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Correlation, Principal Component Analysis and Tolerance of Maize Genotypes to Drought and Diseases in Relation to Growth Traits

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Abstract: Six maize genotypes (IBIZA-EN13) TZBR COMP 2-YC_1S_1, TZBR COMP 2-YC_1S_1 280, AMA TZBR YC_1F_1, TZEI 25, TZEI 22 and TZEI 161) were evaluated for their resistance to drought and diseases in an open field pot experiment conducted at the Research Farm of the Department of Botany, University of Ibadan, Nigeria. The experiment was laid out in a complete randomized design (CRD) with four replications. The genotypes were subjected to drought stress from 6^{th} to 8^{th} week after planting. Data on growth characters were recorded, while the drought and diseases / pest infestations were also scored. Data collected were statistically analyzed using SAS 9.1 statistical package. The genotypes and period of drought experiment were positive and significantly ($p<0.001$) correlated with the growth characters. Also, the genotypes recorded significant correlation with diseasing severity, although no correlation exists between drought resistance and disease severity. The proportion of spread of the genetic variability of the maize genotypes on growth characters ranged from 37.76% to 9.09%, while the drought and disease assessment varied by 58% to 42% as determined according to Eigen analysis. Maize genotype TZEI 161 showed the best drought tolerance but produced the least vegetative growths. AMA TZBR YC_1F_1 conferred the highest resistance against diseases and pest infestations (2.29) but was not drought tolerant (3.58). However, the maize genotype TZBR COMP 2-YC1S1 280 moderately combined the drought tolerant (2.75) and disease resistant (2.54) traits, it also showed the best vegetative performance. Therefore, TZBR COMP 2-YC1S1 280 is the recommended genotype when drought tolerance and disease resistance traits are desired.

Key words: Correlation · Disease resistance · Drought · Genetic variability · Maize genotypes · Pest infestation

INTRODUCTION

Maize (*Zea mays* L.) is a versatile crop grown across a wide range of agro-ecological zones [1]. It is one of the most economically important cereals in the world, after wheat and rice with regards to cultivation area, total production and consumption [2-4]. Maize is high yielding, easy to process, readily digested and cheaper than other cereals. In Nigeria, conventional maize is used directly for animal and human consumption [5,6].

However, it's per hectare yield is still very low due to a number of stress factors which includes a complex pest and diseases that reduces the quantity and quality of production [7]. Insect pests especially variegated grasshopper (*Z. variegatus* (L) are voracious and destructive pest of food crops. *Z. variegatus* alone had been reported to cause an estimated reduction of 50% in maize yield through leaf defoliation and destruction of the stem bark of the food crops, a common occurrence at the end of the dry season that leads to alteration in the plant growth and most important increased yield loss [8].

Maize crop requires about 400 to 600 mm of water during its lifecycle [9]. This is because plant distribution and yield in crop production are largely determined by water availability [10]. However, water resources have become insufficient due to climate change, population growth and competition from other water users [11]. Thereby, leading to environmental stresses such as drought, high temperature, salinity, air pollution, heavy metals, pesticides and soil pH which constitute major limiting factors in crop production because they affect the

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plant functions [12,13]. Whereas, drought is the most important abiotic stress factor that affects almost every aspect of plant growths, thereby limiting crop production [8,14,15].

The defence mechanisms in drought tolerant plants include; osmo regulation, antioxidant and hormonal systems. These enable plants survival and earlier development of the reproductive stages [16]. The responses of maize genotypes to drought tolerance had been reported to vary from different agro-management practices [17]. These variations are mainly due to differences in plant morphology, crowding stress tolerance, intra specific competition for water, plant growth rate, crop duration, sink capacity, vertical leaf area profile, nutrient uptake, utilization potential, relative maturity and yield of different maize hybrids [15].

Insect infestation had been adequately controlled in maize farms by the application of 'Knock off' chemical pesticides [18]. Although successful, but its effect on non-target organisms, persistence in the environment and high cost of purchase had generated an increasing concern about this control measure. Therefore, the need for an environmentally friendly alternative for pest and drought control necessitated the investigation on the resistance of different maize genotypes to environmental stresses such as drought and pest infestation.

MATERIALS AND METHODS

Source of Planting Materials: Six genotypes of maize ((IBIZA-EN13) TZBR COMP 2-YC$_1$S$_1$, TZBR COMP 2-YC$_1$S$_1$, AMA TZBR YC$_1$F$_1$, TZEI 25, TZEI 22 and TZEI 161) used in this study were obtained from the gene bank of the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo state, Nigeria.

Seed Sterilization: This was carried out according to the method described by Anderegg and Guthrie [19]. Each genotype of viable maize seeds were treated separately with 5% Sodium hypochlorite solution for 3 min then rinsed in two changes of sterile distilled water and air dried in laminar flow for 2 h.

Experimental Design: This study was conducted at the Department of Botany, University of Ibadan, Ibadan, Nigeria between June and August, 2013. The experiment arranged was laid out in a complete randomised design (CRD) with four replications in pot experiment at the open field of the Research Farm of Department of Botany, University of Ibadan, Nigeria.

Planting: The perforated polythene bags were filled with 4kg sandy-loam soil and spaced out at 15cm apart. Three viable seeds were then planted per pot in the corresponding genotype treatments. Maintenance practices such as wetting, weeding and thinning to one stand per pot were carried out.

Assessments of Plants' Response to Stress Condition

Disease and Pest Infestation: Assessments of diseases and pest infestation on the maize genotypes were carried out by scale ratings of 1 to 5. These were evaluated on the plants parts based on their resistance/ susceptibility to natural infection, insect/ pest infestation and other damages or wounds created on the plants parts that could further degenerate plants' health. These were assessed according to the modified scales of Kim [20] and CIMMYT [21].

Disease scale	Infected/ infested plant parts (%)
1	< 40 Highly resistant
2	40 – 49 Resistant
3	50 – 70 Moderately susceptible
4	75 – 90 Susceptible
5	100 Highly susceptible

Drought Experiment: Irrigation/ watering of the maize genotypes were stopped at the 6th week after planting, thereby subjecting the plants to drought. Data on the plants morphological growths were collected at 7days intervals till 8th week after planting. Drought was scored for by the wilting scale, according to the procedure of Olawuyi *et al.* [22].

Scale	Drought resistance
1	Excellent
2	Very good
3	Moderate/ Fairly good
4	Poor
5	Very poor

Data Collection and Analysis: Data were collected at 7 days intervals on each replicate on the plant height (cm), number of leaves, stem height (cm), stem girth (cm^2) and leaf area (cm^2). The data gathered were subjected to analyses of variance (ANOVA) using SAS 9.1 [23] statistical software, while the means were separated at 95% confidence interval by Duncan's multiple range test [24].

RESULTS

The interaction of genotypes with duration of this study produced highly significant ($p<0.001$) effect on the morphological growth of maize. This was also recorded in the interaction of these two parameters. The effect of the replicates constituted partial significance as plant height ($p<0.05$) and leaf area ($p<0.001$) showed significant growth. Similar results were obtained for the interactions involving replicates except genotype x replicate which produced significant ($p<0.05$) effects on growth. However, genotype x replicate x WAP was not significant ($p>0.05$) to the growth of the plant (Table 1).

The maize genotype TZBR COMP 2-YC1S1 280 significantly ($p<0.05$) increased the growth on the stem height (11.41), stem girth (11.41), number of leaves (5.94) and leaf area (113.97). This was followed by AMA TZBR YC$_1$F$_1$ which also showed significant ($p<0.05$) growth difference on the plant height (28.67), number of leaves (6.08) and leaf area (114.03). This was followed by TZBR COMP 2-YC$_1$S$_1$, while TZEI 22, TZEI 25 and TZEI 161(Table 2).

No significant ($p<0.05$) difference was recorded on the stem height and number of leaves across the replicates. Slight variation in the level of significance was observed on the plant height, stem girth and leaf area (Table 3). The morphological growth in the maize genotypes significantly ($p<0.05$) increased with the period of observation (WAP). The most significant effects were noticed for growth traits recorded at 6th WAP (Table 4).

The plant height was highly significant ($p<0.001$) and positively correlated with stem height ($r=0.84$), stem girth ($r=0.75$), number of leaves per plant ($r=0.80$), leaf area ($r=0.82$) and WAP ($r=0.88$), while genotypes and replicates were negatively correlated and non significant. Similarly, the stem height was also showed highly significance and positive association with stem girth ($r=0.71$), number of leaves (0.66), leaf area (0.74) and WAP ($r=0.87$), with genotypes and replicates showing negative and non significance correlation. Moreso, the stem girth was highly significant and positively related to number of leaves ($r=0.74$) leaf area ($r=0.73$) and WAP ($r=0.77$), but was negatively though significantly ($p<0.05$) correlated with the genotypes ($r= -0.23$) while it was positive and not significantly related with replicates

However, the number of leaves showed positive and highly significant ($p<0.001$) relation with leaf area ($r=0.17$) and WAP ($r=0.77$) while it was negatively related with genotypes ($r= -0.13$) and positive with replicates ($r = 0.10$) but were not significantly correlated. Leaf area was positively and highly significantly ($p<0.001$) correlated with WAP ($r= 0.77$), no significant relationship occurred with genotype ($r= -0.17$) and replicates ($r=0.10$) which were negatively and positively related respectively (Table 5).

Table 1: Mean square effect of genotype, replicate and genotype x replicate interaction on morphological traits of maize plants

Source	df	Plant height	Stem height	Stem girth	Number of leaves	Leaf Area
Genotype	5	1065.14**	107.19**	5.59**	7.37**	43169.74**
Replicates	3	52.72*	1.19ns	0.90**	0.43ns	12668.05**
WAP	2	28077.02**	5553.19**	91.48**	327.54**	875075.19**
Genotype x Replicates	15	28.65*	7.49ns	0.34*	1.29*	6599.19**
Genotype x WAP	10	268.55**	35.79**	1.21**	2.80**	7243.58**
Replicates x WAP	6	16.13ns	1.60ns	0.42*	0.26ns	6936.38**
Genotype x Replicates x WAP	30	12.36ns	3.444ns	0.12ns	0.35ns	4470.51**
Error	357	5210.49	2234.3	68.65	257.66	379499.13
Corrected Total	428	70520.72	14492.26	306.65	1008.33	2737542.55

Highly significant ($p<0.001$) = **, Significant ($p<0.05$) = *, ns = not significant, WAP = Week after Planting.

Table 2: Effect of genotypes on the morphological characters of maize

Genotype	Plant height (cm)	Stem height (cm)	Stem girth (cm)	Number of leaves	Leaf Area (cm^2)
G1	23.88b	11.41a	2.80a	5.94a	113.97a
G2	28.67a	9.77b	2.58b	6.08a	114.03a
G3	18.29d	10.83a	2.38c	5.41bc	75.99c
G4	19.64c	7.99c	2.45bc	5.93a	69.30c
G5	19.77c	9.73b	1.96d	5.60b	54.89d
G6	23.74b	10.90a	2.38c	5.30c	96.32b

Each value is the mean of four replicates. Values with the same alphabet are not significantly ($p<0.05$) different from one another across the column according to Duncan's Multiple Range Test.

G1= (IBIZA-EN13) TZBR COMP 2-YC$_1$S$_1$, G2= TZBR COMP 2-YC$_1$S$_1$280, G3= AMA TZBR YC$_1$F$_1$, G4 = TZEI 25, G5 = TZEI 22, G6 = TZEI 161

Table 3: Variation of replicates on the growth of maize genotypes

Replicates	Plant height (cm)	Stem height (cm)	Stem girth (cm)	Number of leaves	Leaf Area (cm^2)
1	22.60a	10.17a	2.31b	5.67a	78.93b
2	23.05a	10.02a	2.40ab	5.69a	82.29b
3	22.38ab	10.25a	2.47a	5.66a	85.59b
4	21.38b	10.05a	2.52a	5.80a	103.12a

Each value is the mean of four replicates. Values with the same alphabet are not significantly (p<0.05) different from one another across the column according to Duncan's Multiple Range Test.

Table 4: Effect of period of observation on growth of maize genotypes

WAP	Plant height (cm)	Stem height (cm)	Stem girth (cm)	Number of leaves	Leaf Area (cm^2)
2	9.74c	4.48c	1.59c	4.21c	24.18c
4	19.88b	9.07b	2.51b	5.69b	63.26b
6	37.44a	16.82a	3.18a	7.23a	175.19a

WAP = Week after Planting. Each value is the mean of four replicates. Values with the same alphabet are not significantly (p<0.05) different from one another across the column according to Duncan's Multiple Range Test.

Table 5: Correlation of genotype, replicate and WAP with the growth characters of maize

Correlation	Plant height	Stem height	Stem girth	Number of leaves	Leaf Area	Genotype	Replicates	WAP
Plant height								
Stem height	0.84**							
Stem girth	0.75**	0.71**						
Number of leaves	0.80**	0.66*	0.74**					
Leaf Area	0.82**	0.74**	0.73**	0.71**				
Genotypes	-0.10ns	-0.05ns	-0.23*	-0.13ns	-0.17ns			
Replicates	-0.04ns	-0.00ns	0.09ns	0.03ns	0.10ns	0.00ns		
WAP	0.88**	0.87**	0.77**	0.81**	0.77**	0.00ns	0.00ns	

Highly significant (p<0.001) = **, Significant (p<0.05) = *, ns = not significant, WAP = Week after Planting.

Table 6: Contribution of Principal Component Axis (PCA) to the variation of the morphological traits in maize genotypes

Traits	Prin 1	Prin 2	Prin 3	Prin 4	Prin 5
Plant height	0.57	0.12	-0.42	0.17	-0.68
Stem height	0.30	0.69	0.22	0.51	0.34
Stem girth	0.40	-0.29	0.83	-0.04	-0.24
Number of leaves	0.36	-0.64	-0.24	0.44	0.45
Leaf Area	0.54	0.13	-0.14	-0.72	0.39
Eigen value	1.89	1.19	0.82	0.65	0.45
Proportion %	37.76	23.71	16.41	13.03	9.09

The principal component axis (PCA) obtained from the morphological traits of maize genotypes, showed variation in Eigen values and proportion as; 1.89 (37.76%), 1.19 (23.71%), 0.82 (16.41%), 0.65 (13.03%) and 0.45 (9.09%). The first PCA was highly related to the morphological traits. The second PCA were more related to plant height, stem height and leaf area compared to the third PCA which was related to stem height and stem girth and fourth PCA; plant height, stem height and number of leaves. The fifth PCA however showed more relation to stem height, number of leaves and leaf area (Table 6).

The effect of maize genotype was highly significant (P<0.001) on the drought resistance and disease severity, while significant effect was not shown by replicates on the two characters. Similarly, the interactive effect of Genotype x Replicates did not produce significant (p>0.05) effect (Table 7).

Maize genotype TZEI 161 was the best drought resistant in this study. TZBR COMP 2-YC1S1 280 was fairly drought resistant, while other genotypes showed less drought tolerant especially AMA TZBR YC_1F_1. However, the genotype AMA TZBR YC_1F_1 which was not resistant to drought appeared the most resistant to

Table 7: Mean square effect of genotype, replicate and genotype x replicate interaction on drought and disease severity of maize

Source	df	Drought resistance	Disease severity
Genotype	5	3.48**	1.62**
Replicate	3	0.97ns	0.75ns
Genotype x Replicate	15	0.47ns	0.76ns
Error	120	58	58.5
Corrected Total	143	85.31	80.33

Highly significant ($p<0.001$) = **, Significant ($p<0.05$) = *, ns = not significant, WAP = Week after Planting.

Table 8: Genotypic effect on the disease severity and drought resistance of maize

Genotypes	Drought resistance	Disease severity
G1	2.75cd	2.54abc
G2	3.58a	2.29c
G3	3.17abc	2.50bc
G4	3.04bc	2.92ab
G5	2.54d	2.75ab
G6	3.33ab	2.96a

Each value is the mean of four replicates. Values with the same alphabet are not significantly ($p<0.05$) different from one another across the column according to Duncan's Multiple Range Test.

G1= (IBIZA-EN13) TZBR COMP 2-YC_1S_1, G2= TZBR COMP 2-YC1S1 280, G3= AMA TZBR YC_1F_1, G4 = TZEI 25, G5 = TZEI 22, G6 = TZEI 161

Table 9: Effect of replicates on drought and disease severity of maize genotypes

Replicates	Drought resistance	Disease severity
1	3.25a	2.52a
2	2.92a	2.56a
3	3.17a	2.72a
4	2.94a	2.83a

Each value is the mean of four replicates. Values with the same alphabet are not significantly ($p<0.05$) different from one another across the column according to Duncan's Multiple Range Test.

Table 10: Correlation matrix of drought, disease severity, genotype and replicates on maize

Correlation	Drought resistance	Disease severity	Genotype	Replicate
Drought resistance				
Disease severity	0.138ns			
Genotype	-0.021ns	0.253*		
Replicate	-0.097ns	0.162ns	0.00ns	

Highly significant ($p<0.001$) = **, Significant ($p<0.05$) = *, ns = not significant, WAP = Week After Planting.

Table 11: Contribution of Principal Component Axis (PCA) to the variation of drought and disease severity in maize genotypes

Traits	Prin 1	Prin 2
Drought resistance	0.707	0.707
Disease severity	0.707	-0.707
Eigen value	1.17	0.83
Proportion (%)	58	42

diseases and pest infestation. This was followed by TZBR COMP 2-YC1S1 280 (2.54) and TZEI 25 (2.50), while significant difference ($p>0.05$) was not recorded on TZEI 22 (2.95) and TZEI 161 (2.75). TZBR COMP 2-YC_1S_1 was the most susceptible to diseases and infestation (Table 8). There was no significant ($p>0.05$) effect among the replicates on the drought resistant and disease severity of maize genotypes (Table 9).

Positive but non significant ($p>0.05$) correlation existed between drought resistant and disease severity of maize genotypes. However, the genotypes were positive and significantly correlated with disease severity, while genotypes and replicates produced negative and non significant correlation with drought resistance (Table 10).

The result of the principal component axis (PCA) of maize genotypes in table 11 showed that the first PCA had the Eigen value of 1.17 and accounted for 58% of the total variation, while the second PCA accounted for 42% of the total variation. The Eigen value of the first PCA was higher than the second PCA. The first PCA was similar and highly related to drought resistance and disease severity, while the second PCA is highly related to drought resistance compared to disease severity (Table 11).

DISCUSSION

Global demand for maize had been estimated to increase from 526 million tons to 784 million tons from 1993 to 2020, with most of the increased demand coming from developing countries [25]. However, drought and pest infestation are important abiotic and biotic stresses that still constitutes limiting factors to the increased production of maize as to sustain the rising global demands [15,26,27]. Plant resistance has been identified as a valuable tool in the development of traits that are tolerant to stress conditions [16]. Hence, the resistance of maize genotypes; TZBR COMP 2-YC_1S_1, TZBR COMP 2-YC_1S_1 280, AMA TZBR YC_1F_1, TZEI 25, TZEI 22 and TZEI 161 to drought and diseases were investigated in this study.

Wilting and loss of turgor were observed on the plants subjected to drought stress, this was in accordance with the report of Hsiao [28] that in water deficit conditions plant water potential and turgor are reduced enough to interfere with normal functions of the plants. The data taken on the growth characters after 14 days of drought experiment showed TZBR COMP 2-YC_1S_1 280 as the best performing genotype, followed by AMA TZBR YC_1F_1, then TZBR COMP 2-YC_1S_1, while TZEI 161 had the least growth rate. Similar genetic differences on the morphological characters of maize genotypes was reported by Ihsan [29] and also supported by Welsh [30] who considered the genetic variability as a key to crop improvement. TZEI 161 was the most drought resistant in this study, followed by TZBR COMP 2-YC1S1 280 while TZBR COMP 2-YC_1S_1 and AMA TZBR YC_1F_1 which were rated fairly good / poorly drought tolerant appeared the least. Drought tolerant genotypes distinguished themselves from non tolerant ones by their higher photosynthetic rates [31]. Whereas, the susceptibility of some genotypes to drought was validated by Kramer [26] who reported that about one-third of the world's potentially arable land suffers due to water shortage and most of the crops production is often reduced by drought.

Although, most of the genotypes studied were moderately resistant to diseases, however, AMA TZBR YC_1F_1 which was the most susceptible to drought showed the most resistant to diseases and pest infestation in this study. The symptoms such as necrosis, stunted growths, vein clearing, wilting, leaf defoliation and stem impairments were observed in this study, whereas, for each defoliation that occur as a result of pest infestation, the plants will re-direct their assimilates toward regeneration of new leaves [32] thereby causing set back in the growth process. The resistance of AMA TZBR YC_1F_1 could possibly reveal its potential as a resistant genotype to biotic stress which was considered as a useful component of integrated pest management for several insects that are economically damaging to maize [27].

Relationship exists between the genotypes and period of drought experiment as assessed on the plant height, stem height, stem girth, number of leaves and leaf area. This correlation thereby validates the report of Alam [33] who associated the reduction in shoot elongation in water stress plants with the vegetative period of growth in maize. Moreso, the number of leaves produced were directly correlated with growths of other characters, similar results had been reported by Haq *et al*. [34] reason could possibly as the result of the photosynthetic ability of the leaves which in turn enhances plant growths [31]. The positive interaction of genotype with disease severity could be attributed to the positive response of the growth and other morphological traits in maize as similarly reported by Olawuyi *et al*. [35].

The proportion of spread of the genetic variability on growth characters of the maize genotypes ranges from 37.76% to 9.09%, while the drought and disease assessment varied by 58% to 42% as determined according to Eigen analysis. This result could possibly indicate the differences in the quality and tolerance of the different maize genotypes used, as was found in line with the result obtained by Grzesiak [33] who reported considerable genotypic variability among various maize genotypes for different traits.

Hence, genotype TZEI 161 was ranked best for resistance to drought but had the least vegetative growths, while AMA TZBR YC_1F_1 which best confers highest resistance to diseases and pest infestations (2.29) is not drought tolerant (3.58). Therefore, the maize genotype TZBR COMP 2-YC1S1 280 which produced the best vegetative growths and moderately combines drought (2.75) and disease resistant (2.54) traits is the recommended genotype.

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