



MORPHOLOGICAL ADAPTATIONS OF MAIZE ACCESSIONS UNDER NATURAL FIELD PATHOGEN PRESSURE

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ABSTRACT

This study evaluated the morphological response of ten maize accessions obtained from the International Institute of Tropical Agriculture, Ibadan, to field pathogens. The field experiment was conducted using a completely randomized design with four replicates. The maize accessions were planted in unsterilized soil under natural field conditions. Data on morphological traits were collected over ten consecutive weeks, and disease severity was rated on a scale of 1 to 5. The findings revealed that accession TZM 115 performed better in most morphological traits, while accession TZM 105 showed the highest resistance to field pathogens, with a disease severity rating of 2.90 compared to the highest rating of 3.38 recorded for accession TZM 45. Thus, accessions TZM 115 and TZM 105 are recommended for adoption in maize breeding and improvement programs due to their high disease resistance potential and favorable morphological traits.

Keywords: Maize, Pathogens, Disease severity, Resistance, Morphological traits.

INTRODUCTION

Maize (*Zea mays L.*) is an economically significant cereal crop cultivated across various agro-ecological zones of Nigeria and ranks as the third most cultivated cereal globally (IITA, 2007; Sandhu *et al.*, 2007; Olawuyi *et al.*, 2010; Okoro-Robinson *et al.*, 2014). It thrives in diverse environmental conditions, with an annual production of approximately one million metric tons, making it the most widely produced staple cereal (FAOSTAT, 2012). Maize serves as a vital source of protein and carbohydrates for many people in developing countries, and a significant portion of global maize production is used in the animal feed industry (Shiferaw *et al.*, 2011).

Maize production faces numerous challenges, including susceptibility to various pathogens. Production constraints include biotic

factors such as insect pests and pathogens, abiotic stresses like drought and nutrient deficiencies, and socio-economic challenges such as market price instability and input scarcity (Akanke and Lamidi, 2006; Mosisa *et al.*, 2012). Key biotic threats include fungal, bacterial, viral, nematode, and mycoplasma infections, as well as parasitic plants (Manandhar, 1997).

Pathogens affecting maize include fungal species (*Fusarium spp.*, *Cercospora zae-maydis*, *Puccinia sorghi*, *Physoderma maydis*, *Curvularia spp.*, *Colletotrichum graminicola*, *Mycosphaerella spp.*, *Helminthosporium maydis*, *Rhizoctonia solani*, *Ustilago maydis*, *Trichoderma viride*, *Penicillium sp.*, *Aspergillus sp.*), bacterial species (*Erwinia carotovora*, *Erwinia stewartii*, *Xanthomonas rubrilineans*), and viruses (e.g., maize mosaic virus and leaf fleck virus). Insect pests also cause substantial damage. Moth species,

the most destructive pests of maize, include armyworms, cutworms, earworms, grain moths, and borers. Beetles, which are ranked second in terms of impact, include wireworms, rootworms, weevils, grubs, and grain borers. Finally, sap-sucking pests like aphids and leafhoppers serve as vectors for maize pathogens (Alenjandro, 1987; Subedi, 2015).

Diseases are principal threats to maize production, reducing plant health, market value, and yield (Akande and Lamidi, 2006). The impact of diseases on maize production continues to grow annually. In 2001, global losses from environmental pathogens in maize production were estimated at 9% (Oerke, 2005), and by 2003, production declines due to disease were reported at 10%, with variations across regions—4% in Northern Europe and up to 14% in South Asia and West Africa (Oerke, 2009). Predominantly fungal pathogens lead to considerable losses, with reports suggesting up to 30% of global maize production is compromised (Agrios, 1997; Chhokar, 2001; Owolade *et al.*, 2005; Hussain *et al.*, 2013). The two most common fungal pathogens affecting maize are *Fusarium* and *Aspergillus* species. *Fusarium verticillioides* causes root, ear, silk, seed, and stalk rots in tropical and subtropical regions via airborne conidia (Rossouw *et al.*, 2002; Alankoya *et al.*, 2008; Duncan, 2010). *Aspergillus* species, particularly *Aspergillus niger*, infect maize under cultivation, resulting in black, powdery spore masses on kernels and cobs (CIMMYT, 2004; Somda *et al.*, 2008).

Disease assessment, a key strategy in studying fungal pathogen diversity, involves determining disease incidence and severity (Zhan *et al.*, 2007; Haque *et al.*, 2008; Venturini *et al.*, 2012). Control methods for maize diseases mainly include fungicide application and cultural practices, especially for managing grey leaf spot disease (Ward *et al.*, 1997). However, fungicide use is often impractical and costly for small-scale farmers and can be limited by unpredictable weather and environmental concerns (Danson *et al.*, 2008). A more sustainable approach is the use of disease-resistant maize varieties, which has proven cost-effective in managing various maize diseases (Ininda *et al.*, 2007; Rehman *et al.*, 2021). Broadening the genetic base of existing cultivars is essential for breeding maize varieties with

enhanced resistance to pathogens. This study aims to evaluate the morphological performance of selected maize accessions, focusing on their resistance potential against field pathogens.

MATERIALS AND METHODS

Sources of soil sample and plant materials

The soil used for the experiment was collected from the nursery farm of the Department of Botany at the University of Ibadan. It was sterilized by heating in an electric soil sterilizer and allowed to cool before being used to fill 10 kg polythene bags. Six small perforations were made around the base of each bag to prevent water logging. Ten maize accessions (TZM 102, TZM 105, TZM 179, TZM 115, TZM 1428, TZM 1422, TZM 91, TZM 1376, TZM 45, and TZM 137) were obtained from the Genetic Research Centre (GRC) at the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State.

Study Location and Experimental design

The experiment was conducted from September 2019 to December 2019 in the nursery farm of the Department of Botany, University of Ibadan, Nigeria (Latitude 3.9000°N, Longitude 7.4417°E). It followed a completely randomized design with four replicates. Ten maize accessions were cultivated and labeled as V1, V2, V3, V4, V5, V6, V7, V8, V9, and V10, with each accession having four replicates labeled R1, R2, R3, and R4. In total, 40 maize plants were evaluated and observed throughout the experiment.

Method of planting and cultural practices

The planting method and cultural practices were based on the procedure described by Ali *et al.* (2011). Two seeds from each maize accession were sown in each polythene bag at a depth of 12 cm, with 25 cm spacing maintained between bags. During the second week, thinning was carried out to retain one plant per bag. Each maize plant received daily watering of 250 ml, and regular weeding was conducted to ensure optimal growth conditions.

Evaluation of morphological characters and disease severity.

The morphological characteristics were assessed following the procedure outlined by Martins *et al.* (2014). A 100 cm meter rule was used

to measure leaf length, leaf width, stem height, and plant height. For each plant, a leaf was selected at random, and its length (from apex to base) and width (measured at the midpoint of the leaf margin) were recorded. Plant height was measured from the soil level to the plant apex, and stem height from the soil level to the apex where the plant branches. Leaf count was conducted by counting each leaf on the plant. Tassel length was measured with a meter rule from the tassel tip to its point of growth. A vernier caliper was used to measure the girth of the husk cover.

For assessing plant stand/aspect, disease severity, and husk cover, the rating scales of Kim (1993) and Berger *et al.* (2014) were applied. Disease severity was rated on a scale of 1–5, where 1 represented "highly resistant," 2 "resistant," 3 "moderately susceptible," 4 "susceptible," and 5 "highly susceptible."

Statistical analysis

The data obtained were analyzed using analysis of variance (ANOVA) with the Statistical Analysis System (SAS). Means were separated using Duncan's Multiple Range Test (DMRT) at a 95% confidence level to determine significant differences among the accessions. A correlation matrix was also generated to assess relationships among the various morphological characteristics studied.

RESULTS

Mean square effects of accessions and weeks after planting on growth characters and disease severity of maize

The mean square effects of the accessions and weeks after planting on the growth characteristics and disease severity of maize, as presented in Table 1, indicate that both factors significantly influenced the measured traits. Specifically, the accessions and the duration after planting had highly significant effects ($p < 0.01$) on plant height, stem height, leaf length, leaf width, and the number of leaves per plant. Additionally, the accessions exhibited a significant effect ($p < 0.05$) on disease severity and plant aspect. In contrast, the duration after planting demonstrated a highly significant effect ($p < 0.001$) on disease severity, plant aspect, and husk cover.

Performance of growth, agronomic characters and disease severity of maize accessions.

The effects of accessions on the morphological characteristics of maize, as summarized in Table 2, reveal that accessions TSM 115 and TSM 105 exhibited significantly higher values ($p < 0.05$) across various growth metrics compared to other accessions. The mean values for these two accessions were as follows: plant height (89.19 cm for TSM 115 and 84.89 cm for TSM 105), stem height (43.93 cm and 44.29 cm), leaf length (49.57 cm for both), leaf width (3.84 cm and 4.07 cm), and plant aspect (3.25 and 3.50 cm), with no significant differences among these means.

Conversely, TSM 179 and TSM 137 did not show significant differences in plant height (73.37 cm and 74.99 cm), leaf length (44.64 cm and 44.05 cm), tassel length (21.21 cm and 15.38 cm), husk cover (6.50 cm and 5.50 cm), and husk quality (5.00 cm and 1.50 cm). Accessions TSM 91 and TSM 1422 recorded significantly lower mean values for stem height (26.08 cm and 22.43 cm), leaf width (2.69 cm and 2.80 cm), and number of leaves (7.18 cm and 6.81 cm), respectively, compared to the other accessions.

Regarding disease severity, significant differences were observed only for TSM 115 (mean value of 2.90), TSM 45 (3.38), and TSM 102 (3.30). The accessions TSM 1376, TSM 179, TSM 137, TSM 45, TSM 102, and TSM 1428 did not differ significantly in leaf length, with values of 48.02 cm, 44.64 cm, 44.05 cm, 37.70 cm, 41.42 cm, and 39.80 cm, respectively.

There was no significant variation among accessions in husk quality. However, TSM 102 and TSM 137 showed significant differences in husk cover and plant aspect. Although TSM 115 did not significantly differ ($p < 0.05$) for tassel length, it was significantly different from other accessions. Notably, TSM 1376, TSM 179, TSM 45, and TSM 102 were significantly different regarding the number of leaves per plant, with mean values of 8.81, 8.53, 8.57, and 8.92, respectively. TSM 137 and TSM 1428 had mean values of 9.45 and 9.41 for the number of leaves per plant, showing no significant difference. For leaf width, TSM 1376 (3.38 cm) and TSM 179 (3.43 cm) did not differ significantly, similar to TSM 45 (2.93 cm) and TSM 1428 (2.98 cm).

Principal Component Analysis (PCA) of Growth Characters of Maize

The results presented in Table 3 summarize the principal component analysis (PCA) of the maize accessions, revealing six principal component axes: Prin 1, Prin 2, Prin 3, Prin 4, Prin 5, and Prin 6. Among these, Prin 1 accounted for the highest proportion of variance, with an eigenvalue of 6.75 and a proportion of 0.68. In contrast, Prin 6 represented the least variance, with an eigenvalue of 0.25 and a proportion of 0.03.

Examining the eigenvectors of the morphological characteristics, several traits were closely related within the first principal component (Prin 1): plant height (0.37), stem height (0.31), leaf length (0.35), and leaf width (0.38). This suggests that these characters share a common variance and may respond similarly to environmental factors or genetic influences.

In Prin 2, plant height (0.02), tassel length (0.01), and plant aspect (0.01) were identified as closely related, each exhibiting low eigenvector values around 0.01, indicating a weak association. Prin 3 revealed pairs of closely related characters, including plant height and stem height (0.05 each), leaf width (0.15), number of leaves (0.14), and disease severity and tassel length (0.10 each).

Notably, no characters demonstrated close associations in Prin 4 or Prin 6. However, in Prin 5, plant height and stem height were found to be closely associated, with eigenvector values of 0.33 and 0.31, respectively. This indicates a potential linkage between these two traits, possibly reflecting their interdependence in growth and development. Overall, the analysis illustrates the complex relationships among various morphological characteristics of maize accessions, highlighting key traits that contribute significantly to variance in the dataset.

Table 4: Correlation of growth characters of maize

The results of the correlation coefficient analysis of growth characters in maize, as shown in Table 4, indicate significant interrelationships among various morphological traits. Plant height exhibited a positive and strong correlation ($p < 0.01$) with several characters: stem height, leaf length, leaf width, number of leaves, and tassel length. The correlation coefficients (r values) ranged from 0.75

(for the number of leaves) to a maximum of 0.99 (for stem height), indicating a particularly close association with stem height.

Additionally, plant height showed positive correlations with husk cover ($r = 0.54$) and the number of weeks ($r = 0.51$), suggesting that taller plants also tend to have greater husk cover and that these traits develop positively over time.

Stem height revealed highly significant and strong correlations with leaf length ($r = 0.85$), leaf width ($r = 0.89$), number of leaves per plant ($r = 0.75$), and tassel length ($r = 0.96$). A strong correlation was also observed between stem height and husk cover ($r = 0.52$), indicating that as the stem height increases, the husk cover also tends to increase.

Leaf length had a strong positive correlation with leaf width ($r = 0.89$), number of leaves per plant ($r = 0.60$), husk cover ($r = 0.60$), and tassel length ($r = 0.79$), highlighting its central role in overall plant morphology. Furthermore, leaf length showed a positive correlation with weeks ($r = 0.53$), suggesting that as time progresses, leaf length also increases.

Leaf width exhibited significant positive correlations with the number of leaves ($r = 0.67$), tassel length ($r = 0.77$), and husk cover ($r = 0.60$). The number of leaves showed a strong correlation with tassel length ($r = 0.66$), indicating that plants with more leaves also tend to have longer tassels.

Disease severity was significantly correlated with husk cover ($r = 0.66$) and weeks ($r = 0.72$), indicating that as disease severity increases, the husk cover and duration of growth may also be affected. A strong correlation was found between disease severity and plant aspect ($r = 0.56$), suggesting that the overall appearance of the plant may change with disease progression.

Tassel length was strongly correlated with husk cover ($r = 0.57$) and weeks ($r = 0.55$), indicating that both factors influence tassel development. Lastly, plant aspect had strong correlations with husk cover ($r = 0.55$), husk quality ($r = 0.52$), and accession ($r = 0.55$), underscoring its relationship with overall plant health and morphology.

Overall, the analysis reveals complex interdependencies among growth characteristics, providing valuable insights for selecting desirable traits in maize breeding programs.

Table 1: Mean square effects of accessions and weeks on growth, agronomic characters and disease severity of maize

Source	Df	Plant height	Stem height	Leaf length	Leaf width	Number of leaves	Disease severity	Tassel length	Plant aspect	Husk cover	Husk quality
Accessions	9	5219.92 ^{***}	1951.07 ^{***}	3217.30 ^{***}	7.14 ^{***}	43.70 ^{***}	0.89 [*]	1458.75 ^{ns}	3.28 [*]	0.39 ^{ns}	2.99 ^{ns}
Weeks	9	33813.86 ^{***}	27110.58 ^{***}	8091.71 ^{***}	46.34 ^{***}	109.69 ^{***}	21.10 ^{***}	1381.40 ^{ns}	11.33 ^{***}	15.64 ^{**}	3.65 ^{ns}
Replicates	3	33522.07 ^{ns}	1592.18 ^{ns}	1388.89 ^{ns}	8.66 ^{ns}	102.41 ^{ns}	3.11 ^{***}	1708.28 ^{ns}	4.44 ^{ns}	0.12 ^{ns}	1.41 ^{ns}

Table 2: Effects of growth, agronomic characters and disease severity on performance of maize accessions.

ACCESSIONS	PH(cm)	SH(cm)	LL(cm)	LW(cm)	NOL	DS	TL(cm)	PA	HC(cm)	HQ
TZ _M 115	89.19 ^a	43.93 ^a	49.57 ^a	3.84 ^a	10.41 ^a	2.90 ^c	52.73 ^a	3.25 ^a	6.00 ^{ab}	5.00 ^a
TZ _M 105	84.89 ^a	44.29 ^a	49.57 ^a	4.07 ^a	8.03 ^{cd}	3.10 ^{abc}	22.36 ^b	3.50 ^a	7.00 ^a	1.33 ^b
TZ _M 1376	82.58 ^{ab}	37.41 ^b	48.02 ^{bc}	3.38 ^b	8.81 ^{bc}	3.18 ^{abc}	20.22 ^b	3.38 ^a	7.00 ^a	1.00 ^b
TZ _M 179	73.37 ^b	37.01 ^c	44.64 ^{bc}	3.43 ^b	8.53 ^{bc}	3.08 ^{abc}	21.21 ^b	3.00 ^a	6.00 ^{ab}	5.00 ^a
TZ _M 137	74.99 ^b	36.26 ^b	44.05 ^{bc}	3.25 ^{bc}	9.45 ^{ab}	2.98 ^{bc}	15.38 ^b	1.88 ^b	5.50 ^{ab}	1.50 ^b
TZ _M 45	64.53 ^c	30.17 ^c	37.70 ^{bc}	2.93 ^{cde}	8.57 ^{bc}	3.38 ^a	21.29 ^b	3.88 ^a	7.00 ^a	1.00 ^b
TZ _M 102	63.14 ^c	27.46 ^{cd}	41.42 ^{bc}	3.13 ^{bcd}	8.92 ^{bc}	3.30 ^{ab}	14.00 ^b	3.50 ^a	4.33 ^b	2.00 ^b
TZ _M 1428	61.51 ^c	26.64 ^{cd}	39.80 ^{bc}	2.98 ^{cde}	9.41 ^{ab}	3.05 ^{abc}	14.00 ^b	3.63 ^a	6.50 ^a	3.50 ^{ab}
TZ _M 91	57.47 ^c	26.08 ^{cd}	35.25 ^c	2.69 ^e	7.18 ^{de}	3.18 ^{abc}	13.38 ^b	3.25 ^a	6.00 ^{ab}	1.00 ^b
TZ _M 1422	55.16 ^c	22.43 ^d	35.25 ^c	2.80 ^{de}	6.81 ^e	2.98 ^{bc}	12.44 ^b	4.13 ^a	6.00 ^{ab}	1.00 ^b

PH-Plant height, SH-Stem height, LL-Leaf length, LW-Leaf width, NOL-Number of leaves per plant, DS-Disease severity, TL-Tassel length, PA-Plant aspect, HC-Husk cover, HQ-Husk quality. Means with the same letter in the same column are not significantly different at p<0.05 using Duncan's Multiple Range Test (DMRT)

Table 3: Principal Component Analysis (PCA) of Growth Characters of maize

	PRIN 1	PRIN 2	PRIN 3	PRIN 4	PRIN 5	PRIN 6
P.H (cm)	0.37	0.02	0.05	-0.01	0.33	-0.05
S.H(cm)	0.38	0.05	0.05	-0.06	0.31	-0.07
L.L(cm)	0.36	-0.01	-0.25	0.06	-0.14	0.41
L.W(cm)	0.36	-0.003	0.15	0.16	0.10	0.65
NOL	0.29	0.26	0.14	0.73	-0.09	-0.26
D.S	-0.31	-0.30	0.10	0.58	0.26	-0.09
T.L(cm)	0.35	0.01	0.10	-0.27	0.37	-0.47
P.A	-0.33	0.01	0.32	-0.04	0.63	0.32
H.C(cm)	0.18	-0.55	0.71	-0.11	-0.35	-0.04
H.Q	-0.13	0.73	0.51	-0.10	-0.16	0.04
E.V	6.75	1.26	0.71	0.53	0.37	0.25
Proportion	0.68	0.13	0.07	0.05	0.04	0.03

PH-Plant height, SH-Stem height, LL-Leaf length, LW-Leaf width, NOL-Number of leaves per plant, DS-Disease severity, TL-Tassel length, PA-Plant aspect, HC-Husk cover, HQ-Husk quality.

Table 4: Correlation of growth characters and disease severity of *Zea mays*

	PH	SH	LL	LW	NOL	DS	TL	PA	HC	HQ	GN	WK	R
PH													
SH	0.99**												
LL	0.86**	0.85**											
LW	0.88**	0.89**	0.89**										
NOL	0.75**	0.75**	0.60**	0.67**									
DS	-0.03	-0.08	0.20	-0.01	-0.16								
TL	0.96**	0.96**	0.79**	0.77**	0.66**	0.03							
PA	-0.24	-0.26	-0.11	-0.07	-0.14	0.56**	-0.18						
HC	0.54*	0.52*	0.60**	0.60**	0.25	0.66**	0.57*	0.55*					
HQ	-0.12	-0.11	-0.07	-0.04	-0.01	0.35	-0.07	0.52*	0.24				
AC	0.30	0.32	-0.01	0.13	0.36	-0.17	0.30	-0.24	0.16	-0.19			
WK	0.50*	0.47	0.53*	0.48	0.26	0.72**	0.55*	0.55*	0.93**	0.32	-0.02		
R	0.11	0.15	0.22	0.37	-0.01	0.09	0.07	0.49	0.50*	0.14	-0.02	0.35	

*= Significant at $p < 0.05$, **= Highly significant at $p < 0.01$; PH-Plant height, SH-Stem height, LL-Leaf length, LW-Leaf width, NOL-Number of leaves per plant, DS-Disease severity, TL-Tassel length, PA-Plant aspect, HC-Husk cover, HQ-Husk quality, AC- accessions, WK- weeks R- replicates.

DISCUSSION

The findings of this study elucidate the substantial variability in the morphological responses of various maize accessions to field pathogens, with significant implications for crop improvement strategies and food security.

Variation in Resistance to Pathogens

The maize accession TZM 115 stood out as the most resistant to pathogens among the tested accessions. This accession not only demonstrated superior resistance but also showed advantageous traits such as early germination and rapid maturity. These characteristics are critical for minimizing exposure to pathogens and optimizing yield in environments where diseases are prevalent. The resistance exhibited by TZM 115 aligns with previous studies that highlight the importance of selecting for disease resistance in crop breeding to enhance agricultural resilience.

Other accessions, including TZM 91, TZM 179, and TZM 1376, were noted for their unique morphological traits, particularly their leaf length and width. These traits are crucial as they serve as proxies for photosynthetic efficiency, directly impacting the plant's ability to capture sunlight and convert it into energy for growth. The presence of these novel traits indicates the potential for these accessions to contribute positively to maize yield, especially under varying environmental stress conditions. The genetic variability within these accessions represents an invaluable resource that can be harnessed for breeding programs aimed at improving maize productivity and resilience.

Implications for Breeding and Improvement Programs

The study's results advocate for the inclusion of TZM 115 and TZM 105 in maize breeding programs focused on developing varieties with high disease resistance. The combination of disease resistance with desirable morphological traits positions these accessions as strong candidates for breeding initiatives. By integrating the genetic strengths of these accessions into new cultivars, breeders can potentially create hybrids that not only resist disease but also perform well under diverse agricultural conditions.

Furthermore, the research emphasizes the

necessity for understanding the genetic relationships among various morphological traits. By identifying correlations between traits such as plant height, leaf dimensions, and husk cover, breeders can develop selection strategies that enhance overall plant performance. The correlation analysis and principal component analysis (PCA) conducted in this study provide a robust framework for breeders to select for multiple traits simultaneously, which is crucial for developing resilient and high-yielding maize varieties.

Cultural Practices and Yield Optimization

In addition to the genetic factors influencing maize performance, the study underscores the importance of proper cultural practices in maximizing maize productivity. The presence of various pathogens in local conditions necessitates effective management strategies to mitigate their impact on crop yields. Adopting integrated pest management practices, ensuring proper soil health, and implementing crop rotation can significantly reduce disease pressure on maize crops.

The study's findings point to the need for education and training for farmers on the significance of these practices, as many local farmers may not be aware of the potential yield losses associated with poor management of pathogens. By promoting best agricultural practices alongside the introduction of disease-resistant varieties, the agricultural community can work toward enhancing food security and sustainability in maize production.

CONCLUSION

This study revealed significant variation in the morphological responses of maize accessions to field pathogens. Notably, the maize accession TZM 115 demonstrated the highest resistance to these pathogens, excelling in early germination and maturity. Additionally, other accessions such as TZM 91, TZM 179, and TZM 1376 exhibited valuable traits, including increased leaf length and leaf width, which serve as indicators of enhanced photosynthetic activity. These genetic resources can be effectively harnessed to improve maize production and ensure food security.

Given their performance, accessions TZM 115 and TZM 105 are recommended for adoption in maize breeding and improvement programs aimed

at producing varieties with high disease resistance and enhanced morphological traits. Furthermore, this study underscores the critical importance of implementing proper cultural practices in maize cultivation. Many pathogens are prevalent in local conditions and can significantly reduce achievable yield potentials, highlighting the need for farmers to adopt effective management strategies to optimize productivity.

Overall, this study highlights the critical interplay between genetic diversity, breeding strategies, and agricultural practices in the pursuit of resilient maize varieties. The identification of promising accessions and their unique traits provides a pathway for improving maize production in the face of evolving environmental challenges. As global food demand continues to rise, leveraging the findings from this research can play a significant role in ensuring a stable and secure food supply, particularly in regions where maize is a staple crop. The ongoing collaboration between researchers, breeders, and farmers will be essential for translating these insights into practical applications that bolster food security and agricultural sustainability.

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