YIELD ANALYSIS OF MAIZE VARIETIES IN VARIED AGRO-ECOLOGIES OF SOUTHWESTERN NIGERIA

***OLOYEDE-KAMIYO Q. O., ADETUMBI J. A., OLASOJI J. O. AND AMUSAN I. S.**
Institute of Agricultural Research and Training (IAR&T), Obafemi Awolowo University,
P.M.B.5029, Moor Plantation, Apata, Ibadan, Nigeria.
*qudratkamiyo@gmail.com, 08060993930

ABSTRACT

There is a gap between yield potential of maize varieties and the realized yield on farmers' field in South Western Nigeria. There is need to reduce this yield disparity to boost farmers' productivity. A study was conducted at three outstations of the Institute of Agricultural Research and Training, covering three agro-ecological zones of Nigeria to determine the extent of the yield gap in maize varieties and possible solutions. Four maize varieties-BR9943DMRSR-W, BR9928DMRSR-Y, SUWAN 1-SR and ART/98/SW6-OB were evaluated at Ilora, Kishi and Orin-Ekiti between 2013-2017. Each variety was planted to one hectare and repeated three times. Data were collected on yield, seed yield, percentage seed yield and percentage yield gap. Data were subjected to analysis of variance. Means were separated using Duncan Multiple Range Test (DMRT). Mean squares of variety, location, year and their interactions were significant for all the traits. Variety BR9928DMRSR had the highest mean yield (1.35t/ha), seed yield (1.25t/ha) with the least yield gap (39.9%). The highest mean yield was recorded at Orin-Ekiti, while the least yield and highest yield gap were recorded at Kishi. The highest yield was obtained in 2016 and the least in 2015. ART/98/SW6-OB and BR9928DMRSR-Y performed best at Orin-Ekiti. This study revealed that the yield potentials of most maize varieties according to breeders' presentations are not realized in South Western Nigeria. Hence, effort towards non-limiting management such as good soil management, adequate soil moisture through irrigation, optimum plant population density and timely management practices throughout the crop growth cycle should be intensified.

Keywords: ***Maize (Zea mays), Seed yield, Yield gap, Yield potential.***

INTRODUCTION

Maize is the third most important cereal crop in the world after wheat and rice (FAO, 2009). Maize has always been preferred to any other crop, including cassava because most of the world's civilizations developed around grains rather than tuber crops (Fakorede, 2001). In Nigeria, maize is the most commonly grown crop among subsistent and commercial farmer. The report of a food consumption survey showed that maize was the most often consumed staple, with 20% of the population eating it at least once a week (IITA, 2004).

Maize breeders in both national and international research institutes have developed varieties with tolerance to various field stresses with increased yield over the existing ones, and virtually every year, new maize varieties are registered and released for farmers' use. Each of these new released varieties has its yield potential ranging from 3.5 – 5 t/ha for open-pollinated varieties (NACGRAB catalogue, 2014). Maize productivity remained low despite several efforts by Nigeria government. Wide gap still exists between the actual (4.5t/ha) and potential (above 5t/ha) yield (Remison, 2005). The failure to realize increased productivity in the Nigerian maize sector raises questions about the efficiency with which maize farmers use production resources, technological innovation and other policy factors.

The yield gap between the realized and the potential yield of maize has been attributed to several factors among which are inadequate plant population, under-utilization of inputs, soil physical properties and small farm holdings. Aye and Mungatana (2012) reported that even though farmers may be technically efficient, they may not be cost efficient, that is, they do not utilize the inputs in optimal proportions, given the observed input prices, and hence do not produce at minimum possible cost.

Maize model was used to separate the contributions of soil physical properties, cultivar selections, and management practices to maize yield gaps. The results indicate that approximately 5, 12, and 18% of potential yield loss of maize is attributable to soil physical properties, cultivar selection, and management practices (Zhijuan *et al.*, 2016). This showed that management practices play a vital role in meeting maize yield potential. Although there are several ways of estimating yield per hectare, a more realistic approach is planting the crop on one hectare of land in different locations and in multiple seasons. This should also be followed by optimum plant population and good agronomic practices. This study therefore aims at determining the percentage yield gap in maize varieties in each location, and suggest possible ways of reducing the gap between the yield potentials as presented by breeders and what is realized on the field.

MATERIALS AND METHODS

The evaluation was conducted based on yield realized from foundation seed production from three out-stations of the Institute of Agricultural Research and Training (IAR&T). The stations are located in three agro-ecological zones of Nigeria. The locations were: Ilora (Derived savanna), Orin- Ekiti (Humid rain forest) and Kishi (Northern Guinea savanna). The evaluation focused on four adapted maize varieties in these locations, between 2013-2017 cropping seasons. Each variety was planted to one hectare and repeated three times. The four varieties were BR9928DMRSR-Y, BR9943DMRSR-W, SUWAN 1-SR and ART/98/SW6-OB. The varieties and their attributes are presented in Table 1.

TABLE 1: MAIZE VARIETIES USED IN THIS STUDY AND THEIR ATTRIBUTES

No	Variety	Kernel colour	Year of Release	Attributes
1	**BR9943DMRSR-W**	White	2009	Stemborer resistant, yield 3-4 t/ha
2	**SUWAN 1-SR**	Yellow	1996	Streak and downy mildew resistant, 2.5-3t/ha
3	**BR9928DMRSR-Y**	Yellow	2009	Stemborer resistant, yield 3-4 t/ha.
4	**ART/98/SW6-OB**	White	2009	Quality Protein Maize, early maturing, high yielding (4.0 – 4.6 t/ha)

Source: NACGRAB Catalogue of crop varieties released and registered in Nigeria, 2014.

Planting was done at 75 cm by 50 cm spacing at three seeds per hole, which was later thinned to two plants per hill at three weeks after planting resulting to about 53,333 plants/hectare. Weed management was done with the application of pre-emergence herbicides a day after planting, one manual weeding at four weeks after planting with one supplementary weeding at flowering. Fertilizer was applied at the rate of 90kgN/ha using NPK at 2 weeks after planting (WAP) and urea at 5 WAP. Ampligo insecticide was applied to control armyworm when noticed on the field in 2016 and 2017 at the rate of one sachet per 16litre-knapsack sprayer. Total (field) yield of maize realized per hectare was estimated from field weight at moisture content of 12% for each year. However, since the experimental fields were intended for seed production, actual seed yield realized from the total field yield was determined by weighing the grade 1 seed after mechanical cleaning and grading using multi-seed cleaner and specific gravity separator. The seed yield was expressed as percentage of total yield/ha to obtain percentage seed yield. Yield gap was obtained by deducting the average of realized yield per hectare (for five years) from the yield potential/ha of each maize variety as stipulated in varietal release catalogue as presented in Table 1 and then expressed as percentage of the yield potential. The lower limit of the yield potential was used. Information on challenges on the field were taken from each location each year. Data in percentage were transformed using arcsine before analysis. Means of traits for each variety over the years was estimated and subjected to analysis of variance using SAS version 9.0. Random model was assumed for this analysis. Significant means were separated using Duncan Multiple Range Test at 5% significant level.

RESULTS

The result of analysis of variance for the studied traits is shown in Table 2. The year, location and varietal effects as well as the interaction effects were significant for the traits studied. However, year by location by variety interaction effect was not significant for percentage seed yield and yield gap in this study.

TABLE 2. MEAN SQUARES FROM ANALYSIS OF VARIANCE FOR YIELD IN THE FOUR MAIZE VARIETIES AT ILORA, KISHI AND ORIN-EKITI BETWEEN 2013 - 2017.

Source	df	Mean (field) yield (tons/ha)	Mean seed yield (tons/ha)	Seed yield (%)	Yield gap (%)
Year (Y)	4	8475206.60**	7533091.26**	0.04**	0.73**
Rep/Location	6	2500.00**	2500.00**	1.00**	0.77**
Location (L)	2	242128.11**	231944.94**	0.01*	0.11**
Variety (V)	3	144191.52**	131624.50**	0.04*	0.14**
Y x L	8	453810.69**	524769.59**	0.07**	0.24**
Y x V	12	283227.18**	308386.66**	0.08**	0.20**
L x V	6	458797.11**	367224.55**	0.06**	0.21**
Y x Lx V	24	231004.90*	218647.70*	0.001	0.03
Error	90	30800.65	29153.02	0.001	0.01

*, **: Significant at P= 0.05 and 0.01 respectively, df: degree of freedom

The mean performance of the varieties studied across locations is shown in Table 3. The variety, BR9928DMRSR-Y was the highest in terms of mean yield (1.35t/ha) delivered as well as seed yield (1.25t/ha) followed by ART/98/SW6-OB. SUWAN I-SR was the least in performance (1.01t/ha). Percentage seed yield was however not significant for all the varieties. Yield gap was also lowest in BR9928DMRSR-Y (39.9%) but highest in ART/98/SW6-OB (68.6%).

TABLE 3. OVERALL YIELD PERFORMANCE AND YIELD GAP FOR THE FOUR MAIZE VARIETIES ACROSS LOCATIONS BETWEEN 2013-2017

Variety	Mean yield (tons/ha)	Mean seed yield (tons/ha)	Seed yield (%)	Yield gap (%)
BR9943DMRSR-W	1.16c	1.03c	89.10a	61.76b
SUWAN I-SR	1.01d	0.92d	91.40a	59.89c
BR9928DMRSR-Y	1.35a	1.25a	92.40a	39.89d
ART/98/SW6-OB	1.26b	1.13b	90.20a	68.64a

Means with the same letter are not significantly different from each other

Orin-Ekiti recorded the best result in terms of yield delivered (1.46tons/ha) as well as seed yield (1.36tons/ha) over the period of years followed by Ilora (Table 4). Yield performance was least at Kishi (1.10tons/ha). Percentage seed yield was however not significantly different between Ilora and Kishi. Yield gap was also highest at Kishi (62%) but lowest at Ilora (48.6%).

TABLE 4. OVERALL YIELD PERFORMANCE AND YIELD GAP IN EACH LOCATION BETWEEN 2013-2017

Location	Mean yield (tons/ha)	Mean seed yield (tons/ha)	Seed yield (%)	Yield gap (%)
Ilora	1.22b	1.09b	67.79b	48.56c
Kishi	1.10c	1.00c	76.56ab	61.98a
Orin Ekiti	1.46a	1.36a	85.26a	53.19b

Means with the same letter are not significantly different from each other.

Mean yield performance for each year is presented in Table 5. Highest mean yield delivered, seed yield as well as percentage seed yield was recorded in 2016 (3.37tons/ha, 3.2tons/ha, 95% respectively) with the least yield gap (2%) followed by 2014 with 1.6tons/ha yield delivered and 1.43tons/ha seed yield as well as 47.2% yield gap. Year 2015 recorded the worst performance with yield of 0.63tons/ha, seed yield of 0.58tons/ha and 78.1% yield gap. Rainfall data at each location is presented in Table 6.

TABLE 5. OVERALL YIELD PERFORMANCE AND YIELD GAP ACROSS LOCATIONS FOR EACH YEAR OF STUDY

Year	Mean yield (tons/ha)	Mean seed yield (tons/ha)	Seed yield (%)	Yield gap (%)
2013	0.66d	0.56e	39.31b	77.83b
2014	1.60b	1.43b	83.50a	47.19d
2015	0.63e	0.58d	75.91a	78.10a
2016	3.37a	3.20a	95.00a	2.00e
2017	0.86c	0.81c	83.71a	55.78c

Means with the same letter are not significantly different from each other.

TABLE 6. RAINFALL (MM) DATA DURING THE PERIOD OF STUDY AT THE THREE LOCATIONS

Month	Kishi				Orin-Ekiti				Ilora		
	2014	2015	2016	2017	2014	2015	2016	2017	2015	2016	2017
January	6.1	-	-	-	52.3	8.3	1.8	15.1	-	-	-
February	3.6	18.0	-	-	56.3	3.5	8.8	13.5	-	-	-
March	104.0	52.0	59.2	4.5	108.4	52.3	159.5	188.5	66.5	153.7	118.8
April	156.5	-	158.4	44.0	225.5	38.8	192.5	209.0	61.4	50.7	78.6
May	120.5	116.0	306.0	141.0	83.1	102.1	120.5	141.3	76.5	168.3	228.8
June	192.5	125.0	133.0	197.8	260.5	140.8	520.5	272.1	219.9	278.4	224.4
July	100.0	28.0	140.0	37.0	138.1	109.3	114.5	252.2	60.8	178.7	168.1
August	113.0	166.5	169.3	181.5	267.4	121.9	179.2	115.1	154.8	135.0	217.2
September	281.5	434.0	395.3	148.2	240.4	281.4	271.0	147.6	265.2	369.5	312.5
October	295.0	219.0	9.6	135.0	94.1	251.0	186.7	85.5	158.1	219.4	66.3
November	32.0	-	6.0	-	12.7	23.7	41.9	24.3	4.0	14.6	79.7
December	-	-	18.0	4.9	-	-	-	18.4	-	31.5	-
Total rain	1404.7	1158.5	1394.8	893.9	1538.8	1133.1	1796.9	1482.6	1067.2	1599.8	1494.4
*Cropping period	494.5	628.5	704.6	366.7	614.6	678.0	678.8	372.5	582.1	738.5	675.7

Note: Rainfall data was not available at Kishi and Orin-Ekiti for 2013, and at Ilora for 2013 &2014.
*Amount of rain within the cropping period.
Planting start from July at Kishi, and from August at Orin-Ekiti and Ilora.
All the maize varieties are intermediate maturing.

Performance of each variety in each location is shown in Fig. 1. The result revealed that ART/98/SW6-OB performed best at Orin-Ekiti, followed by BR9928DMRSR-Y, while SUWAN 1-SR was the worst. SUWAN 1-SR performed best at Ilora, while ART/98/SW6-OB was the worst. BR9943DMRSR-W was the best at Kishi where it recorded the highest yield among all the locations.

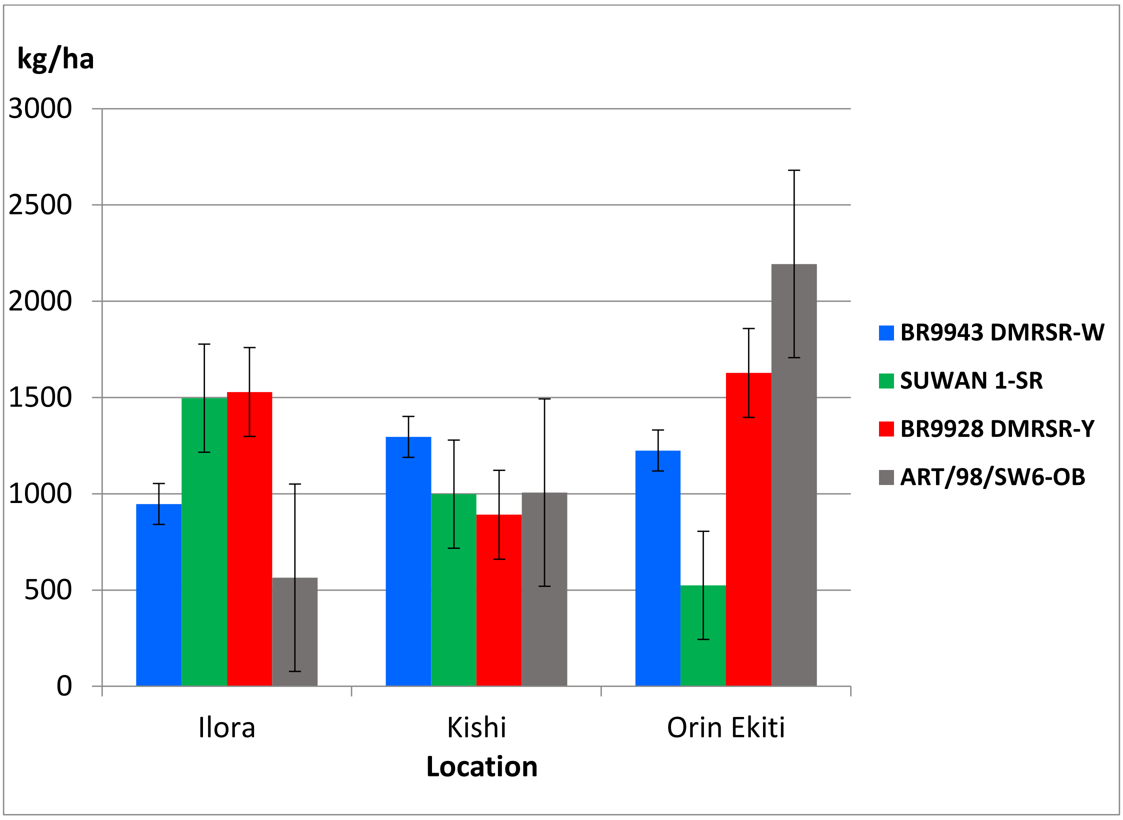

FIG.1. PERFORMANCE OF EACH MAIZE VARIETY IN THE THREE LOCATIONS OVER THE PERIOD OF 5 YEARS

DISCUSSION

The prevalent climate change causes variation in weather at a particular location at a time and this affect agricultural production. The significant mean squares of year, location and variety as well as their interaction effect in this study indicated clear distinction in the performance of the varieties in different agro-ecological zones. Zhijuan *et al.* (2016) also reported significant year-to-year variations in yield gaps caused by soil physical properties, ranging from 0.2% to 14.8% during past five decades. The maize varieties BR9928DMRSR-Y and BR9943DMRSR-W are stem borer resistant varieties developed mainly for the forest agro-ecological zones where stem borers are prevalent. The climate change and outbreak of pests, mainly the fall armyworm in 2016 also affected the performance of the maize varieties from year to year.

Potential yield is the ceiling of the yield for a crop variety at a certain place, which is largely dependent on the particular combination of solar radiation, temperature, soil, and plant density at a specific location (van Ittersum and Rabbinge, 1997). The highest yield performance of BR9928DMRSR-Y with the least yield gap indicated the inherent ability of the maize variety to combine and utilize perfectly the solar radiation, temperature and soil status at a specific location. SUWAN 1-SR is an old maize variety which is gradually losing its ability to utilize these factors well. This must have caused the decrease in yield.

Zhijuan *et al*. (2016) used the Agricultural Production Systems Simulator- Maize model to separate the contributions of soil physical properties, cultivar selections, and management practices to maize yield gaps. The results indicate that approximately 5%, 12%, and 18% of potential yield loss of maize is attributable to soil physical properties, cultivar selection, and management practices, respectively. This indicated that management practices in each location play a major role in achieving yield potential of a particular maize cultivar. In the present study, Kishi which is a Guinea savanna zone recorded the least overall yield and the highest yield gap, while Orin-Ekiti, a humid rain forest recorded the highest overall yield and the least yield gap. This was not expected because maize tends to yield better in the savanna zone due to the high solar radiation and least pest and disease attack. The results obtained in this study may be due to management practices such as planting optimum population and timeliness in fertilizer and herbicide application in each of the locations. Ipsilandis and Vafias (2005) reported that yield potential per unit area was found to be dependent on plant density. Yield will continue to increase up to 10 plants per m^2 (100,000 plants/ha) after which grain yield loss results.

de Bie (2000) classified factors contributing to yield gaps as non-controllable, agronomic, and socioeconomic factors. Non-controllable factors include various environmental conditions and technologies available at research stations for the farmers' field. Highest yield was reported in 2016 followed by 2014 in this study, while the worst yield and highest yield gap was reported in 2015. Year 2015 recorded low percentage of rain during the cropping season which is likely to affect flowering as well as the physiological maturity of the plant, although the amount of rain varied from location to location. Mourice *et al.* (2014) reported that interaction between irrigation and nitrogen significantly affected grain yield. Application of recommended N rate did not result into yield increase when water was limiting. Under adequate soil moisture conditions, recommended N rate attained up to 26% yield gap, suggesting that it would be beneficial to apply nitrogen fertilizer when water is not limiting to close the yield gap. Small nitrogen doses can be an effective strategy towards narrowing yield gaps for resource poor farmers especially in drought prone areas. If soil fertility is well managed, rainfall-dependent crop production turns out to be productive and substantial productivity improvement can be realized (Kalhapure *et al.*, 2013). Ayodele and Omotosho (2008) suggested that the inclusion of Mg and micronutrient such as Cu and Zinc, would correct deficiencies that show up under intensive cultivation and continuous use of NPK fertilizer to increase maize yield. Once the land is opened from fallow and cultivated for more than 4 years, and in soils with less than 3% organic matter, the need to include Mg and micronutrients in the fertilizer schedule becomes essential for high maize yield in the savannah zone of southwest Nigeria.

Aye and Mungatana (2012) evaluated the technical, allocative and cost efficiency of farm households using stochastic distance and production function frontiers. Their result indicated that limited use of modern technologies such as improved maize seed, inorganic fertilizers and conservation practices, smallness of farm holdings, inadequate formal education, access to extension services, credit and market were significant determinants of efficiency.

Genotype by environment interaction helps in allocating variety to the best suited environment. It suggested the best variety to the appropriate mega-environment. ART/98/SW6-OB and BR9928DMRSR-Y performing best at Orin-Ekiti suggested that the location would be the best to produce these varieties. These two varieties were actually bred for forest ecology and this must have contributed to their good performance at Orin-Ekiti, a forest ecological zone of Nigeria. SUWAN 1-SR is an old variety which is now losing its resistance to streak, a common maize viral disease in the forest zone. This has contributed to its poor performance at Orin-Ekiti but better performance at Ilora, a derived savanna zone of Nigeria.

CONCLUSION

It can be concluded in this study that a wide gap exists between the potential and the realized yield of different maize varieties. To close the yield gap, it is suggested that effort towards non-limiting management such as optimum plant population density, good soil management, adequate soil moisture through irrigation, and timely management practices throughout the crop growth cycle should be intensified in southwestern Nigeria.

ACKNOWLEDGEMENTS

The authors appreciate the members of staff of all out-stations of IAR&T for their technical assistance.

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