PARTICIPATORY EVALUATION OF PROVITAMIN A-RICH MAIZE (ZEA MAYS L.) HYBRIDS IN SAVANNA ZONES OF NORTHEAST NIGERIA

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ABSTRACT

Field studies were conducted to assess the adaptability of Provitamin-A rich maize hybrids across farmer locations in Sudan (SS), Northern Guinea (NGS) and Southern Guinea Savannas (SGS). Six intermediate maturing maize hybrids, one Improved and one Local Check were laid out in a randomized complete block design and the treatments replicated 4 times in each site. Plant height was negatively correlated with Anthesis Silking Intervals (ASI) and grain yield/ha (r = - 0.26). Ear heights were positively associated with plant height but negatively correlated with ASI. There was a delay of 5 and 6 days each in period to tasselling in SS compared to the NGS and SGS. Days to tasseling was negatively associated with ASI across the zones and for the Ecologies Combined (EC)(r = - 0.56***). LY0902-12, LY0902-18, LY0906-8 significantly attained period to silking earlier than LY0614-8, LY0614-11 and LY0902-19 across the 3 ecologies and days to silking were potitively correlated with days to tasselling for EC (r = 0.83***). Shorter ASI were observed for LY0902-19, LY0902-18, LY0906-8 and LY0614-11 than LY0614-8. Grain yield of promising hybrids increased: LY0614-8 > LY0906-8 > LY0902-19 > LY0614-11. Farmer preferred traits are high yield, quality nutrient, Striga tolerance, early maturity and drought tolerance. Introduction of maize hybrids with these traits and shorter plants than those tested will improve maize productivity and enhance nutrition in the region.***

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INTRODUCTION

Maize (Zea mays L.) is the major staple food crop for more than1.2 billion people in Africa and Latin America (FAOSTAT, 2013) and can be a major target for alleviating Vitamin A Deficiency in the regions. It is also the most genetically diverse crop with naturally high levels of Provitamin A, and the fastest emerging staple crop replacing sorghum and millet in the savanna regions of many countries of West and Central Africa (Nestel et al., 2006). About 1.15 x 10^9 million metric tons of maize was realized worldwide from 1.94 x 10^8 million hectares in 2018 out of which, Africa contributed 78.9 million metric tons from 38.7 million hectares, while Nigeria contributed 10.1 million metric tons from 4.9 million hectares (FAOSTAT, 2020). The average maize grain yield for the World was approximately 5.9 tons/ha, 2.0 tons/ha for

Africa and 2.1 tons/ha for Nigeria in 2018 (FAOSTAT, 2020), thus 36.6% of the World average for Nigeria.

Research on the use of hybrids in Nigeria started in the early 1970s (Fajemesin, 1978). Experimental hybrids were tested on farmers' fields located across the country in 1984 (Fakorede et al., 1999) and were found to yield considerably higher than the widely grown open-pollinated varieties. Kamara et al. (2006) reported that the hybrids released in 2000 out-yielded those released in 1980 and 1990s at all plant densities thus indicating genetic gains over two decades of plant breeding. According to Duvick and Cassman (1999), average maize grain yield per unit area increased dramatically during the second half of the 20th century. This yield gain was attributed to genetic improvement, climate change, improvement in crop management practices, and greater tolerance of modern hybrids to low soil-moisture stress (Dwyer et al., 1992) and tolerance to weed interference (Tollenaar et al., 1997).

The recent biofortification of maize with provitamin A by conventional breeding has emerged as a potential long-term sustainable strategy to improve vitamin A status in humans (Stewart et al., 2008). The first-generation provitamin A-enriched maize hybrids developed at CIMMYT-Mexico have about 6 to 9 µg/g of provitamin A (Menkir et al. 2008). Alamu et al. (2015) reported increase in b-carotene and provitamin A (PVA) values as the harvesting time increases, and when orange maize hybrids are roasted with husk than those roasted without husk. The International Institute of Tropical Agriculture (IITA) in collaboration with International Centre for Maize and Wheat (CIMMYT) and National partners in Nigeria recently developed provitamin A rich hybrids in HarvestPlus Challenge Programme. The hybrids are being tested across various ecologies including the Sudan and Guinea savannas in Nigeria for ecological adaptation and farmer acceptance. Farmer evaluations help scientists to design, test and recommend new technologies in light of information about farmers' criteria for usefulness of the innovation (Ashby, 1991).

The Maize crop that was mainly cultivated in the Forest ecology has replaced sorghum and millet in most of the savanna ecology as the environmental condition required for maize production are superior in the savanna with higher solar radiation, less incidence of biotic stress, and natural dryness at time of harvest (Kim et al., 1993). However, maize yield in the Nigeria's savanna has remained low compared to developed countries due to biotic, abiotic and socio-economic constraints such as low soil fertility, pests and diseases, Striga infestation and drought, low access to input and output market and uncertain adaptability and acceptability of improved maize germplasm. Adoption of maize hybrids has remained low in the savanna due to the widespread belief that hybrids are less stress tolerant and therefore require higher inputs than open-pollinated varieties (Kamara et al., 2006). Due to the increasing need of the provitamin A-rich yellow maize for alleviating Vitamin A defficiency in Nigeria, it is important to assess their ecological adaptation and acceptance by farmers across the savanna where multiple stresses prevail. The aim of the present study was to assess the adaptability of the recently developed provitamin-A rich maize hybrids across farmer locations in the savanna ecology of north eastern Nigeria.

MATERIALS AND METHODS

Experimental Sites

The experiments were conducted during 2010 and 2011 rainfed cropping seasons at Sabon Gari (Lat.10 ^{o} 48.454'N and Long. 012 ^{o} 27.922'E, 464 m asl) in Sudan Savanna (SS), Maina Hari (Lat.10 ^{o} 71.079'N and Long.12 ^{o} 10.065'E, 675 m asl) in Notthern Guinea Savanna (NGS) and Hema (Lat. 10 ^{o} 32.837'N and Long. 012 ^{o} 07.679'E, 786 m asl) in Southern Guinea Savanna (SGS) of Borno State, north eastern Nigeria. Average annual rainfall in SS ranges from 500 to 800 mm; average temperatures are between 22 and 37 ^{o} C and length of growing season is 100-120 days (June to September). In NGS, average annual rainfall range from 900 to 1000 mm; average temperatures are between 23 – 35 ^{o} C and length of growing season is 120 – 150 days (June to October). In the SGS, average rainfall is from 1000 to 1200 mm, avarege temperatures are between 22 and 35 ^{o} C and length of growing season is 150 – 180 days (May to October) (Dugje et al., 2006). Soils texture across the ecological zones range from sandy clay loam to loam in SS, Sandy clay loam to clay loam in NGS and Sandy clay loam to clay in SGS (Dugje et al., 2008).

Treatments and Experimental Design

Six yellow maize hybrids, one Improved Check (OBA SUPER 2) and one Local Check comprised the treatments in each site. The 6 hybrids and Improved Check belong to late/intermediate maturing groups were sourced from the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. The treatments were laid out in a randomized complete block design and replicated 4 times in each site and each year. Each plot comprised 4 maize rows 5 m long (15 m^2).

Weather and Crop Situation

In 2010 the rains established by second week of June in SGS, end of June in NGS, and second week of July in SS. Consequently, crop establishment followed this pattern of rainfall establishment as the experiments were established within the period across the three ecological zones. No floods were observed and the rains were well distributed within the remaining period during the seasons. There were incidences of rodents at crop establishment especially at Hema in SGS and Maina Hari in NGS that tampered with crop establishment. Missing gaps were filled immediately within the first 10 days of crop establishment. Weed infestation was heavy and persistent probably due to the heavy rains which may have leached the herbicides applied. In 2011 the rains established by third week of June in SGS and NGS, and July in SS. About 2 weeks dry spell was observed between the end of June and first week of July in NGS and end of July and first week of August in SS. No floods were observed during the season. There were incidences of stem borer especially at Hema in SGS in 2011.

Cultural Practices

Land was cleared and the pre-plant herbicide – Paraquat (Gramoxone) was applied at the rate of 3 l/ha to clear emerged weeds before land preparation across the 3 locations. Each trial was sown at 75 cm x 50 cm plant spacing after land preparation with tractor-driven disc plough. In 2010, sowing was done on 29th June at Hema in SGS, 4th July at Maina Hari in NGS and 11th July at Sabon Gari in SS, while sowing dates across the same locations in 2011 were 27th June in SGS, 3rd July in NGS and 7th July in SS. Two seeds were sown per stand at 4-5 cm depth. Seedlings that were more than 2 per stand were thinned to 2 plants at 2 weeks after sowing (WAS). The herbicide pendillin (Pendimanthaline) was applied at the rate of 4 l/ha 0-1 day after planting to prevent weeds from emerging. The recommended fertilizer rate of 100:50:50 was applied in 2 split doses. The first dose of 50:50:50: was applied using NPK 15:15:15 at 7 – 10 days after planting and the second dose of 50 kg N/ha was applied using Urea (46%N) at 4 weeks after planting. Supplementary manual hoe weeding was conducted due to persistent weed infestation. These operations were conducted for each location and repeated each year. The crops were harvested between 30th October and 20th November 2010 and between 31st October and 27th November in 2011 as per the crop maturity across the 3 locations. The cobs were dried, threshed and grains cleaned to determine grain yield per plot. Grain yield (kg ha^{-1}) was measured from 2 row net plot where the border hills were discarded in each experiment (4 m x 1.5m = 6 m^2) to minimize border effect.

Mid – Season Evaluation

Participatory Rural Appraisal (PRA) tools were applied to capture farmers' perceptions and preferences. The mid season evaluation was conducted at Sabon Gari (SS); Maina Hari (NGS); and Hema (SGS) on 13th and 14th October 2010, 15th to 17th October 2011. The objective of the exercise was to participatorily develop hybrid selection criteria and assess the acceptance of the new maize hybrids to the farmers in the communities. The researchers explained the objective of the exercise and intimated the farmers on their role in giving their perceptions on the performance of each hybrid as observed based on their general consensus. The farmers with facilitation from the researchers then went round the treatments in one replicate of the experiment in each site each year. Farmers then listed and ranked their selection criteria. A pair-wise ranking of the criteria was made by the farmers based on their perception.

Data collection and Statistical Analysis

Plant height (cm) was measured from the base of the plant to where tassel branching begin, while ear height (cm) was determined from the base of the plant to the node bearing the upper ear. The number of days from sowing to the time when 50% of the plants have tassels shedding pollen and to 50% of the plants have emerged silks were determined. Anthesis silking interval (ASI) was determined as the interval in days between 50% antheiss and 50% silk extrusion. All data collected were subjected to Analysis of variance (ANOVA) using Statistix version 10.0 (Statistix, 2013) to determine significant differences among treatment means. The means were compared using Duncan Multiple Range Test (DMRT) at 5% level of probability.

RESULTS AND DISCUSSION

Assessment of Agronomic Parameters

The probability of the effects of maize hybrid, ecology, year and their interactions was significant on the maize agronomic parameters determined (Table 1). Plant height, ear height, number of days to 50% tasseling, number of days to 50% silking, anthesis-silking – interval (ASI) and grain yield ha^{-1} of the maize hybrids significantly diffred across ecological zones. The maize hybrids also significantly differed in the expression of these parameters except ear height. Similarly, year had significant effect only on the number of days to tasseling and silking and grain yield per hectare. The ecology x hybrid interaction were significant on ear height, days to 50% tasseling and silking and ASI. Significant interactions were each observed for ecology x year and hybrid x year on number of days to 50% tasseling, 50% silking and ASI. The ecology x hybrid x year interaction was significant on plant height, ear height, number of days to 50% tassling, number of days to 50% silking and ASI.

The mean plant height of the maize hybrids for the combined years was significantly higher in SS than NGS or SGS (Table 2). However the mean plant height in SGS was significantly lower than those in NGS. The lowest plant heigh was thus observed in SGS. Although plant height did not significantly differ across the two years in SS, the hybrid LY902-12 and the IMPROVED CHECK significantly produced shorter plants than the other hybrids in 2010 and 2011, respectively. The three hybrids LY0614-11, LY0902-18 and LY0906-8 produced plants with heights that were greater than the mean, while LY0902-12, IMPROVED CHECK and LY0614-8 produced values that were lower than the mean in SS. Plant heights were significantly higher in 2010 than 2011 in NGS. Values were significantly lower for LY0614-11, LY0614-8 and LY0902-19 than the other hybrids for the combined mean. Two hybrids LY0902-18 and LY0906-8 produced plants that were taller than the mean plant height. In SGS, plant heights did not significantly differ across the years and for the combined mean. Plant heights were significantly lower than the other hybrids for LY0902-19, LY0614-8 and IMPROVED CHECK in 2010, LY0902-12 and LY0902-19 in 2011 and LY0902-19 for the combined mean (Table 2). However, LOCAL CHECK, LY0906-8, and LY0614-11 realized superior plant heights than the mean. The trend in plant height showed that while the hybrid LY0614-8 produced short plants across the three ecologies, the hybrid LY0902-19 produced short plants across the Guinea savannas. However, tall plants were produced by LY0906-8 across the three ecologies, while LY0614-11 produced tall plants across SS and SGS. Plant height was negatively correlated with number of days to tasselling (r = - 0.30*), and days to silking (r = - 0.34*) in NGS, ASI (r = - 0.59**) in SGS and ASI (r = - 0.41***) for the combined mean (Table 8). The superior vegetative growth for the taller hybrids could have suppressed reproductive growth as the hybrids cannot exceed their growth and development potentials. This probably interfered with the final grain yield because Begna et al. (2000) reported that the translocation rate of assimilates to the kernels of shorter hybrids was found to be greater than that of taller ones.

Ear heights were significantly higher in NGS than SS or SGS (Table 3). However, average ear heights were significantly higher in SS than SGS. Similar to the trend in plant heights, ear heights were significantly lower in SGS. There were no significant differences in ear heights within each ecology in 2010 and 2011. In SS, LY0614-8 significantly produced superior ear heights than the other hybrids in 2010, while LY0906-8 realized superior values in 2011. The combined means were significantly higher for LY0614-8, LY0902-18, and LY0902-19, while LY0614-11 and IMPROVED CHECK significantly produced lower ear heights than the other hybrids tested in SS. In NGS, the LOCAL CHECK, IMPROVED CHECK and LY0906-8 siginificantly realized superior ear heights in 2010, while LY0906-8, LY0902-19, IMPROVED CHECK and LY0902-18 significantly produced superior ear heights in 2011 and for combined mean. Hybrids that significantly produced lower ear heights in the ecological zone were LY0614-8, LY0614-11 and LY0902-12 for the combined mean. The results in SGS showed that ear heights were significantly higher for LY0902-12 and LOCAL CHECK in 2010, LOCAL CHECK, IMPROVED CHECK, and LY0614-11 in 2011 and LOCAL CHECK and IMPROVED CHECK for the combined mean. The three hybrids LY0906-8, LY0902-19 and LY0614-8 produced ear heights that were lower than the mean for the combined mean. The hybrid LY0614-11 produced lower ear heights across SS and NGS, while LY0614-8 produced similar results across NGS and SGS. The three hybrids LY0906-8, LY0902-18 and LY0902-19 produced superior ear heights across SS and NGS, while the LOCAL CHECK and IMPROVED CHECK produced similar results across NGS and SGS. High placement of ear is sometimes associated with root lodging especially in loose soils and windy weather. Ear heights were significantly and positively associated with plant height in SS (r = 0.32*), NGS (r = 0.62***), SGS (r = 0.62***) and for the combined mean (r = 0.61***), but negatively correlated with ASI in SGS (r = - 0.40**), and the combined mean (r = - 0.19*), and number of days to silk (r = - 0.28*) in NGS (Table 8).

The period to 50% tasselling significantly differred across the three ecologies (Table 4). There was a delay of 5 and 6 days each in period to tasselling in SS compared to the NGS and SGS, respectively. In SS, the priod to tasslling was significantly earlier in 2010 than 2011 as there was a delay of 4 days in 2011 compared to 2010. The two hybrids LY0902-18 and LY0902-19 significantly tasselled earlier, while LY0614-8 significantly tasselled latter than all the other hybrids in 2010. The hybrid LY0902-18 and IMPROVED CHECK relatively flowered earlier in 2011 and for the combined mean. Days to tasseling in NGS was significantly delayed by 2 days in 2011 compared to 2010. There was a delay of 2 to 8 days in the period to tasselling of LY0614-8 than other hybrids in 2010. Hybrids that significantly tasselled earlier in 2010, 2011 and combined mean include LY0902-12, LY0902-18, LY0906-8, and IMPROVED CHECK. The tasselling dates for the combined mean of LOCAL CHECK, LY0614-8, LY0614-11 and LY0902-19 were higher than the mean. Although there were no significant differences across the years in SGS, there was a delay of one day in 2011 compared to 2010 and the combined mean. Similar to the results observed in NGS, hybrids that significantly tasselled earlier than the other treatments in the SGS in 2010, 2011 and combined mean were LY0902-12, LY0902-18, LY0906-8 and IMPROVED CHECK. Number of days to tasselling was negatively associated with ASI in NGS (r = - 0.37**), SGS (r = - 0.41**) and

Combined mean (r = - 0.56***) (Table 8). The 2 weeks dry spell observed between the end of June and first week of July in NGS and end of July and first week of August in SS in 2011 may have delayed period to flowering across the zones.

The number of days to 50% silking was significantly greater in SS than the Guinea savanna ecologies (Table 5). Number of days to silking was significantly delayed by 6 and 3 days in 2011 and combined mean, respectively, than 2010 in SS. The hybrid LY0902-18, LY0902-19, LY0906-8, IMPROVED CHECK , and LY0902-12 significantly attained period to silking earlier than the other hybrids, while the period to silking was significantly delayed for the hybrid LY0614-8 than all the other hybrids across the years in the zone. In NGS, the period to silking was significantly earlier for LY0902-12, LY0902-18, LY0906-8 and IMPROVED CHECK than the other hybrids. The two hybrids LY0902-18 and LY0906-8 consistently attained period to silking earlier than other hybrids across the years in the zone. There was significant delay of 2 to 7 days in period to silking of LY0614-8, LY0614-11 and LY0902-19 compared to the other hybrids. The results in SGS were similar to NGS as the three hybrids LY0614-8, LY0614-11 and LY0902-19 had significant delay in period to silking. Thus the three hybrids: LY0902-12, LY0902-18, LY0906-8 significantly attained period to silking earlier than LY0614-8, LY0614-11 and LY0902-19 across the years and the three savanna zones of study. The number of days to silking were potitively correlated with number of days to tasselling in NGS (r = 0.94***), SGS (r = 0.92***) and combined mean (r = 0.83***). Also, the number of days to silking was positively correlated with ASI in SS (r = 0.54***) but negatively correlated with ASI in SGS (r= - 0.28) (Table 8). Herrero and Johnson (1981) reported that delay in silk emergence results in a decreased kernel number, which in turn results in lower grain yield. This is because an asynchronous flowering can limit grain production per ear due to lack of pollen, loss of silk receptivity or early kernel abortion (Carcovas and Otegui, 2001).

Anthesis silking intervals (ASI) were significantly shorter in SS than the Guinea savannas (Table 6). This could be attributed to the significant delay observed in period to tasselling and silking in SS compared to the Guinea savannas. ASI was significantly delayed by 1.4 days and 0.7 days in 2011 and the combined mean compared to 2010 in SS, probably due to the dry spell observed in 2011. Shorter ASI were observed for LY0902-12 and LY0902-19 in 2010, LY0902-18 in 2011 and, LY0902-19, LY0902-12, and LY0902-18 for the combined mean. In the Guinea savannas, ASI were significantly higher in 2010 than 2011. Three hybrids LY0902-18, LY0902-19 and LY0906-8 recorded shorter ASI than LY0614-8 in 2010, 2011 and the combined mean in NGS. The three hybrids had ASI shorter by 2-3 days than LY0614-8 across the years in the zone. In SGS, the ASI was longer by 1-2 days for LY0614-8 than other hybrids in 2010, while LY0902-12 significantly had ASI longer by 2-7 days than other hybrids in 2011 and 1-3 days for the combined mean. Significantly shorter ASI were observed for LY0614-11, LY9092-19 and LY0906-8 in 2010, 2011 and combined mean in SGS. Although the hybrids were not bred for drought tolerance, the short dry spell that was observed in 2011 increased the ASI of LY0614-8 and LY0902-12 that may be drought sensitive. When soil water deficit occurs before flowering, silk emergence out of the husks is delayed while anthesis is largely unaffected, resulting in an increased anthesis-silking interval (Edmeades et al., 2000). An increase in ASI is characteristic of maize under environmental stress, such as N-deficiency, drought and higher plant density (Bolanos and Edmeades, 1996). Hybrids with shorter ASI such as LY0902-18, LY0902-19, LY0906-8 and LY0614-11 probably exhibited drought tolerance. Olaoye et al. (2009) reported that drought tolerant genotypes of maize are recognized from sensitive ones by higher photosynthetic rate and short anthesis-silking interval.

Grain yield of the maize hybrids were significantly higher in SGS than SS or NGS (Table 7). Average grain yield of the hybrids in SGS was higher by 18.6 and 25.4% compared to NGS and SS, respectively, while it was higher in NGS by 8.3% than SS. The three hybrids LY0614-8, LY0902-12 and LY0906-8 recorded higher grain yield than the other hybrids across the years in SS. However, these hybrids had comparable yields with the LOCAL and IMPROVED CHECKS. The hybrid LY0614-8 significantly realized the highest yield, while LY0902-18 and LY0614-11 produced the lowest yields across the years. Grain yields in NGS was relatively higher for LY0902-12, LY0902-19, LY0906-8 and LY0614-8 across the years. The hybrid LY0614-8 significantly realized the highest grain yield in 2011 and for the combined mean in the zone. In SGS the hybrids LY0614-8, LY0614-11, LY0906-8, and LY0902-19, IMPROVED CHECK and LOCAL CHECK significantly recorded superior grain yields across the years. The best grain yields for the combined mean were observed for LY0614-8, LY0906-8, IMPROVED CHECK, LY0902-19 and LY0614-11 in that order. Grain yield per ha was negatively correlated with plant height (r = - 0.26***) for the combined mean and negatively but weakly correlated with number of days to tasselling (r = - 0.25) in SS (Table 8).

While the two hybrids LY0614-8 and LY0906-8 were the most promising across the three ecological zones, LY0902-12 was the most promising across SS and NGS, and LY0902-19 was the most promising across NGS and SGS. The superiority of the two hybrids LY0614-8 and LY0906-8 in grain yields across the three ecologies can be explained by the inverse association between plant height and grain yield. These hybrids produced short plants across the ecologies, attained period to tasselling, and silking early and had reduced ASI. The hybrid LY0614-11 that produced tall plants in SS recorded the lowest grain yields in SS and NGS. This is because the vegetative period may have prolonged at the expense of the reproductive phase in environments with relatively low soil fertility and short duration and low amount of rainfall. The agronomic parameters that confer grain yield advantage on the promising hybrids therefore include short plant and ear heights, early period to tasseling, and silking and short ASI. This findings corroborate Sangoi et al. (2002) who reported that increase in ASI reduces number of kernels per ear.

Assessment of Farmers' Selection Criteria

Male and female farmers listing and ranking of their selection criteria for the maize hybrids showed that high yield, quality nutrient, Striga tolerance, early maturity and drought tolerance among others were at the forefront across the three ecologies (Tables 9a to 9c). This indicates that the promotion of pro-vitamin A maize in these communities was appropriate. In a similar study Dugje et al. (2014) reported that the top ranking farmer requirements in a maize variety were Striga tolerance (STR), presence of high quality nutrient such as quality protein as in quality protein maize (QPM) and beta carotene as in yellow maize (Y); and drought tolerance (DT). The trend in the present study showed farmer preference for high nutritive maize to improve nutrition and early maturing, Striga tolerant and drought tolerant maize hybrids for food security and mitigation of biotic and environmental stress complexes. Dugje et al. (2017) suggested that Striga infested fields should be avoided for optimizing the productivity of provitamin A maize in Sudan savanna of Nigeria. Sibiya et al. (2013) reported that high yield and prolificacy, disease resistance, early maturity, white grain colour, and drying and shelling qualities were the characteristics preferred by farmers in maize hybrids in KwaZu-Natal.

CONCLUSIONS

The late and intermediate maturing hybrids responded variously to the environmental conditions across the ecological zones in northeast Nigeria. While the mean plant height, number of days to tasselling and silking were significantly higher in SS than NGS or SGS, ear heights were significantly higher in NGS than SS or SGS. However, Anthesis silking intervals (ASI) were significantly shorter in SS than the Guinea savannas which could be attributed to the significant delay observed in period to tasselling and silking in SS compared to the Guinea savannas. Since grain yield decreased with increase in plant height and number of days to tasselling, grain yields were significantly higher in SGS by 18.6 and 25.4% compared to NGS and SS, respectively, while it was higher in NGS by 8.3% than SS. The most promising and high yielding hybrids across the three ecologies were LY0614-8 and LY0906-8. While the hybrid LY0902-12 was the most promising across SS and NGS, LY0902-19 was the most promising across NGS and SGS. Farmers prefer maize hybrids that is high yielding, with quality nutrient like vitamin A, Striga tolerant, early maturing and drought tolerant. Although the hybrids tested showed promising grain yields, introduction of Provitamin-A rich maize hybrids that have the farmer preference traits with shorter plant height than those tested will improve maize productivity and enhance nutrition in the region.

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Table 1: Probability of F effect of Hybrid and Ecology on maize agronomic parameters across Savannas in Northeast Nigeria

Paramerter/ Effect	Pltht	Earht	D50tass	D50silk	ASI	GydHa
Ecozone (E)	0.0000	0.00000	0.0000	0.0091	0.0000	0.0005
Hybrid (H)	0.0004	0.5110	0.0000	0.0000	0.0000	0.0044
Year (Y)	0.2012	0.5930	0.0000	0.0000	0.7277	0.0222
E x H	0.0168	0.0122	0.0000	0.0000	0.0000	0.7824
E x Y	0.2853	0.9550	0.0000	0.0000	0.0000	0.1361
H x Y	0.0623	0.1076	0.0000	0.0000	0.0005	0.4138
E x H x Y	0.0001	0.0457	0.0003	0.0006	0.0000	0.5296

Table 2: Plant height of Provitamin A rich maize Hybrids tested across Savannas 2010, 2011 and Years Combined

Ecology/	**SS**			**NGS**			**SGS**		
Hybrid	2010	2011	Comb.	2010	2011	Comb.	2010	2011	Comb.
LY0614-8	176a-l	174a-l	175a-c	160j-p	164f-o	162c-e	138qr	163h-o	150ef
LY0614-11	188a-c	181a-h	184a	155m-q	161j-p	158de	159j-p	160j-p	159de
LY0902-12	150o-q	182a-g	166b-d	181a-h	168d-o	175a-c	173b-m	130r	151ef
LY0902-18	189ab	178a-j	184a	180a-i	190ab	185a	158l-p	155m-p	156de
LY0902-19	176a-k	185a-d	181a	160j-p	169c-n	165cd	130r	152n-q	141f
LY0906-8	182a-g	183a-f	183a	180a-i	183a-e	181a	153n-q	168d-o	161de
Improved Check	175a-l	173b-m	174a-c	181a-h	175a-l	178ab	143p-r	170c-n	156de
Local Check	182a-g	184a-e	183a	192a		179ab	161i-o	164g-o	162c-e
Mean	177ab	180a	179a	174ab	172b	173b	152c	158c	155c
SED E					2.357				
SED H					6.669				
SED Y					5.445				
SED E x H x Y					9.431				

Means followed by the same letter in a column or row are not significantly different accroding to the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Table 3: Ear height of Provitamin A rich maize Hybrids tested across Savannas in 2010, 2011 and Years Combined

Ecology/	**SS**			**NGS**			**SGS**		
Hybrid	2010	2011	Comb.	2010	2011	Comb.	2010	2011	Comb.
LY0614-8	86a-g	79c-k	82b-e	76d-l	84b-i	80c-f	62no	73h-o	68ij
LY0614-11	77d-l	72i-o	75e-i	78c-k	82b-i	80c-f	68j-o	74e-n	71g-j
LY0902-12	76d-l	81b-i	79c-g	82b-i	78c-k	80c-g	78d-l	62no	70h-j
LY0902-18	84b-i	79c-k	82b-e	82b-i	86a-e	84b-d	73g-n	65l-o	69ij
LY0902-19	82b-i	83b-i	82b-e	86b-h	88a-d	87a-c	63m-o	65l-o	64j
LY0906-8	72i-o	86a-f	79c-g	90a-c	98a	94a	66k-o	61o	63j
Improved Check	80c-j	76d-l	77d-i	93ab	88a-d	90ab	71i-o	75e-m	73f-i
Local Check	83b-i	74f-n	79.8c-g	94ab	74e-n	83.8b-e	77d-l	76d-l	76.2d-i
Mean	80b	79b	79b	85a	85a	85a	70c	69c	69c
SED E					1.598				
SED H					4.520				
SED Y					2.260				
SED E x H x Y					6.393				

Means followed by the same letter in a column or row are not significantly different accroding to the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Table 4: Number of days to 50% taselling of Provitamin A rich maize Hybrids tested across Savannas 2010, 2011 and Years Combined

Ecology/	SS			NGS			SGS		
Hybrid	2010	2011	Comb.	2010	2011	Comb.	2010	2011	Comb.
LY0614-8	64c-f	67ab	65b	63e-i	60jk	62d	63e-i	60jk	62d
LY0614-11	63e-i	68ab	65bc	61h-k	62f-j	62d	61h-k	67ab	64c
LY0902-12	63e-h	67ab	65bc	55m	64c-f	59e	55m	57kl	56fg
LY0902-18	62f-j	67ab	64bc	55m	55m	55fg	55m	55m	55g
LY0902-19	62f-j	68ab	65bc	61i-k	62f-j	61d	60jk	60jk	60de
LY0906-8	63e-i	66a-d	65bc	57lm	55m	56fg	56m	55m	56fg
Improved Check	63e-h	65b-e	64bc	55m	59kl	57f	55m	55m	55g
Local Check	63e-i	67ab	65bc	68a	68a	68a	68a	68a	68a
Mean	63b	67a	65a	59d	61c	60b	59d	60cd	59d
SED E					0.325				
SED H					0.919				
SED Y					0.459				
SED E x H x Y					1.300				

Means followed by the same letter in a column or row are not significantly different accroding to the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Table 5: Number of days to 50% silking of Provitamin A rich maize Hybrids tested across Savannas 2010, 2011 and Years Combined

Ecology/	**SS**			**NGS**			**SGS**		
Hybrid	2010	2011	Comb.	2010	2011	Comb.	2010	2011	Comb.
LY0614-8	66h-k	71b-d	68cd	71b-d	67h-j	69bc	72ab	68f-h	70b
LY0614-11	65j-m	70b-e	67de	68f-h	71b-d	69bc	68f-h	70b-f	69bc
LY0902-12	64l-o	70b-e	67de	62o-q	68e-h	65f-h	62o-q	67h-j	65gh
LY0902-18	63m-p	69d-h	66ef	62o-q	63m-p	62ij	62o-q	63m-p	62ij
LY0902-19	63m-p	70b-e	67de	67h-j	67h-k	67de	67h-j	65j-m	66e-g
LY0906-8	65j-m	69d-h	67de	63m-p	60q	62ij	63m-p	60q	62ij
Improved Check	65j-m	68g-i	66ef	63m-p	65j-m	64hi	63m-p	60q	62ij
Local Check	64l-o	71b-d	67de	73a	73a	73a	73a	73a	73a
Mean	64d	70a	67a	66bc	67b	66ab	66bc	66bc	66b
SED E					0.285				
SED H					0.806				
SED Y					0.403				
SED E x H x Y					1.140				

Means followed by the same letter in a column or row are not significantly different accroding to the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Table 6: Anthesis Silking Interval (ASI) of Provitamin A rich maize Hybrids tested across Savannas 2010, 2011 and Years Combined

Ecology/	**SS**			**NGS**			**SGS**		
Hybrid	2010	2011	Comb.	2010	2011	Comb.	2010	2011	Comb.
LY0614-8	1.3k-m	3.3hi	2.3g	8.3bc	7.0c-e	7.7ab	9.0ab	8.0b-d	8.5a
LY0614-11	2.0i-m	2.3i-k	2.2g	7.0c-e	8.7ab	7.8ab	7.0c-e	3.0ij	5.0f
LY0902-12	0.7m	3.0ij	1.8g	7.0c-e	4.7gh	5.8ef	7.0c-e	10.0a	8.5a
LY0902-18	1.7j-m	2.0i-m	1.8g	6.3ef	8.0b-d	7.2bc	6.7de	8.0b-d	7.3bc
LY0902-19	0.7m	2.7i-k	1.7g	6.3ef	5.0fg	5.7ef	7.0c-e	5.0fg	6.0d-f
LY0906-8	1.7j-m	2.7i-k	2.2g	6.3ef	5.0fg	5.7ef	7.0c-e	5.0fg	6.0d-f
Improved Check	1.3k-m	2.3i-k	1.8g	8.0b-d	6.0e-g	7.0b-d	8.0b-d	5.0fg	6.5c-e
Local Check	1.0lm	3.3hi	2.2g	5.0fg	5.0fg	5.0f	5.0fg	5.0fg	5.0f
Mean	1.3d	2.7c	2.0b	6.8a	6.2b	6.5a	7.1a	6.1b	6.6a
SED E					0.194				
SED H					0.551				
SED Y					0.275				
SED E x H x Y					0.779				

Means followed by the same letter in a column or row are not significantly different accroding to the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Table 7: Grain yield (kg/ha) of Provitamin A rich maize Hybrids tested across Savannas 2010, 2011 and Years Combined

Ecology/	**SS**			**NGS**			**SGS**		
Hybrid	2010	2011	Comb.	2010	2011	Comb.	2010	2011	Comb.
LY0614-8	7042a-d	4950c-j	5846a-d	4786b-j	6359a-g	5572a-e	7863a	6701a-e	7282a
LY0614-11	3829e-j	3556f-j	3692ef	4513c-j	2940ij	3727d-f	6495a-f	4650c-j	5572a-e
LY0902-12	5743a-j	3692e-j	4718b-f	5675a-j	4103d-j	4889b-f	3487f-j	4171d-j	3829d-f
LY0902-18	3351g-j	3282h-j	3316f	3145h-j	4239c-j	3316f	5607a-j	4239c-j	4923b-f
LY0902-19	4444c-j	3077h-j	3761d-f	5607a-j	5333a-j	5470a-e	6974a-d	5607a-j	6290a-c
LY0906-8	5675a-j	5333a-j	5504a-e	5607a-j	5880a-i	5743a-e	5675a-j	7726ab	6701ab
Improved Check	5538a-j	3282h-j	4410c-f	5265a-j	4308c-j	4786b-f	8205a	4444c-j	6325a-c
Local Check	6017a-h	2735j	4376c-f	3897e-j	5607a-j	4752b-f	6085a-h	7248a-c	6666ab
Mean	5205b	3701c	4453b	4812b	4846b	4829b	6299a	5598ab	5949a
SED E					381.16				
SED H					1078.1				
SED Y					539.04				
SED E x H x Y					1524.6				

Means followed by the same letter in a column or row are not significantly different accroding to the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Table 8: Linear relationships among agronomic parameters of Provitamin A rich maize Hybrids tested across Savanna Ecologies

Parameter	Anthesis Silking Interval	Days to tassel	Days to silk	Ear height	Plant height
SS					
Days to silk	0.54***	0.92***	1.0	1.0	1.0
Ear height	-0.21	0.01	-0.08	1.0	1.0
Plant height	0.20	-0.01	0.07	0.32*	1.0
NGS					
Days to tassel	-0.37**	1.0	1.0	1.0	1.0
Days to silk	-0.04	0.94***	1.0	1.0	1.0
Ear height	-0.09	-0.23	-0.28*	1.0	1.0
Plant height	-0.06	-0.30*	-0.34**	0.62***	1.0
SGS					
Days to tassel	-0.41**	1.0	1.0	1.0	1.0
Days to silk	-0.28*	0.92***	1.0	1.0	1.0
Ear height	-0.40**	0.27	0.13	1.0	1.0
Plant height	-0.59***	0.01	-0.23	0.62***	1.0
EC					
Days to tassel	-0.56***	1.0	1.0	1.0	1.0
Days to silk	-0.01	0.83***	1.0	1.0	1.0
Ear height	-0.19*	0.06	-0.05	1.0	1.0
Plant height	-0.41***	0.14	-0.10	0.61***	1.0

Grain yield/ha	0.15	-0.14	-0.07	-0.14	-0.26**

* = significant (P<0.05), ** = Significant (P<0.01), *** = Significant (P < 0.001), Values without asterisk(s) have no significant linear correlation.

Table 9a: Pair – wise ranking of farmer criteria for Pro-vitamin A maize hybrid selection at Maina Hari, NGS 2010 and 2011

2010											**2011**											
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**	**Score**	**Criteria**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**Score**
1.Fertzer. effic.	X	2	3	1	5	6	7	8	1	6th	1.Early maturity	X	1	3	1	5	6	7	1	9	3	6th
2.Striga resistant		X	2	2	5	6	2	2	5	3rd	2.Large Grains		X	3	4	5	6	7	2	9	1	8th
3.Early maturity			X	3	3	5	6	3	4	4th	3.High nutrients			X	3	3	3	3	3	3	8	1st
4.Short stalk				X	5	6	6	4	1	6th	4.Striga resist.				X	5	6	4	4	9	3	6th
5,Quality nutrient					X	5	5	5	7	1st	5.Good ear filling					X	6	5	5	5	6	3rd
6,High yield						X	6	6	7	1st	6. Intercropping						X	6	6	6	7	2nd
7.Big grains							X	7	2	5th	7. Lodging resist.							X	7	7	4	4th
8.Husk covered								X	1	6th	8.Good fodder								X	9	0	9th
											9. Uniform plants									x	4	4th

Number of farmers = 32 (25 males, and 7 females) in 2010, 28 (20 males and 8 females) in 2011

Table 9b: Pair – wise ranking of farmer criteria for Pro-vitamin A maize hybrid selection at Hema, SGS 2010 and 2011

2010												**2011**										
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**Score**	**Criteria**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**	**Score**
1.Striga resist.	X	1	1	1	1	1	1	8	9	6	3^{rd}	1.Early matur.	X	2	3	4	5	6	1	8	1	7^{th}
2.Drought toler.		X	3	4	2	2	2	8	9	3	6^{th}	2.Striga resist.		X	2	2	5	6	2	8	4	4^{th}
3.Fertilize. eff.			X	3	3	3	3	8	9	5	4^{th}	3.Filled ear			X	3	3	6	3	8	5	2^{nd}
4.Early maturity				X	4	4	4	8	9	4	5^{th}	4.Drought tol.				X	5	6	4	8	2	6^{th}
5.Big cobs					X	6	7	8	9	0	9^{th}	5.Fertzer. eff.					X	6	5	8	4	4^{th}
6.Medium heigt.						X	6	8	9	2	7^{th}	6.Nutritive						X	6	6	7	1^{st}
7.Filled ear							x	8	9	1	8^{th}	7.Good fodder							X	8	0	8^{th}
8.Quality nutr.								X	8	8	1^{st}	8.Interopping								X	5	2^{nd}
9.Good flour									X	7	2^{nd}											

Number of farmers = 18 (15 males, and 3 females), in 2010 and 25 (15 males and 10 females) in 2011

Table 9c: Pair – wise ranking of farmer criteria for Pro-vitamin A maize hybrid selection at Sabon- Gari, SS 2010

Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**	**Score**
1.Fertilizer use eff.	X	1	3	4	5	6	7	1	2	6^{th}
2.Striga resistant		X	2	4	5	2	7	2	3	4^{th}
3.Drought tolerant			X	4	5	3	7	3	3	4^{th}
4.Quality nutrient				X	4	4	4	4	7	1^{st}
5.High yield					X	5	5	5	6	2^{nd}
6.Short stalk						X	7	8	1	7^{th}
7.Early maturity							X	7	5	3^{rd}
8.High yield								X	1	7^{th}

Number of farmers = 20 (15 males, and 5 females)