05) for grain yield, harvest moisture and lodging characteristics. Genotypes x year interactive effect for grain yield revealed different genotypic performance of the genotypes tested with two checks (Oba-Super 1 and DMR-LSR-Y) being responsible for the significant differences obtained in the three years of evaluation. Average grain yield was significantly higher in the year 2011 compared to 2009 and 2010. All the genotypes tested were moderately tolerant to the five diseases ranging from 1.5 (Streak virus) in Oba-Super 1 (check) to 2.9 (Southern leaf blight, Curvularia leaf spot and Leaf rust) in the ART98-SW6-OB and ART98-SW4-OB respectively. Ear rot mostly affected the leaves among diseases with a range of 2.3 to 2.8 in TZPB-OB and DMR-LSR-Y respectively.. Four QPM genotypes (ART98-SW5-OB, ART98-SW4-OB, TZPB-OB and ART98-SW6-OB) were superior for grain yield with yield advantage of 28% over the best OPV check. These QPM genotypes can therefore serve as useful replacement for existing cultivars and also as source of genes for future maize breeding activities in the development of superior maize varieties with high protein contents for the savanna agro-ecology.

Keywords: Tolerance, streak virus, ear rot, leaf spot and blight.

INTRODUCTION

Maize (*Zea mays* L.) has a critical nutritional role to play in human as it is one of the most important cereals in the world after wheat and rice with regards to cultivation area, total production and consumption (Bello and Olaoye, 2009). Maize is high yielding, easy to process, readily digested and cheaper than other cereals. It is also a versatile crop, growing across a wide range of agro ecological zones (Akinbode, 2010). In Nigeria, conventional maize is used directly for human consumption as well as infant nutrition in the form of porridge during weaning period without any protein

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Received on 2/1/2014 and Accepted for Publication on 29/5/2014.

supplement such as egg, meat or beans, which are comparatively expensive especially for poor-resource in the rural areas (Yusuf, 2010). Normal maize has 10% protein which is of poor nutritional quality due to limiting concentration of essential amino acids (lysine and tryptophan) which the human body cannot synthesize and has to be supplemented (Krivanek et al., 2007; Mbuya et al., 2010; 2011). Therefore adoption and cultivation of QPM with high concentration of lysine and trytophan contents therefore could drastically reduced malnutrition, diseases and death among low income maize consumers in the developing countries including Nigeria (Showemimo, 2004; Olakojo et al., 2007; Upadhyay et al., 2009; Mbuya et al., 2011).

Generally, maize production in tropical Africa is constrained by a number of stress factors including a complex of pests and diseases that significantly reduce the quantity and quality of production (Akande and Lamidi, 2006). Grain yield losses ranging from 0-70% have been reported due to some of the major diseases which depend on factors such as genetic constitution of the cultivars and stage of growth at the time of infections (Bua and Chelimo, 2010). Meanwhile, maize diseases of tropical environment such as maize streak virus (MSV) are transmitted by *Cicardulina spp* and southern leaf blight is caused by the fungus *Helminthosporium maydis*. The causative organism of the curvularia leaf spot is *Curvularia lunata*, and that of maize ear rot is *Fusarium moniliforme*. Maize rust on the other hand is incited by *Puccinia polysora* (Olakojo et al., 2005b; Akande and Lamidi, 2006). These five diseases constitute major production constraints in the northern and southern Guinea savanna of Nigeria. They often occur together on maize plants as mixed infections and their occurrence is favoured by warm and humid climate (Olakojo, 2001; Olakojo et al., 2001; 2005a). However, ear and kernel rot diseases decreased grain yield quality and feeding value of the grain, and in some instances, this has even resulted in the production of toxic substances in feed rations. Foliar diseases also reduced the production of carbohydrates stored in the grains, resulting in immature and chaffy kernels, hence low and poor yields (Ngwira and Khonje, 2005; Olakojo et al., 2007). The quest for improved grain yield and disease tolerance/ resistance maize varieties therefore become imperative for profitable maize production. The use of host plant resistance/ tolerance however remains the most economically viable and practical means of controlling disease epidemics (Bua and Chelimo, 2010).

Quality protein maize varieties are known to be more vulnerable to diseases because of the soft floury endosperm of the Opaque-2 maize which foster fungal growth (NRC, 1988). Meanwhile, newly developed QPM varieties are routinely evaluated in various agro-ecological zones of Nigeria for adaptation, yield potentials and disease reactions, to identify genotypes that can replace existing cultivars and as part of the requirements for releasing suitable varieties for cultivation in the farmers' fields (Olakojo and Iken, 2001; Olakojo et al., 2007). Therefore, assessment of newly developed QPM varieties reaction to diseases that may be unique to the environment before being recommended for cultivation is very imperative (Olaoye et al., 2009). In the study reported herein, six (6) newly developed QPM varieties were evaluated along with an earlier version (DMR-LSR-Y) and one hybrid (Oba Super 2) as checks for three years at Ilorin, a typical southern Guinea savanna ecology of Nigeria. The objective was to assess yield performance and reactions of the QPM varieties to five major field diseases: curvularia leaf spot, southern leaf blight, maize rust, ear rot and streak virus prevalent in the agro-ecology with the view to identify high yielding and disease resistant/ tolerant QPM cultivars either suitable for direct cultivation in this ecology or for further improvement in the breeding programmes.

1. MATERIALS AND METHODS

Germplasm Used

Six newly developed QPM and two local (checks) genotypes were evaluated for yield performance and disease reactions in the southern Guinea savanna agro-ecology of Nigeria. The field trials were conducted at the Lower Niger River Basin Development Authority station, Oke-Oyi, Ilorin, Nigeria (8^0 30'N & 8^0 36'E) during late cropping seasons of 2009, 2010 and 2011. Table 1 shows the source of collection and characteristics of the QPM genotypes and checks, while monthly rainfall and temperature data collected from Meteorological Department of Lower Niger River Basin Development Authority Ilorin are presented in Figure 1 and 2, respectively.

Table 1. Source of collection and characteristics of the QPM genotypes evaluated at Ilorin, Nigeria

Genotypes	Source of collection	Seed colour	Kernel texture	Type
ART98-SW6-OB	IAR & T, IBADAN	White	Flint/ Dent	Hybrid
ART98-SW5-OB	IAR & T, IBADAN	White	Flint	Hybrid
ART98-SW4-OB	IAR & T, IBADAN	White	Flint	Hybrid
ART98-SW1-OB	IAR & T, IBADAN	White	Flint	Hybrid
TZPB-OB	IAR & T, IBADAN	White	Flint	Hybrid
ILEI-OB	IAR & T, IBADAN	White	Flint	Hybrid
Oba-Super 1	Pioneer / check	White	Flint	Hybrid
DMR-LSR-Y	Local check	Yellow	Flint/Dent	OPV

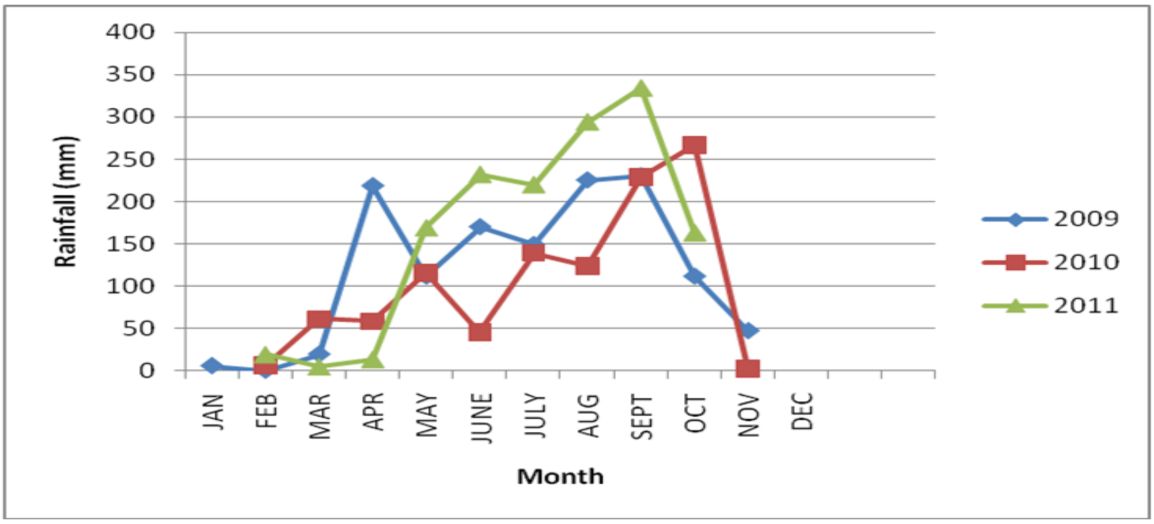

Figure 1: Monthly rainfall distribution pattern (3 years) at Ilorin from 2009 to 2011

Source: Meteorological Department of Lower Niger River Basin Development Authority Ilorin, Nigeria

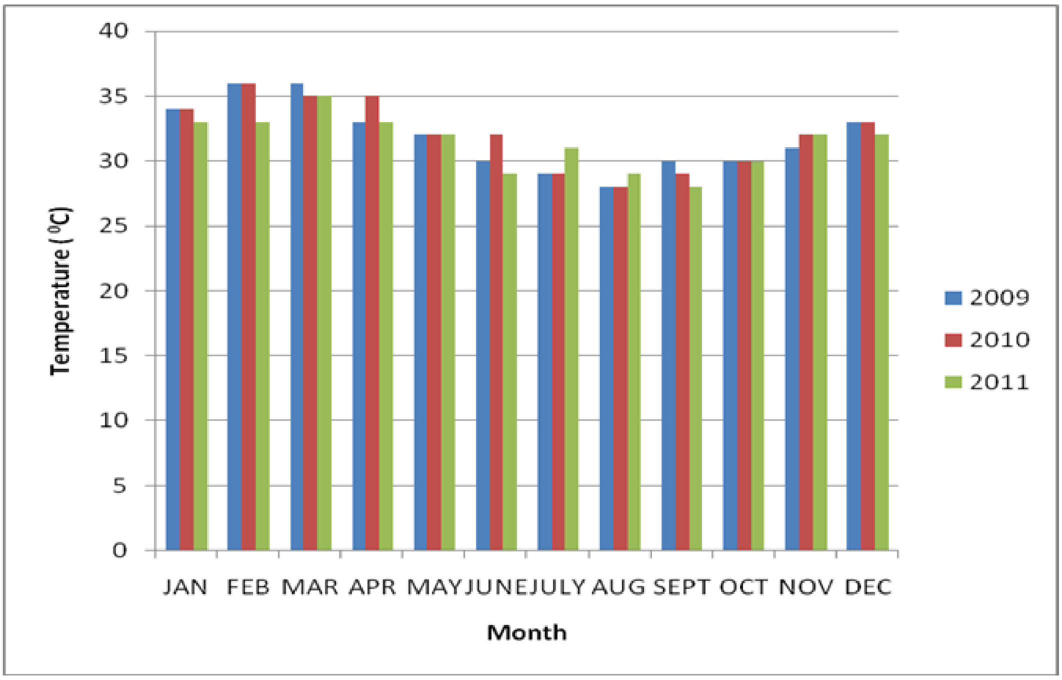

Figure 2: Monthly atmospheric temperature (3 years) at Ilorin from 2009 to 2011
Source: Meteorological Department of Lower Niger River Basin Development Authority Ilorin, Nigeria

Experimental Design and Cultural Practices

Maize seeds were planted under rainfed on 26th July, 2009, 28th July, 2010 and 2nd August, 2011 in a randomized complete block design with four replications. Each plot consisted of four rows of 5m long, with 0.50m intra-row and 0.75m between rows spacing respectively. Three seeds were planted per hill, drilled 3-4cm deep in the ridges and thinned to two plants per hill two weeks after seedling emergence to provide a uniform plant population of about 53,333 plants /ha. NPK fertilizer was applied at the rate of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O per hectare for optimum plant growth. All plots were weeded by using herbicides (3kg/l Metolachlor, 170g/l Atrazine and 3kg/l Paraquat per hectare) and supplemented by hand weeding to achieve weed control. This was supplemented by a regime of hand weeding 6 weeks after planting to achieve weed control, improve soil aeration and prevent root lodging.

Field Measurements

Just before flowering, all plants from the two middle rows in a plot were observed and counted for five foliar diseases symptoms (Curvularia leaf spot (*Curvularia lunata*), southern leaf blight (*Helminthosporium maydis*), leaf rust (*Puccinia polysora*), ear rot (*Fusarium moniliforme*)) and maize streak *virus* (MSV) *(Puccinia polysora)* prevalent in the area according to Badu-Apraku et al., (2012). Severity of each of the five diseases were evaluated using 10 plants in the central part of the plot and take an average, with a rating scale of 1-5. For curvularia leaf spot and MSV, 1 = slight infection Less than 10% of the ear-leaf covered by lesions. 2 = light infection 10–25% of the ear-leaf covered by lesions. 3 = moderate infection 26–50% of the ear-leaf covered by lesions. 4 = heavy infection 51–75% of the ear-leaf covered by lesions, leading to premature death of the plant and light cobs and 5 = very heavy infection 76–100% of the ear-leaf covered by lesions, leading to premature death of the plant and light cobs. Data on southern leaf blight was taken, within the 2–4 weeks period after 50% silking with a rating scale of 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 and 5 = very heavy infection All leaves with large number of lesions leading to premature death of the plant and light ears.

Leaf rust rating was taken within the 2–4 weeks after 50% silking where 1 = no rust and 5 severe rust. Ear rot score was based on the proportion of the ears showing rot, where 1 = little or no rot, 5 = most of the ears rotten. When the cobs were fully developed, the genotypes were assessed for their susceptibility to root and stem lodging based on scale of 1-5, where, 1= excellent (no lodging) 2 = very good, 3 = good, 4 = fair and 5 = poor. At harvest, husk cover as well as plant and 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 respectively, and 5 = opened husk, yellowish plant appearance as well as rotten, small and partially filled ears respectively. Grain yield was obtained from ear weight per plot (assuming 80% shelling percentage) and converted to tonnes per hectare after adjusting to 12.5% moisture content. Three hundred grain samples were collected from each plot at harvest for the determination of harvest moisture. Moisture at harvest was determined according to A.O.A.C. (1980) methods. Crucibles were washed and dried to a constant weight in an air oven at 100°C, They were later removed and cooled in a desiccator and weighed (W_1). Two grams of the grounded sample was placed in the weighed moisture dish (W_2); the crucible containing the sample was kept in an oven at 100°C for 24 hours and weighed. It was kept back in the oven and re-weighed after about 3 hours to ensure a constant weight (W_3). The moisture content at harvest was calculated as:

$$\% \text{ Moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times \frac{100}{1}$$

Statistical Analyses

Data collected were subjected to analyses of variance (ANOVA) first on individual year basis before a combined ANOVA over years using PROC GLM model of SAS (SAS Institute, 2007) to compute mean squares for each character. The degree of variation was determined using % coefficient of variation $P < 0.05$. Differences in character means were also measured using least significant difference (LSD).

2. RESULTS

Rainfall, Temperature and Relative Humidity of the Site

Rainfall pattern during the three-year cropping period (Figure 1) was evenly distributed throughout the flowering/grain filling periods of September to October. In the month of August however, there was a sharp drop in rainfall in the year 2009 and early onset of terminal drought in 2010. Atmospheric temperature across the years was high in February, 2009 and 2010 as well as March, 2009 compared to 2011 (Figure 2). Effect of year and genotype differed significantly for all the agronomic characters except plant and ear heights (Table 2). However, genotype x year interactions was significant for grain yield only.

Table 2. Combined analysis of variance of grain yield and other related attributes of QPM genotypes evaluated from 2009 to 2011 at Ilorin, Nigeria

	Mean squares						
Source	Plant aspect	Ear aspect	Stalk lodging	Root lodging	Husk cover	Harvest moisture %	Grain yield (t ha^{-1})
Replicate	3.6	5.2	1.9	7.3	2.6	1.9	120.4*
Year	12.4	34.57	78.4*	98.5*	68.4*	79.2*	134.8**
SE±	13.5	12.3	10.5	9.2	11.9	14.2	10.5
Genotype	34.9*	10.5	92.1*	86.9*	94.7*	87.1*	99.7**
Genotype x Year	21.4	13.5	10.7	34.88	21.11	12.34	64.8*
SE±	2.6	11.8	10.3	2.6	5.7	7.2	1.9
%CV	34.76	0.38	1.64	11.38	1.93	10.57	34.65

*, **, significant at the 0.05 and 0.01 probability levels.

The husk cover had lower score in both 2009 and 2010 compared to 2011 (Table 3). However, rating for ear aspect (although non-significant) was better in 2009 and 2010 when the volume of rainfall was low in October, which also coincided with period of crop maturity compared to similar period in 2011. Similarly, plant aspect remained relatively unaffected by differences in growing conditions among the three years, while year 2011 had highest score rating. Plant and ear aspects ratings were moderate and varied from 2.1-2.5 and 2.2-2.6 respectively, with ILEI-OB being superior in the ratings. The OPV check (DMR-LSR-Y) however showed better husk cover rating than Oba-Super 1.

Grain yield was significantly higher in 2011 by 0.9 t/ha compared to 2010 that had the lowest yield, representing 22% yield increase (Table 4). This increase was accompanied by higher grain moisture content, lower disease rating for lodging characteristics as well as plant and ear aspects. Grain moisture percentage at harvest also ranged between 56.25 and 58.13 with ART98-SW1-OB having the highest percentage, while ART98-SW6-OB had the lowest value. The OPV check was also the latest to attain maturity as indicated by the highest grain moisture at harvest. Two genotypes, OPV check DMR-LSR-Y and ART98-SW1-OB showed high disparity in grain yield in the three years with differences of 1.6 and 1.2 t/ha respectively. Genotype ART98-SW5-OB ranked best for grain yield and differed in yield potential from any of the QPM genotypes. However, ART98-SW5-OB which ranked second for grain yield, yielded higher than the OPV check (DMR-LSR-Y) by more than 20% yield advantage with better husk cover. Hybrid check (Oba-Super 1) that was ranked first for grain yield was superior also for lodging characteristics and moisture at harvest, while the OPV check (DMR-LSR-Y) had the worst rating for these traits in comparison. Hybrid check, Oba-Super 1 demonstrated instability of performance for maize grain yield with a difference of 14.7% yield loss in 2010 compared to 2011. ILEI-OB was the most stable of all the entries for grain yield, with a difference of 0.4t/ha in the three years.

Table 3. Genotype x year interaction for agronomic characters of QPM genotypes evaluated from 2009 to 2011 at Ilorin, Nigeria

	Plant aspect				Ear aspect				Stalk lodging				Root lodging				Husk cover			
Year	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Genotypes																				
ART98-SW6-OB	2.4	2.3	2.5	2.4	2.3	2.2	2.4	2.3	1.4	1.3	1.4	1.4	1.4	1.4	1.6	1.5	2.5	2.3	2.6	2.5
ART98-SW5-OB	2.3	2.2	2.4	2.3	2.3	2.0	2.4	2.2	1.3	1.3	1.3	1.3	1.4	1.3	1.4	1.4	2.3	2.2	2.4	2.3
ART98-SW4-OB	2.1	2.0	2.1	2.1	2.6	2.5	2.6	2.6	1.5	1.5	1.6	1.5	1.7	1.6	1.7	1.7	2.8	2.8	2.9	2.8
ART98-SW1-OB	2.5	2.3	2.6	2.5	2.3	2.1	2.4	2.2	1.9	1.8	1.9	1.9	1.4	1.3	1.4	1.4	2.6	2.5	2.6	2.6
TZPB-OB	2.2	2.2	2.4	2.3	2.5	2.4	2.6	2.5	1.2	1.1	1.3	1.2	1.6	1.5	1.6	1.6	2.4	2.4	2.6	2.5
ILEI-OB	2.1	1.8	2.2	2.0	2.2	2.1	2.3	2.2	1.5	1.3	1,6	1.4	1.1	1.0	1.1	1.1	2.4	2.3	2.5	2.4
Oba-Super 1+	2.5	2.4	2.6	2.5	2.5	2.3	2.6	2.5	1.1	1.1	1.2	1.1	1.3	1.2	1.3	1.3	2.9	2.8	2.9	2.9
DMR-LSR-Y++	2.5	2.3	2.7	2.5	2.6	2.5	2.6	2.6	1.6	1.5	1.8	1.6	2.0	1.9	2.0	2.0	1.1	1.0	1.2	1.1
SE±	13.4	2.9	6.9	11.2	3.8	8.4	12.9	10.5	4.7	8.4	1.4	7.9	10.6	2.8	2.6	11.5	13.5	4.6	3.6	10.7
Mean	2.3	2.2	2.4	2.3	2.4	2.3	2.5	2.4	1.4	1.4	1.5	1.4	1.5	1.4	1.4	1.4	2.4	2.3	2.5	2.4
$LSD_{(0.05)}$	0.3	Ns	0.3	ns	ns	0.2	0.2	ns	0.3	0.4	0.3	0.5	0.5	0.4	0.5	0.8	0.5	0.6	0.5	0.7

Table 4. Genotype x year interaction for grain yield and harvest moisture of QPM genotypes evaluated from 2009 to 2011 at Ilorin,

Year	Harvest moisture %				Grain yield (t/ha)				Ranking based on average grain yield (t/ha)	% yield advantage or loss over best check	
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009-2010	2009-2010	
Genotypes										OPV	Hybrid
ART98-SW6-OB	10.5	10.3	10.7	10.5	3.8	3.6	4.5	4.5	5th	21.6	-15.1
ART98-SW5-OB	12.3	12.0	12.4	12.2	5.0	4.5	5.1	4.9	2nd	32.4	-7.5
ART98-SW4-OB	12.5	12.4	12.6	12.5	4.8	4.5	5.0	4.8	3rd	29.7	-9.4
ART98-SW1-OB	12.7	12.5	12.8	12.7	4.1	3.7	4.4	4.1	7th	10.8	-22.6
TZPB-OB	12.4	12.4	12.5	12.4	4.5	4.4	5.2	4.7	4th	27.0	-11.3
ILEI-OB	12.4	12.2	12.4	12.3	4.2	4.0	4.4	4.2	6th	13.5	-20.8
Oba-Super 1+	12.3	12.3	12.3	12.3	5.3	4.9	5.6	5.3	1st		
DMR-LSR-Y++	13.4	13.3	13.6	13.4	3.8	3.4	3.9	3.7	8th		
SE±	2.8	12.5	7.9	11.3	9.3	2.6	2.1	2.7			
Mean	12.3	12.2	12.4	12.3	4.4	4.1	5.0	4.5			
$LSD_{(0.05)}$	0.5	0.6	0.5	0.6	0.5	0.6	0.6	0.6			

+, ++; Hybrid and Open pollinated genotype (OPV) checks respectively.

Effect of genotype differed significantly for all the diseases studied except ear rot (Table 5). All the genotypes tested were moderately tolerant to the five diseases ranging from 1.5 (Streak virus) in Oba-Super 1 (check) to 2.9 (Southern leaf blight, Curvularia leaf spot and Leaf rust) in the ART98-SW6-OB and ART98-SW4-OB respectively. Ear rot mostly affected the leaves among diseases with a range of 2.3 to 2.8 in TZPB-OB and DMR-LSR-Y respectively.The effect of year was significant for leaf rust and streak virus. Genotype x year interactive effect on the other hand was differed significantly for streak virus only. Although, severity of southern leaf blight and curvularia leaf spot were higher in 2011 compared to other crop growing years (Table 6), differences in the three years were non-significant for these parameters. Average ear rust severity in 2011 was 2.9, but in 2009 and 2010, it was 1.6 and 2 respectively. Maize streak virus severity was significantly higher in 2009 with by 1.4 compared to 2011 that had the lowest score value, representing 50% increase over the highest disease rating. Generally, the severity of the diseases was low with disease score of less than 3.0 in all cases. All the genotypes were moderately tolerant to the disease ranging from 1.5 (Streak virus) in Oba-Super 1 (check) to 2.9 (southern leaf blight, curvularia leaf spot and leaf rust) in the ART98-SW6-OB and ART98-SW4-OB. Ear rot mostly affected the leaves among five diseases with a range of 2.3 to 2.8 in TZPB-OB and DMR-LSR-Y, respectively. However, the genotypes showed slight susceptibility to both blight and curvularia leaf diseases, ranging from 1.6 in Oba-Super 1 check to 2.9 in the ART98-SW6-OB for leaf blight and from 1.8 in DMR-LSR-Y check to 2.9 also in the ART98-SW6-OB for curvularia leaf spot. However, the lowest severity of maize streak virus recorded for Oba-Super 1 differed significantly only from that of the ART98-SW6-OB. Similarly, DMR-LSR-Y appeared to be the most tolerant with ear rust rating of 1.6 with significant genotypic differences only from ART98-SW4-OB. Genotypic differences for maize streak virus in the three years were also moderate with low mean score (1.4) recorded in 2010. Oba-Super 1 check had the lowest streak rating among the genotypes in the three of cropping years.

Table 5. Combined analysis of variance for disease ratings of QPM genotypes evaluated from 2009 to 2011 at Ilorin, Nigeria

	Mean squares				
Disease	Ear rot	Curvularia leaf spot	Leaf rust	Southern leaf light	Streak virus
Replicate	23,6	12.9	14.4	34.2	23.8
Year	12.6	23.5	208.6**	0.68	123.6**
SE±	11.5	5.8	12.6	10.3	20.5
Genotype	Ns	79.4*	69.9*	98.1*	174.5**
Genotype x Year	36.8	15.4	33.5	26.8	96.8*
SE±	3.6	23.8	12.7	17.1	12.3
%CV	10.3	0.56	1.48	12.5	5.63

*, **, significant at the 0.05 and 0.01 probability levels.

Table 6. Genotype x year interaction for disease ratings of QPM genotypes evaluated from 2009 to 2011 at Ilorin, Nigeria

	Ear rot				Curvularia leaf spot				Leaf rust				Southern leaf light				Streak virus			
Year	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Genotypes																				
ART98-SW6-OB	2.3	2.7	2.5	2.5	2.9	2.8	2.9	2.9	2.4	2.7	2.6	2.6	2.9	2.8	2.9	2.9	3.0	3.0	1.6	2.8
ART98-SW5-OB	2.4	2.6	2.7	2.6	2.4	2.2	2.3	2.3	2.3	2.5	2.7	2.5	2.3	2.5	2.4	2.4	2.7	3.0	1.5	2.4
ART98-SW4-OB	2.3	2.5	2.4	2.4	2.2	2.1	2.2	2.2	2.7	2.8	2.9	2.8	2.4	2.2	2.3	2.3	3.0	2.3	1.3	2.3
ART98-SW1-OB	2.3	2.6	2.6	2.5	2.3	2.5	2.4	2.4	2.4	2.2	2.3	2.3	2.3	2.6	2.5	2.5	3.1	2.7	1.5	2.5
TZPB-OB	2.2	2.4	2.3	2.3	2.4	2.2	2.3	2.3	2.3	2.5	2.6	2.5	2.5	2.7	2.6	2.6	3.0	3.0	1.5	2.6
ILEI-OB	2.4	2.7	2.6	2.6	2.3	2.6	2.6	2.5	2.1	2.0	2.1	2.1	2.3	2.5	2.4	2.4	2.9	2.6	1.3	2.4
Oba-Super 1+	2.3	2.5	2.7	2.5	2.2	2.0	2.1	2.1	2.3	2.2	2.3	2.3	1.6	1.5	1.6	1.6	2.0	2.0	1.0	1.5
DMR-LSR-Y++	2.7	2.9	2.8	2.8	1.8	1.7	1.9	1.8	1.7	1.4	1.6	1.6	2.4	2.2	2.3	2.3	2.6	2.1	1.5	1.8
SE±	11.4	2.9	4.6	3.9	8.4	2.8	3.5	2.7	8.3	10.4	2.9	13.4	11.7	6.4	9.3	3.8	9.4	11.4	5.7	9.1
Mean	2.4	2.6	2.6	2.5	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3	2.4	2.4	2.4	2.8	2.6	1.4	2.3
$LSD_{(0.05)}$	0.5	Ns	ns	ns	0.2	ns	ns	ns	ns	ns	0.1	ns	ns	ns	0.2	ns	0.2	0.4	0.3	0.5

+, ++; Hybrid and open pollinated variety (OPV) checks respectively.

3. DISCUSSION

The main effort in varietal evaluation of QPM genotypes in the developing countries is to identify most superior that could replace existing ones. The QPM genotypes can serve as sources of genes for the extraction of inbred lines aimed at development of productive cultivars that will increase protein intake in the rural poor setting. Generally, rainfall amount and distribution as well as atmospheric temperature during the growing periods in the three years played significant role in the expression of genotypes' potential in this study. The reflection of weather pattern (available soil moisture, temperature) during crop's reproductive phase may stimulate plants to speed up the process of maturation with vulnerable disease infections. For instance, rainfall was evenly distributed with high temperature throughout the flowering/grain filling period of September and October in the three years. This condition favoured accumulation and translocation of photo-assimilates in the genotypes with corresponding bigger ear size, subsequently higher grain yield in all the genotypes, especially in the year 2009 and 2011. The genotypes had the lowest grain yield in 2010, possibly when rainfall dropped sharply during flowering/grain filling stage of that year compared to other years with even distribution during the latter part of the growing period. Differences in grain yield and the other four characters in the three years could be due to differences in environmental conditions which vary from year to year (Akande and Lamidi 2006; Olaoye, 2009; Sanari *et al*., 2010). Results from this study also suggests that breeding of maize for adaptation in Nigerian southern Guinea savanna should among other factors considered varietals yield potential as well as seasonal variation of the year where it is predictable. Conversely, non-significant year effect on plant and ear aspect suggests that variation in environmental conditions between the three years did not significantly influence the proportion and degree of susceptibility of genotypes to these diseases.

Differences among the six QPM genotypes and two local checks that were significant for grain yield, harvest moisture as well as plant aspect and lodging characteristics indicate considerable genetic differences among the genotypes for these characters and their potential in breeding for improved grain yield (Akande and Lamidi 2006). High soil moisture at maturity period also reduced termite infestation, consequently, lower stalk and root lodging (Olaoye, 2009). However, lower relative humidity (Figure not shown) during the cropping periods especially in 2010 and 2011 could reduced the severity of ear and foliar fungi diseases in the genotypes with lower husk cover and ear aspect scores, which includes factors such as yield, appearance of the grain and ear rot. Ear rust disease often revealed differences in maturity among genotypes. This variation in response suggests that QPM genotypes have tolerance/ resistance to this disease which could be exploited. Similarly, the variation in response to ear rot suggests that some QPM donors have ear rot resistance/ tolerance, and this may be related to both genetic and agronomic factors such as like shoot bagging (Okello *et al*., 2006). It has been observed that only QPM genotypes with tight husk cover that wrapped the entire ear should be selected in order to reduce the ear rot problem in maize. This could provide additional protection against the fungi diseases. Susceptibility to the diseases were mild in 2010 when the volume of rainfall was low in October and November that year, which also coincided with period of crop maturity compared to similar period in 2009 and 2010 respectively.

The desire of maize breeders is that increased grain yield would be associated with the disease resistant gene blocks accompanied by negligible changes, if any, in other agronomic characters (Fakorede *et al.*, 2001). The severity of each of the five diseases on the QPM genotypes and the two checks were low. This result suggests a reasonable level of tolerance to these diseases. Hybrid check, Oba-Super 1 and OPV check, DMR-LSR-Y were superior with lower disease ratings compared to the QPM genotypes. Olakojo *et al.* (2005) also reported considerable level of tolerance of normal OPV and hybrid maize genotypes to these diseases in southwest Nigeria. However, Oba-Super 1 was superior to all other genotypes both for grain yield (5.3 t/ha) and most of the disease ratings with yield advantage of 8% over the best QPM genotypes. Normal maize hybrid varieties were also known to be superior to OPVs in yield potential as demonstrated by earlier workers (Kim et al., 1993; Ajibade and Ogunbodede, 2000; Akande and Lamidi 2008). This result also showed that despite the yield improvement, the genes for resistance to the causal organisms have not been eroded in the check. Resistance/ tolerance to maize diseases could be incorporated into susceptible cultivars through recombination with resistant/ tolerance normal maize genotypes (Akande and Lamidi 2006). However, severity of southern leaf blight was higher in 2009, a condition that is often encouraged by high moisture during the growing period (Amadi, 1998). Four QPM lines (ART98-SW5-OB, ART98-SW4-OB, TZPB-OB and ART98-SW6-OB) had moderate disease ratings and high yielding with a range of 4.5 -4.7 t/ha. QPM hybrids had been reported to be high yielding and tolerant to maize rust and southern leaf blight diseases in Ghana (Asiedu *et al.*, 2003).

Significance genotype x year interaction effect for grain yield in this study could be attributed to instability in performance of ART98-SW6-OB and OPV check (DMR-LSR-Y) which had poor yield in 2009 and 2010 cropping years as reflected in wide disparity in grain yields among the genotypes in the three years. Similarly, significance genotype x year interaction effect for maize streak virus could be attributed to instability in performance of ART98-SW1-OB and ART98-SW6-OB which had relatively high streak scores in all the cropping years, as reflected in wide disparity in streak ratings in the genotypes. However, non-significant genotype x year interactions recorded for lodging and other eight characteristics indicated that the relative ranking of the genotypes with respect to the characteristics were not the same in each of the three years.

4. CONCLUSION

The newly developed QPM genotypes tested were generally suitable for southern Guinea savanna ecology of Nigeria. They were fairly resistance/ tolerance to the prevailing diseases in the region. However, four QPM genotypes (ART98-SW5-OB, ART98-SW4-OB, TZPB-OB and ART98-SW6-OB) have been identified to be higher yielding compared with other genotypes tested. They were not only moderately tolerant/ resistance to the five diseases evaluated, but also had higher yield advantage of 28% over the best OPV check (DMR-LSR-Y). They were also compared favourably with the hybrid check for grain yield. These QPM genotypes can therefore, serve as useful replacement to OPV check. They could also assist as source of genes for future maize breeding activities in the development of superior maize cultivars with high protein for the savanna agro-ecology.

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تأثير التداخل بين المورثات والسنة على التفاعل المرضي، انتاج الحبوب والصفات الزراعية الأخرى للذرة المطورة حديثا عالية المحتوى البروتيني في نيجيريا

بيللو [1]، أولاولي [2]، إيجي [3]، محمود [4]، أفولابي [5]، جانيو [1]، عزيز [6]، عبد المالك [7]

ملخص

أجريت عدة تجارب لمدة ثلاث سنوات (2009–2011) على ستة مورثات طورت حديثا من الذرة عالية البروتين (QPM) واثنتين من المدخلات كشاهد للمقارنة. كان هدف الدراسة تقييم الانتاجية وتحمل المرض او المقاومة لهذه الانماط الوراثية في جنوب غينيا سافانا في نيجيريا. كان كل من النمط الجيني والسنة مهما لتقييم ناتج الحبوب (P <0.01 و0.05>)، رطوبة الحصاد وخاصية الكسح. ادت بعض المورثات الى ظهور فروق معنوية في الانتاجية مقارنة بالشاهد (أوبا سوبر 1 وDMR LSR-Y). كان متوسط محصول الحبوب أعلى بكثير في عام 2011 مقارنة بالاعوام 2009 و 2010. كانت جميع المورثات ذات قدرة على تحمل الامراض الخمسة وتتراوح بين 1.5 (مرض التخطط الفيروسي) في أوبا سوبر 1 إلى 2.9 (لفحة الاوراق، تبقع Curvularia وصدأ الاوراق) في ART98-SW6-OB وART98- SW4-OB على التوالي. كان مرض تعفن كوز الذرة من اهم الأمراض تأثيرا على الاوراق وتراوحت الاصابة من 2.3 الى 2.8 في المورثات TZPB-OB وDMR LSR-Y على التوالي .كانت المورثات الاربعة ART98-SW5-OB، ART98-SW4-OB، TZPB-OB وART98-SW6-OB) الافضل من حيث انتاج الحبوب بنسبة 28٪ مقارنة بالشاهد (OPV) . وبالتالي يمكن اعتبار هذه المورثات (QPM) كبدائل واعدة للأصناف الحالية وأيضا كمصدر للجينات في اي دراسة وراثية في المستقبل لتطوير أصناف الذرة عالية البروتين في منطقة سافانا.

الكلمات الدالة: القدرة على التحمّل، الفيروس، تبقع وصدأ الأوراق.

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تاريخ استلام البحث 2014/1/2 وتاريخ قبوله 2014/5/29.