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AGRO-NUTRITIONAL VARIATIONS OF QUALITY PROTEIN MAIZE (*ZEA MAYS* L.) IN NIGERIA

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Abstract: Quality protein maize (QPM) combining the enhanced levels of lysine and tryptophan with high grain yield and desirable agronomic traits could reduce food insecurity and malnutrition in West and Central Africa. Twenty-two varieties of QPM and two local checks were evaluated for agronomic characteristics and nutritional qualities in the southern Guinea savanna of Nigeria for two years (2009 and 2010). Though crude protein levels are good indicators of quality, amino acid composition analyses, especially lysine and tryptophan that would provide a final proof are in progress. The genotypes comprised five open pollinated varieties (OPVs), nine inbred lines, eight hybrids and two local varieties. Differences among the varieties were significant ($P < 0.01$) for grain yield, days to tasselling as well as plant and ear heights, while year x variety interaction was only significant ($P < 0.05$) for days to tasselling. Most of the QPM inbred lines (CML 437, CML 490 CML 178) and hybrids (Dada-ba, ART98-SW5-OB, ART98-SW4-OB and TZPB-OB) have superior performance for grain yield, other yield attributes and nutritional qualities compared with the OPVs and local checks. These inbreds could be potential sources of favorable alleles useful for future maize breeding, while the hybrids could be evaluated in different environments of Nigeria for comparative advantages in different environments and quality of the grains to be released to farmers.

Key words: crude protein, inbred lines, open pollinated varieties, hybrids.

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Introduction

Maize (*Zea mays* L.) ranks third behind rice and wheat as the most important cereal crop, mainly used as staple food and animal feed in most developing countries (Akande and Lamidi, 2006; Olakojo et al., 2007; Mboya et al., 2011). Several million people, particularly in the developing countries, derive their protein and calorie requirements from maize (Mbuya et al., 2011). With its high content of carbohydrates, fats, proteins, some essential minerals and vitamins, maize acquired a well-deserved reputation as a nutria-cereal. Maize grain accounts for about 15 to 56% of the total daily calories in diets of people in about 25 developing countries, particularly in Latin America and Africa, where animal protein is expensive and consequently, unavailable to a vast sector of the population (CIMMYT, 1999; Vasal, 2000). In Nigeria, the bulk of the maize serves as the major source of dietary protein for weaning children, sick adults and children, or it is eaten during lean crop production cycles since it has a biological nutritional value of 40% of that of milk (Bressani, 1992). Therefore, hunger and malnutrition are prevalent in the economically deprived areas, especially the rural poor. They were also prone to a number of essential amino acid deficiencies and health problems such as kwashiorkor, underweight, weakened resistance to infections and impaired intellectual development (Mbuya et al., 2010). Unfortunately, complementary protein sources such as animal products or grain legumes are beyond the means of the rural poor.

The discovery of the quality protein maize (QPM) varieties based on the Opaue-2 mutation by the International Maize and Wheat Improvement Center (CIMMYT) that contained about twice the levels of lysine and tryptophan and 10% higher grain yield than the most modern varieties of tropical maize (Vasal, 1993) brought a great hope in the effort of its improvement as human and animal nutrition (Akande and Lamidi, 2006; Olakojo et al., 2007). A high level of these two amino acids not only enhances the manufacture of complete proteins in the body, but also offers 90% of the nutritional value of skim milk, thereby alleviating malnutrition (Olakojo et al., 2007; Upadhyay et al., 2009). QPM has similar qualities as normal maize regarding grain texture, taste, colour, tolerance to biotic and abiotic stresses as well as high yield (Sofi et al., 2009; Olawuyi et al., 2013). QPM also looks like normal maize, but can only be reliably differentiated through laboratory tests (Ganesan et al., 2004; Srinivasan et al., 2004). In 1993, 33 tropical and 22 subtropical QPM lines were released as CIMMYT maize lines (CMLs). Hybrids derived from these lines are being tested at the international research centres where Central America, China and Mexico are at the fore-front (Mbuya et al., 2010). In Africa, among the 17 countries that breed and promote QPM to the populace are Nigeria, Ghana, Mozambique, South Africa, Burkina Faso, Tanzania, Cameroon,

Ivory Coast, Togo, Zimbabwe, Ethiopia, Guinea, Kenya, Malawi, Mali, Uganda and Senegal (Olakojo et al., 2007; Upadhyay et al., 2009).

The collaborative research efforts by maize scientists in Nigeria have focused on improvement in maize grain quality characteristics of organoleptic and nutritional properties by both international and national research thrusts including International Tropical Agriculture (IITA), Institute of Agricultural Research and Training (IAR & T), Ibadan, and Institute for Agricultural Research (IAR), Samaru, Zaria, for release and adoption by the farmers (Olaoye et al., 2009). The nutritive value of QPM both as human food, especially for women and children and as animal feed for pigs, poultry and other livestock was widely demonstrated in many countries (Ganesan et al., 2004; Akande and Lamidi, 2006; Upadhyay et al., 2009). In order to meet the increasing demand for maize in Nigeria as human food, feed for livestock and industrial raw materials, there is need to increase its productivity. The assessment of QPM yield potentials and nutritional values will enhance the production of readily available and affordable source of protein for the teeming population especially in the poor-resource rural communities, particularly for lactating mothers, babies, adults and livestock in order to improve nutrition (Krivanek et al., 2007). It could also enhance reduction in the prevalence and persistence of malnutrition. An increase in the land area for cultivation of QPM cultivars would improve food security in the Sub-Saharan Africa. This study was therefore conducted to assess grain yield, agronomic potentials and nutritional qualities of some QPM inbred lines, hybrids and OPVs, with a view to recommending suitable varieties either for release for cultivation in farmers' fields or for further breeding in the southern Guinea savanna environment of Nigeria.

Material and Methods

Twenty-two QPM genotypes and two local checks were evaluated for agronomic characteristics and nutritional qualities for two years (2009 and 2010) during late cropping seasons (1st August, 2009 and 29th July, 2010) at the Lower Niger River Basin Authority station, Oke-Oyi, Ilorin (8°30'N, 8°36'E) located in the southern Guinea savanna of Nigeria. The genetic materials comprised five OPVs, nine inbred lines and eight hybrids, while two local varieties adapted to local conditions were used as checks. The seeds of nine inbred lines and four OPVs were obtained from the International Institute of Tropical Agriculture (IITA), while five hybrids were obtained from the Institute of Agricultural Research and Training (IAR & T), Ibadan, Nigeria. One of the OPVs (Obatanpa) and three hybrids were obtained from the Crops Research Institute (CRI), Kumasi, Ghana (Table 1).

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

Genotypes	Source of collection	Seed colour	Kernel texture	Type
Obatanpa	CRI Ghana	White	Dent	OPV
EV8766-SR	IITA/CIMMYT	Yellow	Dent	OPV
EV8363-SR	IITA/CIMMYT	White	Dent	OPV
Pool 18-SR	IITA/CIMMYT	Yellow	Flint	OPV
Pool 19-SR	IITA/CIMMYT	White	Flint	OPV
Mama-ba	CRI Ghana	White	Flint	Hybrid
CIDA-ba	CRI Ghana	White	Dent	Hybrid
Dada-ba	CRI Ghana	White	Flint / Dent	Hybrid
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
TZPB-OB	IAR & T, IBADAN	White	Flint	Hybrid
ILEI-OB	IAR & T, IBADAN	White	Flint	Hybrid
CML176	IITA/CIMMYT	White	Flint / Dent	Inbred line
CML177	IITA/CIMMYT	White	Flint / Dent	Inbred line
CML178	IITA/CIMMYT	White	Flint / Dent	Inbred line
CML181	IITA/CIMMYT	White	Flint / Dent	Inbred line
CML437	IITA/CIMMYT	White	Flint / Dent	Inbred line
CML490	IITA/CIMMYT	White	Flint / Dent	Inbred line
CML491	IITA/CIMMYT	White	Flint / Dent	Inbred line
CML492	IITA/CIMMYT	White	Flint / Dent	Inbred line
CML493	IITA/CIMMYT	White	Flint / Dent	Inbred line
Oba-Super 1	Local check	White	Flint	Non QPM commercial hybrid
SUWAN-1-SR(DMR)	Local check	White	Flint	Non QPM OPV

Soil analyses and rainfall distribution

The physico-chemical characteristics of the soil at the experimental site were determined by collecting soil samples randomly at the depth of 0–15cm with an auger and analyzed in the laboratory before planting in 2009 and 2010 cropping seasons (Table 2). The samples were air-dried and passed through a 2 mm sieve to remove large particles, debris and stones. The soil pH was determined in water using the Coleman pH meter. Organic carbon was determined by Walkley and Black procedure (Nelson and Somers, 1992). Total nitrogen was determined by the micro Kjeldahl method described by Bremner (1965), while available phosphorus was extracted by Bray's P₁ method (Bray and Kurtz, 1945) and read from the atomic absorption spectrometer. Exchangeable Ca, Mg, K, Na and effective cation exchangeable capacity (ECEC) were analyzed using atomic absorption spectrophotometry (IITA, 1989), while textural analysis was performed by the

hydrometer method. The rainfall distribution data for the years of 2009 and 2010 are shown in Figure 1.

Table 2. Physico-chemical characteristics of the soil of the experimental site.

Soil characteristics	2009	2010
<i>Physical characteristics</i>		
Clay	6.0%	6.1%
Silt	19.0%	18.9%
Sand	72.0%	71.8%
Organic matter	8.5%	8.6%
Texture	Sandy loam	Sandy loam
<i>Chemical characteristics</i>		
Organic carbon	8.7 g/kg	8.7 g/kg
Nitrogen	0.5 g/kg	0.6 g/kg
pH	6	6
Potassium K ⁺	0.29 cmol kg ⁻¹	0.31 cmol kg ⁻¹
Sodium Na ⁺	0.18 cmol kg ⁻¹	0.19 cmol kg ⁻¹
Calcium Ca ²⁺	1.5 cmol kg ⁻¹	1.5 cmol kg ⁻¹
Magnesium Mg ²⁺	1.3 cmol kg ⁻¹	1.4 cmol kg ⁻¹
Available phosphorus	6.2 cmol kg ⁻¹	6.1 cmol kg ⁻¹
Effective cation exchange capacity	11.90	11.92
Total acidity	1.1 cmol kg ⁻¹	1.1 cmol kg ⁻¹

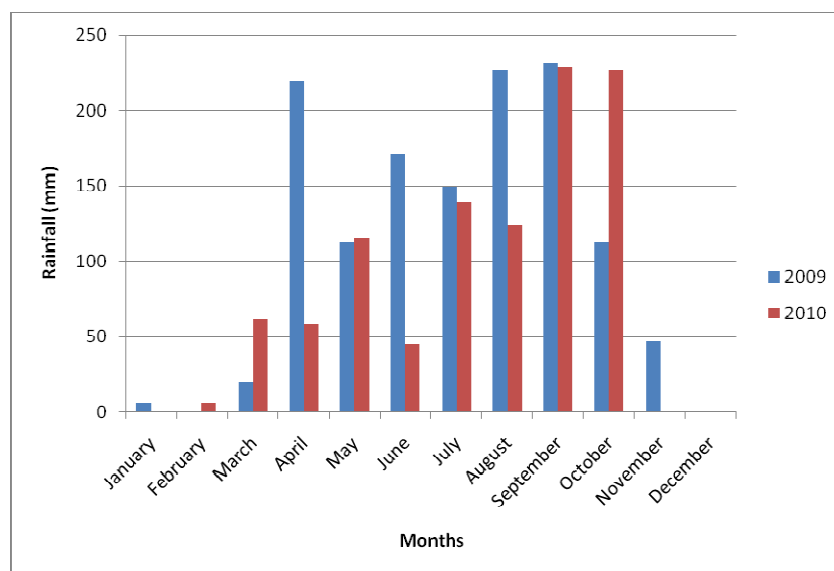


Figure 1. Monthly rainfall distribution pattern at Ilorin in 2009 and 2010.

Source: Lower Niger River Basin Development Authority, Ilorin, Nigeria.

Field studies

The experiment was laid out in a randomized complete block design (RCBD) with four replications. Each plot consisted of four 5-m-long rows, with 0.50-m intra-row and 0.75-m spacing between rows respectively. Three seeds were planted per hill, drilled 3–4 cm 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 of N, 40 kg of P₂O₅ and 40 kg of K₂O per hectare for optimum plant growth. All plots were weeded by using herbicides (3 kg/l of Metolachlor, 170 g/l of Atrazine and 3 kg/l of Paraquat per hectare) and supplemented by hand weeding to achieve weed control. Agronomic characteristics collected from each plot across years were seedling emergence, days to tasselling and silking, plant and ear heights. Other yield related attributes include plant and ear harvests, and grain yield. Plant and ear heights were measured as the distance (cm) from the base of the plant to the height of the first tassel branch, and the node bearing the upper ear respectively, at harvest stage. Days to 50% tasselling and silking were calculated as the number of days from planting to when 50% of the population have tasselled and silked respectively. The total number of plants and ears were counted in each plot at the time of harvest. Grain yield per plot was determined at 12.5% moisture content from which grain yield per hectare was estimated.

Proximate composition of maize grain

The laboratory studies involved the determination of proximate composition of QPM and the local maize varieties. Five ears were randomly selected from each plot at harvest, followed by careful removal of the grains by hand. From each variety, an equal number of grains were selected from each plot, mixed together to form the balanced bulk and then subjected to proximate analyses in the laboratory. The grains obtained were ground to form a fine powder and each sample was oven dried to a constant weight at 80°C to obtain grain moisture content (%MC). Three replicates were determined for each variety and the mean was recorded for each sample. Crude protein (CP) and ash were also determined using standard micro-Kjeldahl procedure (AOAC, 2006) and method described by Pearson (1973), respectively. Crude lipid (CL) determination was made by the Soxhlet method using petroleum ether at boiling point 40–60°C as solvent (AOAC, 1985). Crude fibre (CF) determination was done by digesting the defatted sample followed by drying the residue obtained from washing with boiled distilled water in an oven to a constant weight at 105°C for 2 hours and cooling in a desiccator. Nitrogen free extract (NFE) was determined by difference as:

$$\%NFE = 100 - [\%MC - \%CP + \%Ash + \%CF + \%CL]$$

Total carbohydrate was obtained by the summation of CF which represents the insoluble carbohydrate and the NFE which is the soluble carbohydrate (that is %CF + %NFE). However, two mineral elements, calcium and phosphorus were also analyzed for each variety using the standard laboratory procedures and the mean recorded for each sample.

Statistical analysis

Data collected from the field experiments were first computed using analysis of variance (ANOVA) separately before a combined ANOVA using PROC GLM model of SAS (SAS Institute, 2007). Data from proximate composition and mineral content determinations were pooled across sites. Pertinent means were separated using least significance difference (Steel and Torrie, 1980).

Results and Discussion

Characteristics of varieties, soil analysis, and rainfall distribution

The kernel textures of the QPM inbred lines, ART-98SW6-OB and Dada-ba were flint/dent (Table 1). All OPVs and local genotypes (checks) were flint except EV8766-SR, EV8363SR and CIDA-ba that were dent. All the seeds of the QPM genotypes were white, except EV8766-SR and Pool 18-SR that were yellow.

The soil at the trial site had similar physical and chemical properties in both 2009 and 2010 (Table 2). The physical soil characteristics showed that the soil texture was loamy sand with low organic matter and clay. The chemical properties on the other hand revealed that soil had a pH of 6 which is moderately acidic. The soil nitrogen was low, while the soil available phosphate and the exchangeable cations (K, Na, Ca and Mg) were moderate for maize production in this area.

Rainfall amount and distribution during the crop growing periods played significant roles in the expression of plants' potentials during the flowering/grain filling period especially for maize. The weather pattern (temperature, available soil moisture, etc.) during the reproductive phase of the crop is vital in stimulating plants to speed up the process of maturation (Olaoye, 2009). The rainfall was evenly distributed throughout the flowering/grain filling period from July to September in 2009, whereas in 2010 there was a significant drop in rainfall in August.

Genotypic performance for agronomic and yield related characteristics

Mean square (MS) values in Table 3 indicated that the effect of year was highly significant ($P < 0.01$) on plant and ear heights, days to silking, number of plants harvested per plot, number of ears harvested per plot and grain yield, but not for other agronomic characters. This result indicates that year has a significant

impact on the agronomic parameters which were expressed by the maize varieties. This is possible as a result of a significant effect of environmental factors on the agronomic development of plants especially maize as each of the cropping year exhibited different rainfall patterns which normally affect the performance of maize. The rainfall in 2009 growing season was more favourable for the expression of all studied characters among the genotypes than the rainfall in 2010. Differences in grain yield between the two years and the other three characters could be due to differences in environmental conditions which vary from year to year. Crop variety effects on plant height, ear height, days to silking and grain yield were highly significant ($P < 0.01$). This indicated considerable genetic differences among the genotypes for these characters and their potential in breeding for improved grain yield. The wide variability observed for these yield parameters showed quantitative inheritance and there is ample opportunity for improvement of important characters of economic value through selection among the genotypes. Among the yield related parameters the two years differed significantly ($P < 0.05$) for grain yield as well as plant and ear harvests, while differences among genotypes were highly ($P < 0.01$) significant for grain yield only. This indicates variability among the genotypes for grain yield which has a pre-requisite advantage in breeding programme.

Table 3. Interactive effects of genotype x year on QPM for agronomic and grain yield characters of QPM evaluated in 2009 and 2010 at Ilorin, Nigeria.

Source of variation	DF	Seedling emergence (No.)	Plant height (cm)	Ear height (cm)	Days to tasselling	Days to silking	Plant harvest (No.)	Ear harvest (No.)	Grain yield (t/ha)
Year	1	0.25	9.34**	5.68**	0.47	1.56**	4.64*	7.73*	3.34**
Rep (Year)	3	0.34	0.51	3.45*	0.23	0.04	0.070	0.04	0.09
Genotype	23	0.45	14.45**	7.39**	2.39*	0.36	0.004	0.17	4.78**
Year x Genotype	23	0.04	0.023	0.112	10.03*	0.005	0.045	0.003	0.05
Error	138	0.009	0.006	0.005	0.008	0.003	0.01	0.006	0.001

*, ** Significant at $P < 0.05$ and $P < 0.01$ respectively.

High rainfall distribution in 2009 compared to 2010 could contribute to significant differences among the genotypes for days to silking as well as plant and ear heights. The lower yield in 2010 (3.6 t/ha) as compared to 2009 (4.4 t/ha) is largely determined by a smaller number of harvested ears in 2010 (31.2 ears) compared to 2009 (37.1 ears). Days to silking usually show differences in maturity. The genotypes that showed silking 4 days earlier attained maturity earlier. The genetic expression for early maturity which was noted in some of the genotypes could be responsible (Table 4). This rainfall pattern could favour accumulation and translocation of photo-assimilates in the genotypes with corresponding larger ear size in 2009, subsequently higher grain yield in all the genotypes. This favourable

condition is often encouraged by high moisture during the growing period (Akande and Lamidi, 2006; Olakojo et al., 2007). Similarly, with high rainfall, there were correspondingly higher plant heights as well as ear height and ear harvest. These results conform to previous studies (Olakojo et al., 2005a; 2005b; Olaoye et al., 2009). In consonance with higher ear harvest, grain yield was significantly higher in 2009 by 0.8 t/ha compared to 2010, representing 22.2% yield increase. However, this increase was accompanied by higher ear placement in the genotypes. The differences in performance among the genotypes for these traits indicate variability which could be heritable and can be exploited in the overall process of selection in breeding programmes. On the other hand, anthesis remained relatively unaffected by differences in growing conditions between the two years. Although seedling emergence was higher in 2009 season, difference between years for this trait was not significant. Across the years however, seedling emergence was better in inbred lines compared to hybrids, OPVs and the local varieties (Table 5). The local varieties had lower plant height and ear placement compared with the inbred lines, OPVs and hybrids. This result may be due to genetic constitution of the genotypes. The local checks attained early anthesis. The hybrids ranked best for grain yield followed by inbred lines and OPVs. The range was as follows: 4.0–4.7, 4.0–4.4 and 3.4–3.7 t/ha of the hybrids, inbreds and OPVS values respectively. It is obvious that the yield of inbred lines and hybrids is approximately the same with a difference of 0.26 t/ha. The hybrids are not the combination of the inbred lines. It could also be noted that most of the hybrids and some inbred lines out-yielded the OPVs and local checks with yield advantage of about 38% over the best OPVs and local varieties. This agrees with the findings of Yusuf (2010), who reported CIMMYT inbred lines as superior to local varieties. It has also been reported by many researchers that QPM varieties widely grown in many African countries produce higher grain yield compared with the currently released normal maize varieties regarding most grain yield characters (Vasal, 2000; Sallah et al., 2003; Olakojo et al., 2007). However, along with hybrid ART98-SW5-OB which ranked first for grain yield, this variety yielded higher than the OPV checks by more than 44% with corresponding plant height and ear harvest as well as low plant aspect.

Table 4. Mean values for grain yield and other related characters of QPM varieties evaluated in 2009 and 2010 at Ilorin, Nigeria.

Characters	2009	2010
Seedling emergence (No.)	36.5	36.3
Plant height (m)	194.6	172.2
Ear height (m)	89.7	71.3
Days to tasselling	55.6	55.0
Days to silking	56.6	52.2
Plant harvest (No.)	37.2	31.8
Ear harvest (No.)	37.1	31.2
Grain yield (t/ha)	4.4	3.6

Table 5. Mean performance for agronomic characters of QPM varieties evaluated in 2009 and 2010 at Ilorin, Nigeria.

Variety	Seedling emergence (No.)	Plant height (cm)	Ear height (cm)	Days to tasselling	Days to silking	Plant harvest (No.)	Ear harvest (No.)	Grain yield (t/ha)
<i>OPVs</i>								
Obatanpa	34.5	193.3	73.2	55.9	57.1	34.2	34.1	3.4
EV8766-SR	34.4	181.2	84.3	54.9	57.3	34.1	34.0	3.5
EV8363-SR	36.2	182.1	82.1	55.0	57.5	36.0	36.0	3.5
Pool 18-SR	34.0	181.4	71.3	56.2	57.3	34.0	34.0	3.7
Pool 19-SR	35.3	194.3	75.2	55.0	56.2	35.1	35.0	3.6
<i>Hybrids</i>								
Mama-ba	39.2	169.6	91.4	55.0	57.6	39.0	39.0	4.1
CIDA-ba	35.7	180.5	82.5	56.2	57.3	37.4	36.1	4.0
Dada-ba	41.4	193.5	91.3	55.0	57.1	41.3	41.2	4.6
ART98-SW6-OB	37.6	169.5	82.4	55.7	57.8	37.2	37.0	4.4
ART98-SW5-OB	34.5	193.4	84.4	54.3	57.7	38.1	37.0	4.7
ART98-SW4-OB	35.6	168.2	82.2	55.7	57.1	39.4	39.2	4.6
TZPB-OB	34.4	180.5	92.2	54.3	57.7	34.2	34.1	4.6
ILEI-OB	36.5	179.1	90.3	55.7	57.3	36.2	36.0	4.0
<i>Inbred lines</i>								
CML176	34.1	179.4	72.3	55.0	57.5	34.0	34.0	4.0
CML177	35.7	181.5	72.3	56.0	57.7	35.2	35.1	4.0
CML178	39.1	184.3	75.5	55.0	56.2	36.0	35.0	4.4
CML181	39.2	207.1	92.4	55.0	57.6	36.0	35.0	4.4
CML437	35.5	191.4	95.4	56.2	57.3	37.3	35.1	4.1
CML490	41.0	192.4	73.5	55.1	57.6	38.0	36.0	4.1
CML491	37.5	168.3	90.1	56.2	57.3	37.3	37.0	4.0
CML492	34.6	195.5	86.2	55.7	57.3	34.4	34.4	4.1
CML493	35.5	180.3	83.1	54.3	57.5	35.2	35.1	4.0
<i>Local checks</i>								
Oba-Super 1 (Non QPM hybrid)	34.4	180.3	82.3	54.9	57.7	34.0	34.0	3.2
SUWAN-1-SR(DMR) (Non QPM OPV)	36.3	179.2	91.2	54.0	56.2	34.2	36.1	3.3
Mean	36.3	176.0	83.2	55.3	57.3	36.2	35.8	4.0
CV (%)	16.03	10.34	9.56	1.69	12.47	21.4	17.3	11.6
LSD 0.05	0.06	0.01*	0.01*	0.13*	0.14	2.12	3.07	0.45*

*Significant F test at 0.05 level of probability. CV = Coefficient of variation.

Nutritional performance of the QPM varieties and local checks

It is clear that crude protein levels are good indicators of quality, and amino acid composition analyses (especially lysine and tryptophan) would provide a final proof of the results. However, grain protein content can be considered as the amount of protein per seed. It is directly controlled by the plant's capacity to take up and transfer nitrogen from roots and leaves to the seed (Sentayehu, 2008). In the present study, significant differences were observed among the genotypes for grain moisture, carbohydrate contents and grain crude protein indicating the presence of inherent genetic differences among the genotypes for these characters (Table 6). Earlier studies showed that QPM varieties differed significantly for grain protein (Vasal, 2005). The QPM hybrids were superior in crude protein contents followed by the OPVs, inbred lines and local varieties. Hybrid Mama-ba with the highest crude protein contents has 46% crude protein advantage over the local varieties. These results are consistent with those of earlier studies (Prasanna et al., 2001; Vasal, 2005). Letchworth and Lambert (1998) also observed that hybrids were higher in grain protein in the endosperm than self-pollinated grains. The genotypes also differed significantly for grain moisture, carbohydrate and calcium contents, but were similar for other characteristics as reported by Olaoye et al. (2009). QPM varieties were higher in crude fiber content than the local varieties. Omega et al. (2009) had earlier reported 3.33% and 4.80% of crude fiber for QPM and regular maize respectively. Except for CML176, grain moisture content was higher in the inbreds followed by the local checks and OPVs. Conversely, the local checks had high carbohydrate contents with low crude protein and nitrogen free extracts compared with other genotypes. It is obvious that the hybrids that were low in carbohydrate contents were higher in crude protein and nitrogen free extracts comparing to other genotypes in reverse order. Hybrids Dada-ba, ART98-SW5-OB, ART98-SW4-OB and TZPB-OB that had significantly higher grain yield were also superior for % calcium and phosphorus indicating superiority in calcium and phosphorus absorption from the soil and assimilating them into the grains. Similar to Olaoye et al. (2009) report, phosphorus content remained relatively unchanged in all genotypes but other parameters especially Ca content showed no consistent trend between the different sets of genotypes. It is worth mentioning that the QPM variety, Obatanpa, developed in Ghana in 1992 and widely grown in many African countries (Sallah et al., 2003) had similar scores with currently released normal varieties for most yield components except for nutritional qualities. Mbuya et al. (2010) also reported this finding. Meanwhile, the overall average performance of the genotypes for the characters signified that there is substantial variability within the germplasm which could be used in quality protein maize breeding programmes to develop suitable hybrids and varieties.

Table 6. Nutrient composition and mineral elements (%) of QPM varieties evaluated in 2009 and 2010 at Ilorin, Nigeria.

Variety	Grain moisture	Ash	Carbo-hydrate	Crude protein	Crude fat	Crude fibre	Nitrogen free extract	P ₂ O ₅	Ca
<i>OPVs</i>									
Obatanpa	8.20	2.05	72.32	8.30	6.31	3.92	70.37	0.21	0.14
EV8766-SR	7.28	2.18	73.24	8.41	6.34	4.28	70.38	0.23	0.13
EV8363-SR	7.45	2.25	73.32	8.30	6.53	4.12	71.11	0.25	0.15
Pool 18-SR	8.20	2.11	74.26	8.31	6.59	3.98	72.45	0.28	0.16
Pool 19-SR	7.72	2.15	73.35	7.50	6.21	4.02	70.87	0.22	0.18
<i>Hybrids</i>									
Mama-ba	7.42	2.38	66.55	10.67	6.49	4.18	71.22	0.33	0.21
CIDA-ba	9.29	2.45	67.78	10.44	6.11	4.00	71.45	0.24	0.15
Dada-ba	8.56	2.28	65.25	10.12	6.44	4.22	72.48	0.30	0.21
ART98-SW6-OB	8.92	2.45	65.44	10.56	6.72	3.72	72.67	0.31	0.21
ART98-SW5-OB	8.99	2.34	66.29	10.24	6.58	3.88	72.99	0.32	0.20
ART98-SW4-OB	9.32	2.35	67.92	10.35	6.39	4.02	71.37	0.29	0.15
TZPB-OB	8.56	2.48	65.24	10.61	6.45	3.97	71.43	0.26	0.15
ILEI-OB	8.78	2.45	67.32	8.90	6.25	4.11	71.98	0.24	0.14
<i>Inbred lines</i>									
CML176	8.29	2.59	67.27	7.61	6.34	3.89	70.56	0.23	0.12
CML177	9.62	2.17	69.32	7.44	6.76	3.90	71.36	0.27	0.16
CML178	9.45	2.37	67.02	7.22	6.49	3.99	70.39	0.22	0.14
CML181	9.34	2.35	68.32	7.56	6.71	3.92	71.45	0.21	0.16
CML437	9.47	2.57	69.66	7.54	6.84	3.90	70.88	0.28	0.13
CML490	9.56	2.10	68.37	7.35	6.66	3.97	70.79	0.24	0.14
CML491	9.49	2.38	69.22	7.67	6.41	4.02	71.08	0.21	0.17
CML492	9.34	2.45	67.65	7.53	6.59	3.92	70.55	0.25	0.11
CML493	9.67	2.65	69.44	7.65	6.64	3.88	70.57	0.28	0.13
<i>Local checks</i>									
Oba-Super 1 (Non QPM hybrid)	9.52	2.52	84.32	7.33	6.51	4.88	65.37	0.21	0.17
SUWAN-1-SR(DMR) (Non QPM OPV)	9.32	1.23	84.16	7.31	6.91	4.70	66.11	0.23	0.18
Mean	8.66	2.35	70.13	8.54	6.50	4.06	70.83	0.27	0.16
CV %	14.05	2.56	21.34	3.78	11.23	7.42	12.78	10.36	8.01
LSD (0.05)	1.27*	ns	1.5*	1.01*	ns	ns	ns	ns	ns
SED	2.03	4.15	0.45	1.10	0.98	3.15	3.01	0.04	0.97

*Significant F test at 0.05 level of probability, ns – non-significant. CV = Coefficient of variation. SED = Standard error of difference between means.

Conclusion

The main focus in varietal evaluation is to identify superior genotypes that could replace existing cultivars as sources of genes for the extraction of inbred lines aimed at breeding superior varieties. Though crude protein levels are good indicators of quality, amino acid composition analyses (especially lysine and tryptophan) that would provide a final proof of the result in this study are in progress. Most of the QPM inbred lines and the hybrids evaluated in this study have superior performance for grain yield, other yield attributes and nutritional qualities, especially inbreds CML 437, CML 490, CML 178 and hybrids Dada-ba, ART98-SW5-OB, ART98-SW4-OB and TZPB-OB. These inbreds could be a source of genes for future maize breeding activities in the development of productive maize varieties. The hybrids however could be assessed in different agro-ecologies of Nigeria for yield characteristics, pest infestations and disease infections on the field and in the storage. These will reveal the comparative advantages of the different environments and quality of the grains. It would also provide information on the QPM varieties for release to farmers in each environment and for further breeding programmes in the southern Guinea savanna ecology of Nigeria. Growing these QPM varieties in this sub-region could reduce hunger and malnourishment affecting the Nigerian populace, especially the children of poor rural background.

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AGRO-NUTRITIVNE VARIJACIJE KUKURUZA (*ZEAMAYS* L.)
VISOKOG KVALITETA PROTEINA U NIGERIJ

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R e z i m e

Kukuruz visokog kvaliteta proteina (QPM) kombinujući poboljšane nivoe lizina i triptofana sa visokim prinosom zrna i željenim agronomskim osobinama bi mogao smanjiti nebezbednost hrane i pothranjenost u zapadnoj i centralnoj Africi. Dvadeset i dve QPM sorte i dve lokalne kontrole su ocenjivane u pogledu agronomskih osobina i hranljivih svojstava u savani južne Gvineje u Nigeriji tokom dve godine (2009. i 2010. godine). Iako su nivoi sirovog proteina dobri pokazatelji kvaliteta, analize sastava aminokiselina, posebno lizina i triptofana koje bi mogle dati konačni dokaz, su u toku. Genotipovi obuhvataju pet slobodno oprašenih sorti (OPV), devet inbrid linija, osam hibrida i dve lokalne sorte. Razlike među sortama su bile vrlo značajne ($P < 0,01$) u pogledu prinosa zrna, dana do metličanja kao i visine biljke i klipa, dok je interakcija godina x sorta bila samo značajna ($P < 0,05$) za dane do metličanja. Većina QPM inbrid linija (CML 437, CML 490 CML 178) i hibrida (Dada-ba, ART98-SW5-OB, ART98-SW4-OB i TZPB-OB) imaju vrhunski učinak kada su u pitanju prinos zrna, druge komponente prinosa i hranljiva svojstva u odnosu na OPV genotipove i lokalne kontrolne sorte. Ove inbrid linije mogu predstavljati potencijalne izvore poželjnih alela korisnih za buduće oplemenjivanje kukuruza, dok bi se hibridi mogli ocenjivati u različitim životnim sredinama Nigerije zbog komparativnih prednosti u različitim sredinama i kvaliteta zrna koje bi bilo ponuđeno poljoprivrednicima.

Ključne reči: sirovi protein, inbrid linije, sorte slobodnog oprašivanja, hibridi.

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