

THE PERFORMANCE OF NEW EARLY MATURING PRO-VITAMIN A
MAIZE (*ZEAMAYS* L.) HYBRIDS IN THE DERIVED SAVANNA
AGRO-ECOLOGY OF NIGERIA

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Abstract: Maize (*Zea mays* L.) is a staple food for millions of people across the globe, and it supplies more than 30% of total dietary calories. However, the normal endosperm lacks a sufficient quantity of the nutritive precursor of vitamin A. To achieve food security and avert malnutrition, there is a need to adopt the cultivation of the early multiple stress-tolerant pro-vitamin A maize hybrid. The objective of this study was to assess the agronomic performance and yield of the newly developed maize hybrids. Fifteen improved maize hybrids and one commercial hybrid used as a local check were evaluated in a randomized complete block design with two replications for two years at the Ladoke Akintola University of Technology Teaching and Research farm in Ogbomoso, Nigeria. Hybrids exhibited significant variation ($P < 0.01$) for grain yield, number of days to anthesis and silking, ear height and husk cover. Across the years, the grain yield of hybrids ranged between 4,780.8 kg ha⁻¹ (PVAEH-19) and 7,886.9 kg ha⁻¹ (PVAQEH-1), with a mean of 6,354.2 kg ha⁻¹. PVAEH-15 ranks the best on the basis of superiority in grain yield, early flowering and tight husk cover. Fourteen hybrids out-yielded the local check (4,947.2 kg ha⁻¹), and five hybrids had a significant ($P < 0.05$) yield advantage of > 26% over the local check. The consistent performance of PVAEH-15 and PVAEH-16 in the two years of evaluation indicates potential for the adaptability of the hybrids to the agro-ecology. Farmers' adoption of these maize hybrids will boost maize production and prevent malnutrition in the derived savanna agro-ecology of Nigeria.

Key words: adaptation, agronomic traits, evaluation, grain yield, malnutrition.

Introduction

Maize (*Zea mays* L.) is a staple crop and source of calories, proteins, vitamins and minerals. It accounts for an average of 15–20% of the daily calories in the diets

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of inhabitants of sub-Saharan Africa (SSA) and is the source of income for smallholder farmers (FAOSTAT, 2016). Maize adapts to different environments and serves as an important feed, fodder and industrial crop due to its popularity across regions (Randjelovic, 2011). It has been forecasted to become the crop with the highest production by 2025, and the demands will be doubled by 2050 (Rosegrant et al., 2008). The development and deployment of improved maize cultivars by international and national research institutes assured increased maize productivity in the savanna agro-ecologies.

The savanna agro-ecologies of Nigeria have great potential for food production because of their high solar radiation favouring maize production (Bello et al., 2012). Like the rainforest region, the derived savanna experiences adequate annual precipitation and ample solar radiation as the Guinea savanna. These weather conditions result in a suitable environment for agricultural production. In spite of the growing reputation of maize as a chief income earner for resource-limited farmers in SSA over the last few decades (Fakorede et al., 2003; FAOSTAT, 2016), its yields on smallholder farmers' fields remain low owing to diverse abiotic and biotic stresses (drought, heat waves, low soil nitrogen (low-N), foliar diseases, insect infestations and *Striga hermonthica* parasitism) among which drought is the most disturbing (Hao et al., 2011; Mir et al., 2012).

In the tropics, maize cultivation occurs mainly under rainfed conditions and is usually exposed to random drought, which results in crop losses and, occasionally, a total crop failure. This situation is worsened by the rising impact of global climate change, compelling maize production into marginal, drought-prone zones (Bello et al., 2012). Terminal drought during grain-filling growth phases can be devastating in maize breeding as a result of enhancing leaf senescence, reduction in leaf gas exchange parameters, chlorophyll content of the plant and consequently a reduction in grain yield (Habuš-Jerčić et al., 2018). With the occurrence of random drought in the derived savanna, early maturing maize genotypes that can avoid drought and other stress factors at flowering could be important in reducing losses (Olaoye et al., 2009; Hussain, 2011). Early maturing maize varieties can be beneficial in various cropping systems like intercropping and mixed cropping by competing less for moisture, light, and nutrients than the late-maturing varieties. Their planting period can also be adjusted, thereby aiding multiple planting cycles in a season to lessen the risk of losing a single crop to weather hazards (Pswarayi and Vivek, 2008). The unpredictable changes in environmental conditions affect the performance of maize genotypes. Thus, evaluating the performance of new maize hybrids in a specific agro-ecology is essential.

Furthermore, maize varieties of standard grain quality have a deficiency in amino acids (lysine and tryptophan) and micronutrient supplements (pro-vitamin A), which may result in widespread malnutrition. Micronutrient deficiency, also known as hidden hunger, is a health condition caused by the lack of essential

vitamins and minerals required by the human body in small quantities (Nguyen et al., 2014). Vitamin A deficiency (VAD) has been established as a serious public health problem worldwide (Tsegaye Demissie et al., 2009; Akhtar et al., 2013). The menace of VAD is more pronounced in the developing economies of the world, where it is mainly caused by the inadequate consumption of foods that are rich in vitamin A (Tsegaye Demissie et al., 2009). In Africa, it has affected 54 million children and 4 million women (WHO, 2009; Mason and Shrimpton, 2010). β -carotene is a precursor of vitamin A and enhancing their concentration in maize grain enables better absorption of mineral nutrients (Kravić et al., 2014). However, maize may be used as a vehicle to tackle this deficiency through the utilization of improved quality varieties with the crop biofortification approach (Miller and Welch, 2013). Therefore, the adoption of early multiple stress-tolerant, pro-vitamin A (PVA) maize hybrid for cultivation by farmers will boost maize nutrient availability, productivity and income.

The maize improvement programme of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, possesses a genetically variable maize germplasm. They develop and maintain diverse genetic resources, which are useful sources of resistance and/or tolerance to biotic and abiotic stresses, higher grain yield potential, improved quality, earliness and wide adaptation. Improved genetic materials from the Institute's breeding programmes are disseminated to partners as either regional or international trials. The evaluation of the improved genotypes for adaptability and yield potential in the diverse growing environments will determine their suitability for cultivation by farmers in the agro-ecologies. Therefore, it is pertinent to assess the newly developed early maturing PVA enhanced maize hybrids for their reactions to other stress factors that may be unique to the derived savanna agro-ecology and also to identify hybrids that can replace existing cultivars for cultivation in farmers' fields. The objective of this study is, therefore, to assess the agronomic performance and yield of the early multiple stress-tolerant PVA enhanced maize hybrids, with the view to identify hybrids cultivated in the derived savanna agro-ecology of Nigeria.

Materials and Methods

Genetic materials

Sixteen (16) hybrid varieties comprising fifteen (15) multiple stress-tolerant PVA maize hybrids belonging to the early maturing group, which was originally part of international trials developed by the maize improvement programme (MIP) of IITA Ibadan, Nigeria, and a popular farmers' commercial hybrid, Oba Super 6, which is well adapted to the Savanna agro-ecologies, were used in this study (Table 1).

The hybrids were evaluated during the main growing seasons of 2018 and 2019 at the Teaching and Research (T&R) Farm of the Ladoké Akintola University of Technology (LAUTECH), Ogbomoso (8°10'N, 4°10'E, and altitude 341 m above sea level). The location is in the derived savanna agro-ecology of Nigeria. The annual mean rainfall of the experimental site ranges between 1,000 and 1,200 mm, while the daily temperature is between 28°C and 30°C. The soils are characterized as alfisol, which is generally low in nitrogen. The rainfall data for the years of the experiment (Figure 1) was obtained from the weather station situated at the Faculty of Agricultural Sciences, LAUTECH, Ogbomoso.

Table 1. The list of genetic materials used in this study.

Entry	Hybrid	Grain colour	Origin
1	PVAEH-14	Orange	IITA
2	PVAEH-15	Orange	IITA
3	PVAEH-16	Orange	IITA
4	PVAEH-17	Orange	IITA
5	PVAEH-18	Orange	IITA
6	PVAEH-19	Orange	IITA
7	PVAEH-20	Orange	IITA
8	PVAEH-21	Orange	IITA
9	PVAEH-22	Orange	IITA
10	PVAEH-23	Orange	IITA
11	PVAEH-24	Orange	IITA
12	PVAQEH-1	Orange	IITA
13	PVAEH-25	Orange	IITA
14	PVAQEH-2	Orange	IITA
15	Check(RE)	Yellow	IITA
16	Oba super 6	Yellow	Local Check

PVAEH = Pro-vitamin A early hybrid; PVAQEH = Pro-vitamin A QPM early hybrid; RE = Reference entry.

The experiment for each year was established in the first week of June when the rains have become steady. The sixteen hybrids were planted each year in a randomized complete block design (RCBD) with two replications. Each plot was a double 5-m row spaced 0.75 m apart with 0.50-m spacing between plants within each row. Three seeds were planted per hole and were later thinned to two plants per stand 2 weeks after sowing to attain the optimum population density of 53,333 plants ha⁻¹. NPK 15-15-15 fertilizer was applied at the rate of 60 kg N, 60 kg P, and 60 kg K per hectare at the time of sowing. Urea (45% N) was applied 4 weeks after sowing as top-dressing at the rate of 60 kg N ha⁻¹ to achieve a total of 120 kg N ha⁻¹ recommended for maize production in the zone. A mixture of herbicides including gramoxone (post-emergence) and primextra (pre-emergence) was applied at the rate of 5.0 l ha⁻¹ at sowing, and manual weeding was subsequently done to keep the experimental plots weed-free.

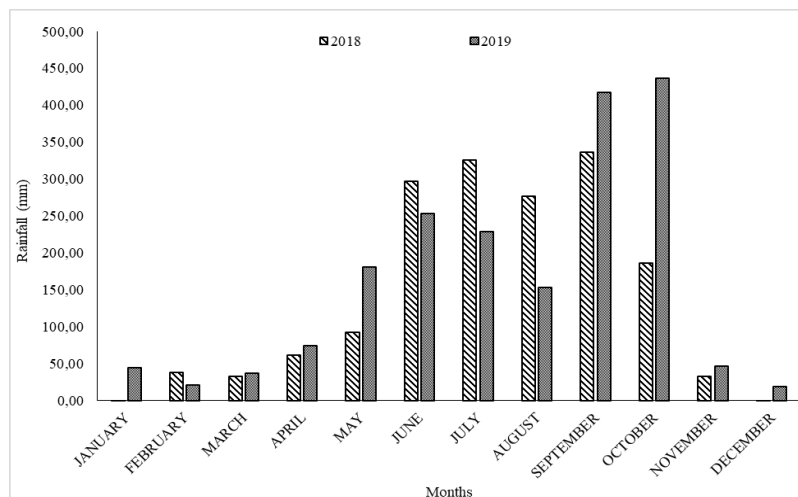


Figure 1. The monthly rainfall distribution pattern for Ogbomosho in 2018 and 2019.

Source: LAUTECH weather station, Ogbomosho, Nigeria.

Data collection and analyses

For each plot in each year's experiment, data were taken on the following traits: anthesis dates were recorded as the number of days from sowing to pollen shed for 50% of the plants in a plot; silking dates were taken as the number of days from sowing to silk emergence for 50% of the plants in a plot; anthesis-silking interval (ASI) was then calculated as the difference between silking and anthesis dates; plant height was measured in centimeters (cm) as the distance from the base of the plant to the height of the first tassel branch; ear height was also measured in cm as the distance from the base of the plant to the node bearing the upper ear; plant aspect was visually scored on a scale of 1–5, where 1 = excellent overall phenotypic appeal and 5 = poor overall phenotypic appeal; husk cover was visually rated on a scale of 1–5, where 1 = husks tightly arranged and extended beyond the ear tip and 5 = ear tips exposed; ear aspect was also visually assessed on a scale of 1–5, where 1 = clean, uniform, large, and well-filled ears, and 5 = rotten, variable, small, and partially filled ears; number of ears per plant was calculated as the ratio of number of harvested ears to number of harvested plants; grain yield measured in kg ha^{-1} was extrapolated from field weight and grain moisture recorded at harvest and was adjusted to 15%.

A separate analysis of variance (ANOVA) was performed on the data collected on an individual year basis. The ANOVA results of 2018 and 2019 data show moderate heritability estimates (0.35–0.83) and a low coefficient of variation

(2.34–24.26%) for all traits measured, thereby justifying the analysis across the years. The data for the two years were pooled for combined ANOVA, year and replications were considered as random factors, whereas the hybrids were considered as fixed effects. Entry means were generated for each trait and were separated using Fisher's protected least significant difference test (LSD) at $P < 0.05$ according to Steel and Torrie (1980). All analyses were performed using PROC GLM, in SAS (SAS Institute, 2011). A rank summation index (RSI) (Mulumba and Mock, 1978) was constructed to determine the overall performance of each entry. The index was obtained by ranking each entry for grain yield, number of days to anthesis, number of days to silking and tight husk cover. The 16 genotypes were ranked from the lowest to the highest for each trait, and RSI was calculated by summing the ranks to select the top five outstanding maize hybrids. Thus, the lowest index value obtained by an entry would be 4.0 if it was superior for all four traits.

Results and Discussion

The combined ANOVA revealed that year was a significant ($P < 0.01$) source of variation for all measured traits, and its sums of squares, expressed as percentages of the corrected total sums of squares, accounted for 3–49% of the total variation for all agronomic traits measured. On the other hand, the mean square of hybrid \times year interaction was significant ($P < 0.05$) only for number of days to anthesis, suggesting that the hybrids displayed consistent performance over the years of evaluation, therefore aiding the identification of potentially high-yielding hybrids for the location. Previous authors have identified superior hybrids based on the absence of significant interaction between the hybrids and year for grain yield in maize (Menkir et al., 2014; Abera et al., 2016). The mean square of hybrids differed significantly ($P < 0.05 / 0.01$) for grain yield, number of days to anthesis and silking, ear height and husk cover. The observed variations may be a result of the diverse genetic makeups and backgrounds of the parental materials used in their formation. The coefficient of variation (CV) was $> 20\%$ only for ASI, ear aspect and husk cover ratings (Table 2).

Considering the traits that showed significant variation, the year of 2018 was the most favourable for the expression of grain yield potential. Although the amount of rainfall was evenly distributed in both years, the year of 2018 had higher rainfall between June and August (Figure 1) which were crucial periods for growth, flowering and grain filling. Hence, grain yield varied between 7,509.4 kg ha⁻¹ (PVAEH-19) and 11,349.3 kg ha⁻¹ (PVAEH-23) with a mean of 9,272.9 kg ha⁻¹. PVAEH-23 had the highest grain yield potential, which differed significantly ($P < 0.05$) from 9 of the early maturing PVA maize hybrids. All the early maturing PVA maize hybrids out-yielded the local check (6,656 kg ha⁻¹), but only 8 hybrids had a

significant ($P < 0.05$) yield advantage of $> 25\%$ over the local check. The hybrids shed pollen between 46 and 58 days, and number of days to silking was between 52 and 62 days after sowing (DAS) with PVAEH-16 and PVAEH-15 as the earliest for both traits. The hybrids also had vigorous growth, with ears placed at an average of 105.1 cm and a mean husk cover rating of 2.3. Incidentally, PVAEH-23, which had the highest grain yield, also was superior for tight husk cover (Table 3). The abundant soil moisture at anthesis and silking in 2018 allowed each hybrid to express their yield potential. The hybrids flowered earlier and had a shorter ASI than the check. The early flowering results in early seed set, grain filling and maturity, which are important for drought escape (Shavrukov et al., 2017; Senapati et al., 2019). Lower ear height in comparison to the local check was desirable because plants with higher ear placement are usually more prone to root and stalk lodging.

Table 2. Combined mean squares for grain yield and other agronomic traits of the evaluated maize hybrids.

Source	df	Grain yield (kg ha ⁻¹)	Anthesis (days)	Silking (days)	Anthesis -silking interval (days)	Plant height (cm)	Ear height (cm)	Number of ears per plant	Husk cover (1-5)	Plant aspect (1-5)	Ear aspect (1-5)
Year (Y)	1	318647490.5***	7.6*	74.4**	34.5**	36247.4***	47006.2***	2.3**	18.1***	93.8***	6.9***
Replicate	1	68705325.7***	18.5**	103.8***	44.6**	15848.7***	6353.2***	0.1	0.1	24.0***	0.8
Hybrid (H)	15	3882455.8**	204.2***	16.2***	4.4	189.9	172.1*	0.3	0.5*	0.4	0.5
H × Y	15	1972515.7	4.4*	2.8	4.2	203.4	87.7	0.3	0.2	0.2	0.4
Error	32	1393889.5	2.2	6.2	4.7	195.7	114.0	0.2	0.4	0.5	0.3
CV		18.8	2.9	4.5	37.4	8.7	14.1	9.1	22.2	18.8	21.7

*, **, *** indicate mean squares significant at 0.05, 0.01 and 0.001 probability levels, respectively.

On the other hand, the highest amount of rainfall in 2019 was between September and October towards the end of the grain filling period, and this resulted in a grain yield range of 2,961.8 kg ha⁻¹ (PVAEH-19) to 5,863.1 kg ha⁻¹ (PVAQEH-1) with a mean of 4,370.9 kg ha⁻¹. PVAQEH-1 had the highest grain yield potential, which differed significantly ($P < 0.05$) from five of the early maturing PVA maize hybrids, while the same hybrid (PVAEH-19) with the lowest yield in the previous year was still the poorest in terms of yield potential in 2019. Twelve hybrids had higher grain yield than the local check (3,808.0 kg ha⁻¹), but only one hybrid (PVAQEH-1) had a significant ($P < 0.05$) yield advantage of 35% over the local check (Table 3). Number of days to anthesis was between 49 and 54 DAS, while silking dates varied between 54 and 63 DAS with PVAEH-16 as the earliest for both traits. The hybrids had a reduced mean ear height of 54.7 cm and a mean husk cover rating of 3.2, with PVAEH-17, PVAEH-18 and PVAEH-23 hybrids with the lowest husk cover rating (2.7).

Table 3. The mean performance of maize hybrid traits with significant variations from the two years of evaluation.

Hybrid	2018				
	Grain yield (kg ha ⁻¹)	Anthesis (days)	Silking (days)	Ear height (cm)	Husk cover (1–5)
PVAEH-14	8106.7	51.0	57.0	104.5	2.3
PVAEH-15	11093.4	47.5	52.5	111.5	2.3
PVAEH-16	8362.7	46.0	54.5	95.0	2.3
PVAEH-17	8192.0	51.5	55.5	100.0	2.0
PVAEH-18	8618.7	50.5	55.0	107.0	2.3
PVAEH-19	7509.4	51.0	54.5	104.5	2.8
PVAEH-20	9216.0	49.5	54.0	99.0	2.8
PVAEH-21	8960.0	51.0	53.5	108.0	2.3
PVAEH-22	7594.7	50.5	55.0	102.0	2.3
PVAEH-23	11349.3	50.5	54.5	106.5	1.5
PVAEH-24	8362.7	51.0	55.5	101.0	2.3
PVAEH-25	9386.7	49.0	53.5	103.0	2.3
PVAQEH-1	10922.7	52.5	58.5	113.0	2.3
PVAQEH-2	10752.0	51.0	55.0	116.0	2.3
Check(RE)	10666.7	49.5	53.0	105.5	2.8
Minimum	7509.4	46.0	52.5	95.0	1.5
Maximum	11349.3	52.5	58.5	116.0	2.8
Grand mean	9272.9	50.1	54.8	105.1	2.3
LSD (0.05)	2190.4	3.0	2.8	13.5	1.1
Local check	6656.0	58.0	61.5	113.0	1.8

Hybrid	2019				
	Grain yield (kg ha ⁻¹)	Anthesis (days)	Silking (days)	Ear height (cm)	Husk cover (1–5)
PVAEH-14	5137.8	52.3	59.7	50.4	3.0
PVAEH-15	3808.0	49.0	57.0	58.4	3.0
PVAEH-16	4533.3	48.7	54.3	55.6	4.0
PVAEH-17	3868.4	50.3	58.0	64.8	2.7
PVAEH-18	4291.6	52.3	59.3	57.5	2.7
PVAEH-19	2961.8	51.7	59.7	49.4	3.7
PVAEH-20	4231.1	51.0	56.7	54.7	3.0
PVAEH-21	3445.3	52.0	57.0	60.3	3.7
PVAEH-22	4352.0	53.0	58.3	57.2	3.7
PVAEH-23	4714.7	52.0	59.0	49.2	2.7
PVAEH-24	4835.5	52.0	57.3	57.0	3.0
PVAEH-25	3928.9	52.0	58.3	33.0	3.7
PVAQEH-1	5863.1	52.3	60.0	61.7	3.0
PVAQEH-2	5319.1	51.0	58.0	55.4	3.0
Check(RE)	4835.6	52.7	57.3	56.8	3.0
Minimum	2961.8	48.7	54.3	33.0	2.7
Maximum	5863.1	53.0	60.0	64.8	4.0
Grand mean	4408.4	51.5	58.0	54.7	3.2
LSD (0.05)	1775.7	2.1	4.2	19.5	1.1
Local check	3808.0	53.3	62.3	69.4	3.0

Other agronomic traits from each year of the evaluation showed disparity for all traits measured (Table 4). In the first year of evaluation, the flowering parameters were earlier, the hybrids had shorter ASI with a corresponding higher grain yield and number of ears per plant, taller plant and ear heights, lower husk cover, plant aspect and ear aspect ratings in comparison to the second year of the evaluation. Moreover, the grain yield of 11,349.3 kg ha⁻¹ by PVAEH-23 in 2018 was more than twice the mean grain yield recorded (4,370.8 kg ha⁻¹) in 2019 and close to double the mean grain yield of the top hybrid (5,863.1 kg ha⁻¹) in 2019. Also, the commercial local check (Oba Super 6) showed instability for grain yield with a difference of 43% between the two years of the evaluation. The growth of the male and female flowers and their synchrony, which ensures good nicking, are dependent on the weather and edaphic features of the trial location. As a reflection of the weather pattern, growth and maturation progressions in 2018 were desirable in comparison to 2019. During the growing season of 2019, we experienced an unpredicted change in the rainfall pattern of Ogbomosho and its environs, which resulted in the form of random drought.

Table 4. Effects of years on the mean performance of grain yield and other measured agronomic traits of the evaluated PVA maize hybrids.

Traits	2018		2019		Mean±Standard error		Mean difference
	Min.	Max.	Min.	Max.	2018	2019	
Grain yield (kg ha ⁻¹)	7509.4	11349.3	2961.8	5863.1	9272.9±345.9	4377.9±205.8	4895.0
Anthesis (days)	46.0	52.5	48.7	53.0	50.1±0.4	51.4±0.3	-1.3
Silking (days)	52.5	58.5	54.3	60.0	54.8±0.4	58.0±0.4	-3.3
Anthesis-silking interval (days)	2.5	8.5	5.0	8.0	4.6±0.4	6.6±0.3	-2.0
Plant height (cm)	188.0	220.0	115.4	146.6	201.7±2.4	132.9±2.3	68.8
Ear height (cm)	95.0	116.0	33.0	64.8	105.1±1.4	54.6±2.1	50.5
Husk cover (1–5)	1.5	2.8	2.7	4.0	2.3±0.1	3.2±0.1	-0.9
Plant aspect (1–5)	2.0	2.8	4.3	5.7	2.3±0.1	4.9±0.1	-2.6
Ear aspect (1–5)	2.0	2.8	2.0	3.3	2.3±0.1	2.7±0.1	-0.4
Number of ears per plant	1.0	1.1	0.6	0.9	1.0±0.0	0.8±0.0	0.2

Likewise, armyworm (*Spodoptera frugiperda*) infested maize fields during the rainy season of 2019, causing serious devastation, which was unprecedented. The above exigencies contributed to the significant reduction in grain yield and poor agronomic performance of the maize hybrids evaluated in 2019. Consequently, the mean performance of all measured traits in the two years of the evaluation was adversely affected.

From the combined entry means over the two years, the grain yield of hybrids ranged between 4,780.8 kg ha⁻¹ (PVAEH-19) and 7,886.9 kg ha⁻¹ (PVAQEH-1) with

a mean of 6,354.2 kg ha⁻¹ (Table 5). Across the years, PVAQEH-1 had the highest yield, all of the early maturing PVA maize hybrids except for PVAEH-19 out-yielded the local check (4947.2 kg ha⁻¹), and five hybrids had a significant ($P < 0.05$) yield advantage of $> 26\%$ over the local check. The mean difference between the flowering dates of the hybrids and the local check was around 4–5 days, whereas ASI was just one day. Other measured traits of the hybrids were comparable to the local check except for ear height which was lower. The mean grain yield of 6.3 t ha⁻¹ reported in this study is a reduction in yield expectation over the years. The disparity between the yields obtained in 2018 and 2019 is responsible for the lower average yields. The average hybrid maize grain yield between 8 and 10 t ha⁻¹ has been previously reported under disease-free conditions in maize breeding (Ininda et al., 2006; Adebayo et al., 2014). Hence, the genetic potentials of the hybrids were influenced by the year variation, as having been similarly identified in previous studies as a cause of a possible yield reduction (Beyene et al., 2012; Chabala et al., 2015; Jaya et al., 2020).

The agronomic traits that showed significant variability among the hybrids evaluated were used to rank their performance. These desirable agronomic traits are essential in determining the suitability and adaptability of the hybrid to the derived savanna agro-ecology. Across the years, the rank summation index based on the aforementioned traits shows that PVAEH-15 ranked best and PVAQEH-2 ranked 5th, although PVAEQH-1 gave the highest grain yield (7,886.9) across the years. In 2018, three of the hybrids listed among outstanding hybrids constituted the top five across the years, whereas, in 2019, four of the hybrids listed among superior hybrids constituted the top five across the years. Ranking based on each year shows that both years had two hybrids (PVAEH-15 and PVAEH-16) in common listed among the top five (Table 6). Although several PVA open-pollinated varieties and hybrids have been released for commercialization in SSA, their agronomic performance differs across several production environments, but adaptability to the specific environment will determine suitability for farmers' cultivation. It is imperative to note that the top five hybrids across the years (PVAEH-15, PVAEH-16, PVAEH-20, PVAEH-23 and PVAQEH-2) were also among the outstanding hybrids listed from each year of the evaluation based on superiority in grain yield, flowering traits and husk cover ratings. In spite of the disparity in the distribution and amount of rainfall in the two years of evaluation, the consistent performance of PVAEH-15 and PVAEH-16 across the years indicates potentials for adaptability of the hybrids to the agro-ecology, especially as they also out-yielded the local check. These hybrids can be especially important for small-scale farmers, providing stable food production from year to year. Hence, the adaptability of these outstanding hybrids to the growing environment will enhance sustainable productivity, and these early maturing PVA maize hybrids may be used to replace existing cultivars in the derived savanna agro-ecology of Nigeria.

Table 5. The combined mean performance for grain yield and other agronomic traits of the evaluated maize hybrids.

Hybrid	Grain yield (kg ha ⁻¹)	Anthesis (days)	Silking (days)	Anthesis-silking interval (days)	Plant height (cm)
PVAEH-14	6325.3	51.8	58.6	6.8	150.6
PVAEH-15	6722.1	48.4	55.2	6.8	172.6
PVAEH-16	6065.1	47.6	54.4	6.8	165.6
PVAEH-17	5597.9	50.8	57.0	6.2	163.2
PVAEH-18	6022.4	51.6	57.6	6.0	163.3
PVAEH-19	4780.8	51.4	57.6	6.2	158.6
PVAEH-20	6225.1	50.4	55.6	5.2	153.4
PVAEH-21	5651.2	51.6	55.6	4.0	162.3
PVAEH-22	5649.1	52.0	57.0	5.0	158.0
PVAEH-23	7368.5	51.4	57.2	5.8	156.6
PVAEH-24	6246.4	51.6	56.6	5.0	155.8
PVAEH-25	6112.0	50.8	56.4	5.6	163.0
PVAQEH-1	7886.9	52.4	59.4	7.0	166.3
PVAQEH-2	7492.3	51.0	56.8	5.8	153.0
Check(RE)	7168.0	51.4	55.6	4.2	167.7
Minimum	4780.8	47.6	54.4	4.0	150.6
Maximum	7886.9	52.4	59.4	7.0	172.6
Grand mean	6354.2	50.9	56.7	5.8	160.7
LSD (0.05)	1503.0	1.9	3.2	2.8	17.8
Local check	4947.2	55.2	62.0	6.8	167.0
Hybrid	Ear height (cm)	Husk cover (1 – 5)	Plant aspect (1 – 5)	Ear aspect (1 – 5)	Number of ears per plant
PVAEH-14	72.0	2.7	3.6	2.4	0.9
PVAEH-15	79.6	2.7	3.5	2.7	0.8
PVAEH-16	71.3	3.3	4.0	2.6	0.9
PVAEH-17	78.9	2.4	3.6	2.7	0.8
PVAEH-18	77.3	2.5	3.9	2.4	0.9
PVAEH-19	71.4	3.3	4.3	2.9	0.9
PVAEH-20	72.4	2.9	4.0	2.7	0.9
PVAEH-21	79.4	3.1	4.1	2.7	0.9
PVAEH-22	75.1	3.1	3.6	2.5	0.9
PVAEH-23	72.1	2.2	3.8	2.0	1.0
PVAEH-24	74.6	2.7	4.0	2.6	0.9
PVAEH-25	61.0	3.1	4.1	2.9	0.9
PVAQEH-1	82.2	2.7	3.5	2.3	1.0
PVAQEH-2	79.6	2.7	4.3	2.5	0.9
Check(RE)	76.3	2.9	3.8	3.1	1.0
Minimum	61.0	2.2	3.5	2.0	0.8
Maximum	82.2	3.3	4.3	3.1	1.0
Grand mean	74.9	2.8	3.9	2.6	0.9
LSD (0.05)	13.6	0.8	0.9	0.7	0.1
Local check	86.8	2.5	4.4	3.2	0.8

Table 6. The ranking of early maturing PVA maize hybrids based on traits with significant variations.

S/N	Hybrid	Grain yield (kg ha ⁻¹)	Anthesis (days)	Silking (days)	Husk cover (1-5)	Rank summation index
	Hybrid (2018 and 2019 combined)					
1	PVAEH-15	6722.1	48.4	55.2	2.7	15
2	PVAEH-16	6065.1	47.6	54.4	3.3	23
3	PVAEH-20	6225.1	50.4	55.6	2.9	24
4	PVAEH-23	7368.5	51.4	57.2	2.2	25
5	PVAQEH-2	7492.3	51.0	56.8	2.7	27
	Mean of top 5	6774.6	49.8	55.8	2.8	
	Grand mean	6354.2	50.9	56.7	2.8	
	LSD (0.05)	1503.0	1.9	3.2	0.8	
	Hybrid (2018)					
1	PVAEH-15	11093.4	47.5	52.5	2.3	9
2	PVAEH-23	11349.3	50.5	54.5	1.5	18
3	PVAEH-16	8362.7	46.0	54.5	2.3	22
4	PVAEH-25	9386.7	49.0	53.5	2.3	23
5	Check(RE)	10666.7	49.5	53.0	2.8	27
	Mean of top 5	10171.7	48.5	53.6	2.2	
	Grand mean	9272.9	50.1	54.8	2.3	
	LSD (0.05)	2190.4	3.0	2.8	1.1	
	Hybrid (2019)					
1	PVAEH-20	4231.1	51.0	56.7	3.0	20
2	PVAEH-15	3808.0	49.0	57.0	3.0	21
3	PVAEH-16	4533.3	48.7	54.3	4.0	22
4	PVAQEH-2	5319.1	51.0	58.0	3.0	22
5	PVAEH-17	3868.4	50.3	58.0	2.7	23
	Mean of top 5	4352.0	50.0	56.8	3.1	
	Grand mean	4408.4	51.5	58.0	3.2	
	LSD (0.05)	1775.7	2.1	4.2	1.1	

Conclusion

Variations among the 15 early maturing multiple stress-tolerant PVA maize hybrids were attributed to grain yield, number of days to anthesis and silking, ear height and husk cover rating. The superior hybrids, viz. PVAEH-15, PVAEH-16, PVAEH-20, PVAEH-23 and PVAQEH-2, identified in this study, combined desirable agronomic traits and could increase maize yield and solve malnutrition problems. Consequently, these superior hybrids that flowered and matured early with high yield potential and tight husk cover may, if adopted, escape moisture stress and are therefore recommended for sustainable production in the derived savanna agro-ecology.

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UČINAK NOVIH RANIH HIBRIDA KUKURUZA (*ZEa MAYS* L.)
OBOGAĆENIH PROVITAMINOM A U USLOVIMA
IZMENJENE SAVANE U NIGERIJII

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R e z i m e

Kukuruz (*Zea mays* L.) je glavna namirnica za milione ljudi širom sveta i čini više od 30% ukupnih kalorija u ishrani. Međutim, normalnom endospermu nedostaje dovoljna količina prekursora vitamina A. Da bi se postigla prehrambena sigurnost i sprečila neuhranjenost, potrebno je da se usvoji gajenje ranog višestrukog hibrida kukuruza obogaćenog pro-vitaminom A tolerantnog na stres. Cilj ove studije bio je da se proceni agronomski učinak i prinos novorazvijenih hibrida kukuruza. Petnaest poboljšanih hibrida kukuruza i jedan komercijalni hibrid, koji je korišćen kao lokalna kontrola ocenjeni su u potpuno slučajnom blok dizajnu sa dva ponavljanja tokom dve godine na naučno-istraživačkom imanju Tehnološkog univerziteta Ladoke Akintola u Ogbomosu u Nigeriji. Hibridi su pokazali značajne varijacije ($P < 0,01$) u pogledu prinosa zrna, broja dana do cvetanja, visine klipa i ovojnih listova klipa. Tokom godina, prinos zrna hibrida kretao se između $4.780,8 \text{ kg ha}^{-1}$ (PVAEH-19) i $7.886,9 \text{ kg ha}^{-1}$ (PVAQEH-1), sa srednjom vrednošću od $6.354,2 \text{ kg ha}^{-1}$. PVAEH-15 se pokazao kao najbolji na osnovu prinosa zrna, ranog cvetanja i čvrstih ovojnih listova klipa. Četnaest hibrida je nadmašilo lokalnu kontrolu ($4.947,2 \text{ kg ha}^{-1}$), pet hibrida imalo je značajnu ($P < 0,05$) prednost u prinosu od $> 26\%$ u odnosu na lokalnu kontrolu. Dosledan učinak PVAEH-15 i PVAEH-16 tokom dvogodišnje procene ukazuje na potencijal hibrida da se prilagode lokalnim uslovima. Usvajanje ovih hibrida kukuruza od strane poljoprivrednika, povećaće proizvodnju kukuruza i sprečiti neuhranjenost u uslovima izmenjene savane u Nigeriji.

Ključne reči: adaptacija, agronomske osobine, procena, prinos zrna, neuhranjenost.

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