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INAUGURAL LECTURE

"PLANT BREEDING FOR SURVIVAL OF MANKIND"

By

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Ladies and Gentlemen.

Preamble

To God be the Glory, Great Things He hath done.

I stand before you today to present my inaugural lecture which is a recognition of God's faithfulness in my life and favour upon my family. As a son of a peasant farmer, born and raised on the farm, going to the University was a tall dream and a far-fetched wish. So becoming an academic and rising to the rank of a professor was more than a dream and indeed a latent vision. This inaugural lecture is the second in the Department of Agronomy. Today, the son of a farmer will tell the story of the love for the farm, what that love has propelled in the quest for more food and the rewards of being on the farm.

Historical Perspective of Plant Breeding

Plant breeding is the art and science of modeling plants to produce desired characteristics and has been practised since the beginning of human civilization (Sleper & Poehlman, 1955). As an art, early farmers simply selected food plants with particular desirable characteristics and used them as seed source for subsequent generations, resulting in accumulation of characteristics over time. Although it started with sedentary agriculture particularly the domestication of the first agricultural plants, plant breeding is now practised worldwide by individuals such as gardeners and farmers; or professional plant breeders employed by organizations such as government institutions, universities, crop-specific industry associations; and research centres. The principal aim is to produce crops that are high yielding, with good quality products especially as the world population keeps increasing.

Plant breeding looks at organisms as a whole and also at the molecular level {(DNA sequences, protein products) (Gepts and Hancock, 2006)}. Plant breeding transformed from art to science following the rediscovery of Gregor Mendel's earlier studies on hybridization. This ultimately led to the new science of genetics. Before then, plant improvement was by farmers who domesticated many plants as crops, continued to modify them and were also responsible for moving them from one continent to another and in the process, made efforts to adapt them to new climates, new cultural practices and new uses. The records show that hybridization probably started before 1900 (Strampeli, 1994). Modern plant breeding also referred to as *Applied Genetics*, is broader and encompasses advances in science that cover molecular biology, cytology, systematics, physiology, pathology, entomology, chemistry, and statistics (biometrics). It has also developed its own technology and introduced new tools that accelerate breeding efforts.

The Gene-Environment Complex

Environment is the sum of all biotic (all surrounding living species) and abiotic (light, temperature, water, atmospheric gases, etc.) factors that influence organism's survival, growth and development. Environments do modify the expression of the genetic constitution of an individual and consequently, play a significant role in modifying the phenotype of the individual. While the breeder may have control over certain factors of environment, others such as the weather pattern of a given location (temperature, relative humidity, rainfall distribution and amount, etc.) or combinations of any of these, are problematic because they are unpredictable. Any deviation from favourable environment will compel the plant to adopt a survival strategy by adjusting its genome to evolve genes for adaptation to the specific stress environmental condition. In the case of Nigeria, each of its agro ecosystems (Figure 1) has specific stress factor(s) to which plant breeders have developed and are still developing tolerant and/or resistant genotypes.

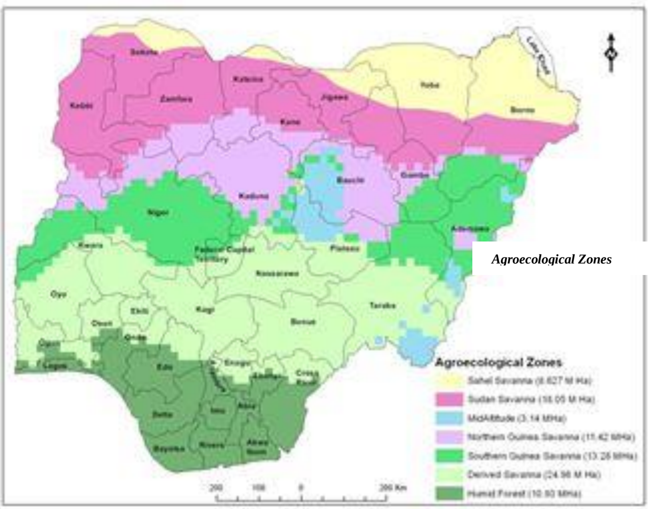

Figure 1: Map of Nigeria showing major Agroecological Zones

The outwards manifestation of the response of genotypes to prevailing environmental factors, often referred to as gene-environment interaction (G x E), is of three types (Figure 2). The first two have no direct implication on varietal development and testing. However, the third type, which is the cross-over type, usually has a confounding effect on plant breeding activities and must be clearly understood by the plant breeder in order to make progress in varietal improvement for yield and adaptation in order to ensure the survival of man. This is because genotypic performance varies from one environment (years, location) to the other. Suffice it to say that this complex has been manipulated and exploited by Plant and Animal Breeders for the overall benefit of agriculture as man must eat to survive, no matter the environment in which he finds himself.

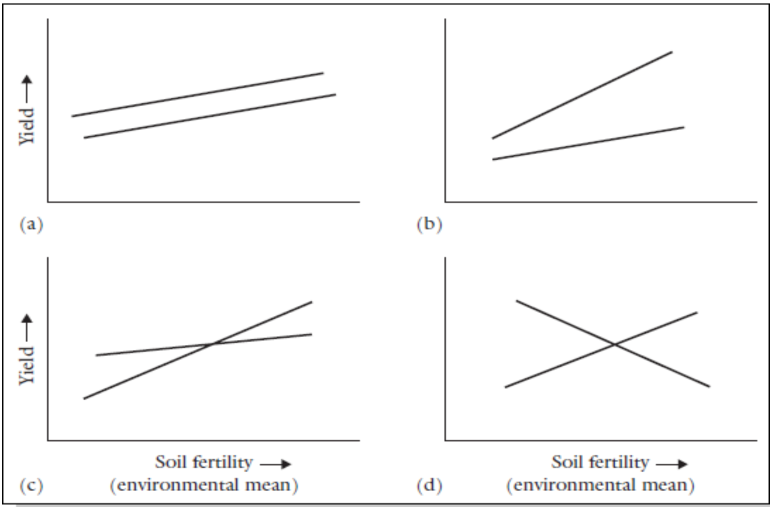

Figure2: Graphical presentation of (a) genotype× environment (G× E) interactions, (b) heterogeneity, (c) crossover interactions, and (d) combined interactions.

The Journey So Far

Mr. Vice Chancellor sir, I became exposed to the art of plant breeding early in life as a young technician at the Maize Breeding Unit of the Federal Department of Agricultural Research (FDAR), Ibadan {now National Cereals Research

Institute, (NCRI) Badeggi}. At that time, it was intriguing to observe offsprings of maize with small cobs bringing out big cobs each time we dust pollen grains from a maize plant with big cob on it or that of a diseased plant bringing out offsprings that are healthy when pollen grains from a healthy plant is dusted on its silk. This influenced my picking a project topic on Plant Breeding in my final year at the Department of Plant Science, University of Ife (now Obafemi Awolowo University). Of course, I later went further to obtain a Masters of Philosophy (M. Phil) Degree in the same University. Even when I had the opportunity for my Doctor of Philosophy (Ph.D) Degree at the University of Minnesota, (USA), my desire and inclinations remained with plant breeding, striving to improve plants for the benefit of the society and humanity. Therefore, this inaugural lecture which is titled "***Plant Breeding for Survival of Mankind"***, would give an account of my stewardship as a devout researcher in sugarcane and maize improvement and as a teacher and instrument of change in the lives of the resource-limited farmers in different parts of Nigeria. All through my work, advancing the course of humanity and society has been my motivation. This is to ensure that these crops survive and are able to produce well in any environment in order to make adequate food available for the survival of man.

Initial Research Activities in Sugarcane

(i) Basic information necessary for sugarcane varietal improvement

At the inception of my work as a Research Fellow (Sugarcane Breeder) at the Unilorin Sugar Research Institute (USRI), there was paucity of information on virtually all aspects of sugarcane improvement. Not much was documented in the country regarding its flowering and breeding behaviour, fertility status, compatibility in crosses and extent of relationship among the available genetic resources that could be utilized to maximize heterosis required for sugarcane varietal development. We also had challenges ascertaining profitability of cane cultivation (i.e. ratooning ability), appropriate medium for fuzz (true sugarcane seeds) germination and growth, as well as mechanisms of adaptation to different environmental conditions (low soil nutrient and moisture deficit) peculiar to the sugarcane growing ecologies of the southern guinea savanna (SGS). Consequently, our initial research activities at the USRI drew considerably from the knowledge acquired from previous research activities on sugarcane at NCRI. It was indeed encouraging that attributes that determine sugar yields (cane yield and sucrose content) were substantially covered by **Olaoye** and Agbana, (1987 & 1988) and **Olaoye** and Fatunla, (1991 & 1992). These reports and information on yield potential and breeding values of local sugarcane genetic resources (**Olaoye**, 1995a; 1995b) were very useful in the selection index adopted in the identification of superior progenies from the hybridization programme that hastened the process for use of varietal development in sugarcane (Table 1).

Table 1: List of parameters that exhibit positive association with yield and quality in sugarcane (*Saccharum officinarum* L.)

S/N	Trait	Associated characters
1.	Cane yield	Field establishment; stalks/stool; stalk diameter; stalk length; internodes/stalk; length of longest internode; millable cane population; fast regrowth following ratooning.
2.	Sucrose content	^{o}Brix; top weight; leaf area; number of green leaves/plant.
3.	Sugar yields	Kg-brix; %Polarity; % Purity; Brix spindle; Ton sucrose/Ton cane.

Source: Olaoye, 1987; Olaoye and Agbana (1987 & 1988); Olaoye and Fatunla (1991 & 1992); Olaoye, (1995 a & b).

(ii) Protocol for sugarcane fuzz (seed) germination

Sugarcane fuzz are usually germinated in vermiculite which is a specialized medium that enhances optimum germination and also facilitates transplanting from the seed trays either into polybags or directly to the field with minimal damage to the tender roots. In most cases, vermiculite is not available. We initiated the use of top soil in the Institute as a medium for germinating fuzz. However, we noted that raising fuzz in top soil alone required frequent watering (twice daily) to maintain adequate moisture level. Furthermore, extensive root damage could result in loss of seedlings during transplanting. Consequently, we needed to establish an appropriate medium for sugarcane fuzz. We evaluated a combination of four growth media (**Olaoye** and Adams, 1996) – top soil (TS), sawdust (SD), filter mud (FM) and bagasse (BS) which are byproducts of sugarcane milling, as growth media to germinate and nurture fuzz from three sugarcane cultivars Co 1001, CP 29/116 and Q70. Growth medium comprising of TS/BS/FM consistently enhanced cultivar performance either in terms of seedling growth or other morphological characteristics as well as extensive root formation (Table 2). This combination has since become the established protocol for raising fuzz in the Institute.

Table 2: Effects of growth media on morphological characteristics of three sugarcane cultivars.

Growth Medium	Seedling height (cm) 5WAP	6WAP	7WAP	8WAP	No. of green leaves	Leaf width (cm)	Leaf length (cm)	Top fresh weight (g)	Root fresh weight (g)
TS	7.75	11.42	15.54	18.7	9	0.59	8.46	5.31	2.72
TS/SD	1.18	1.52	2.15	2.88	5	0.48	5.33	0.37	0.14
TS/SD/BS	3.62	5.36	7.43	10.7	7	0.60	6.60	4.99	2.33
TS/SD/BS/FM	3.45	4.95	7.49	11.3	9	0.98	9.00	4.74	2.23
TS/SD/FM	5.18	7.17	10.66	13.5	9	0.76	8.67	8.86	4.07
TS/BS/FM	8.16	16.17	26.0	29.9	12	2.15	12.30	12.14	5.51
LSDα 0.05	ns	2.20	3.51	3.40	ns	ns	9.53	0.33	0.17

TS = Top soil; SD = Saw dust; BS = Bagasse; FM = Filter mud

Source: Olaoye & Adams (1996).

(iii) Study of flowering behaviour in sugarcane

Utilizing parents in planned crosses depends upon knowledge of their flowering behaviour (flowering or non-flowering), fertility status (male or female) and compatibility in crosses. The study conducted by **Olaoye** (1996a), elucidated the nature of the male sterile systems in flowering varieties. These include (i) production of defective pollen grains (Plate 1), (ii) failure of anther to dehisce due to structural sterility, and (iii) self-incompatibility (Table 3). Based on days to arrow (sugarcane flower) emergence, all existing flowering genotypes were classified as either early, mid or late flowering. A related study by **Olaoye** (1996b) further established the relationship between flowering period and pollen fertility under natural conditions which paved way for the development of breeding scheme for sugarcane under natural conditions (i.e. outside the glasshouse condition).

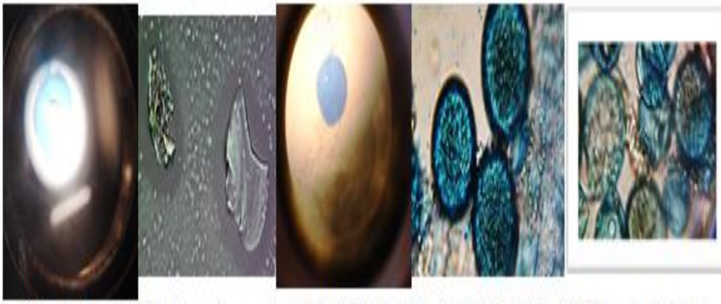

Plate 1: Infertile/defective pollen grains in B6604, B78679 and DB95/57 (1st and 2nd from left); fertile pollen grain in BJ82112 (middle); sulcate viable pollen grains in USRI08/03, USRI 08/43 and Co 6806 (4th from left) and colpate viable pollen grains in USRI08/63, USRI08/68, USRI08/80 (extreme right).

Table 3: Flowering behaviour, pollen shed, pollen viability and seed set in selected flowering sugarcane clones under natural conditions (Ilorin, Nigeria).

	Flowering		Pollen production				
Clone	Behaviour	Period+	Pollen shed	Total count	No. viable	% viability	Seed set/0.5g fuzz
B6604	Profuse	L(345)	6	235	4	1.7	0
B69620	Profuse	L(324)	7	806	67	7.7	10
BR6223	Profuse	M(277)	6	84	56	66.7	69
Co395	Shy	E(274)	7	698	9	1.3	37
Co404	Profuse	M(295)	8	454	0	0.0	0
Co440	Shy	L(318)	0.7	701	494	70.5	20
Co453	Profuse	E(257)	8	395	210	53.2	17
Co1001	Profuse	M(296)	7	769	252	32.8	15
Co6304	Shy	M(285)	3	90	36	40.0	32
CP29/116+	Profuse	E(260)	0	866	243	28.1	0
DB95/57	Shy	L(364)	0.3	970	13	1.3	0
IAC48/65++	Profuse	M(291)	8	547	377	68.9	5
LSI-047	Profuse	E(265)	1.7	1033	5	0.5	2
LSI-050	Profuse	L(308)	6	125	90	72.0	21
Q70+	Profuse	E(260)	0	1308	273	20.9	0
USRI85/30	Profuse	E(258)	6	450	207	46.0	33
USRI85/39	Shy	M(254)	8	50	3	6.0	8
S. spontaneum	Shy	E(263)	9	74	61	82.4	63

E = Early flowering; M= Mid-flowering; L= Late flowering. + = Structural sterility; ++ = Self Incompatibil +; figures in parenthesis is days from planting to first arrow emergence. Source: (Olaoye, 1996a).

(iv) Breeding Scheme for Varietal Development in Sugarcane

Hybridization in sugarcane is usually carried out in specially constructed glasshouses in order to avoid contamination from unwanted pollen source. The male and female flowering stalks are cut and brought to the glasshouse, with the cut ends immersed in a preservative solution to keep them alive during crossing. Such a facility was lacking in the Institute hence we fashioned out a breeding scheme (*Modified Polycross Mating System*) in 1997, to evolve superior genotypes to replace existing and unproductive varieties. It entails sandwiching male sterile clones (as females) among the male fertile genotypes (as males) on the field (Figure 3). With this scheme, each of the female clones whose flowering periods were synchronized (based on period of flowering) in a crossing block, received bulk pollen from all available male clones of the same flowering period and the resultant progenies are similar to the regular melting pot of the Hawaiian breeding scheme. Testing the efficiency of the breeding scheme showed that it was as good as the Hawaiian polycross mating scheme (**Olaoye** and Ogundipe, 1997; **Olaoye,** 2001). It was heartwarming to note that progenies emanating from the breeding scheme were superior to the existing commercial varieties during subsequent evaluations in plant cane, first and second ratoon crops (**Olaoye** *et al*., 2010; 2011; Atanda, **Olaoye** and Amuda, 2015).

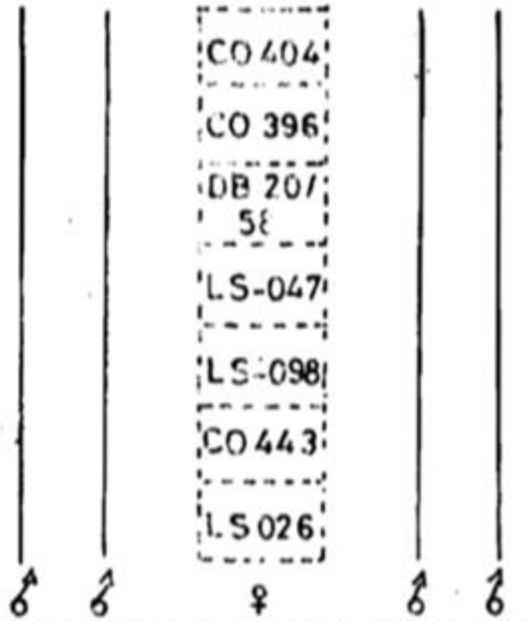

Figure 3: Outline of the breeding plan showing the mating scheme between selected male clones as pollinator rows to the identified female clones.

In 2010, the Institute in conjunction with other colleagues within and outside the University (Josepdam Sugar Company Bacita and Usmanu Danfodiyo University, Sokoto), won a research grant under the aegis of the Competitive Agricultural Research Grants Scheme (CGARS) of the Agricultural Research Council of Nigeria (ARCN), Abuja to conduct research into the development of sugarcane varieties for high sugar and ethanol content. Part of the activities under this project was the evaluation of the progenies generated from the modified polycross breeding scheme across diverse sugarcane growing ecologies of Nigeria's guinea savannas (NGS). Using progenies from this scheme, (**Olaoye** *et al*., 2014) we were able to identify three progenies that were superior to the existing commercial sugarcane varieties for sugar yield as well as those that could be used for high ethanol content (Table 4). This result broadens the scope of mounting separate breeding programmes with respect to sugar and alcohol contents.

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Table 4: cane yield attributes and ethanol contents in 10 sugarcane progenies and standard varieties (Ilorin, 2012).

Genotype	Single stalk weight (kg)	°Brix	Cane yield (t/ha)	∑Rank (cane + °Brix)	Ethanol content (%)	Kinetic viscosity of the slurry (cm^3/s) at 27°C
USRI08/03	0.70	20.3(5)	68.9(3)	8	15	6.1
USRI08/16	0.50	19.6(14)	58.4(10)	24	10	5.4
USRI08/43	0.60	20.1(6)	58.6(9)	15	8	1.1
USRI08/46	0.83	20.4(2)	67.5(4)	6	5	1.2
USRI08/58	0.80	20.0(7)	56.1(12)	19	5	4.5
USRI08/63	0.70	20.0(8)	71.6(1)	9	10	1.0
USRI08/68	0.77	19.7(11)	62.8(6)	17	10	8.5
USRI08/80	0.67	20.4(13)	62.5(7)	10	5	5.3
USRI08/85	0.33	19.7(12)	55.4(13)	25	8	2.5
USRI08/87	0.40	19.9(10)	63.0(5)	15	8	2.3
Co 8606	0.97	20.4(4)	71.0(2)	6	----	---
Co 957	0.47	20.9(1)	57.6(11)	12	26	6.1ᵻ
ILS-001	0.50	19.7(13)	54.4(14)	27	51	2.1ᵻ
ILS-002	0.50	19.6(15)	60.4(8)	23	46	5.0ᵻ
Local Check	0.40	20.0(9)	8.14(15)	24	---	---
Mean	0.61	20.1	61.09			
SD	0.269	0.69	9.24			

ᵻ Values determined in 2011 immediately after harvest. 2012 values were determined long after flowering.

Source: Olaoye et al., (2014).

Drought stress and crop productivity

Water plays a crucial role as solvent, transport medium and evaporative coolant as well as providing the energy necessary to drive photosynthesis. However, soil moisture deficit continues to be one of the most significant environmental stress factors because of continuous decrease in soil moisture content occasioned by irregular rainfall pattern and increase in global temperature (Graham and Vance, 2003). Consequently, drought is one of the major factors militating against crop productivity especially in drought-prone ecologies. It therefore becomes necessary for Plant Breeders to find and incorporate drought tolerant genes into existing germplasm in order to build prosperity in our ever changing world.

Sugarcane Breeding for Drought Tolerance Capacity

The wish of every Plant Breeder is to carry out crop improvement activities under favourable environmental conditions. Empirical evidence has however shown that no single environment possesses all the attributes necessary for the survival of crop species. This was my experience upon assumption of duty in the USRI in 1990. Indeed, the SGS ecology where USRI is located is endowed with abiotic stress factors (drought, fragile soil with low water holding capacity and poor nutritional status) to which any crop must possess adaptive genes in order to survive and be productive. The USRI progenies which were undergoing yield evaluation at the time I assumed duty included genotypes that combined high yield potential with drought tolerant features. Thus, contrary to the basic plant breeding theory and empirical data which support genotypic selection in favourable environments, two of the USRI progenies from the initial breeding programme (USRI 85/46 and USRI 86/04) exhibited high yield potential in multilocational trials across sugarcane growing ecologies of the Nigeria's savannas (Table 5) and were eventually registered and released as Ilorin Sugarcane -ILS-001 and ILS-002 (Plate 2), along with two other varieties from NCRI thereby becoming the first four indigenous sugarcane varieties to be released for cultivation in Nigeria.

Table 5: Average cane yield and sucrose content of first set of indigenous sugarcane varieties in sugarcane growing ecologies of Nigeria.

Genotype	Ilorin Cane yield (t/ha⁻¹)	Ilorin Sucrose content	Bacita Cane yield (t/ha⁻¹)	Bacita Sucrose content	Badeggi Cane yield (t/ha⁻¹)	Badeggi Sucrose content	Numan Cane yield (t/ha⁻¹)	Numan Sucrose content
USRI 85/31	11.81	20.8	60.10	N/A	38.78	16.22	57.75	18.6
USRI 85/46	12.77	20.9	42.18	N/A	60.73	17.7	33.27	18.7
USRI 86/04	17.31	19.7	51.24	N/A	57.84	16.7	76.40	17.9
BD 83/04	10.54	20.0	44.78	N/A	41.51	16.8	42.89	17.2
BD 83/019	12.34	19.2	54.06	N/A	74.13	17.1	51.23	16.9
BD 83/025	12.18	18.2	50.29	N/A	60.27	15.3	39.82	14.2
Check	15.98	20.8	47.69	----	55.74	16.8	85.93	18.6

+; Mean of Plant and two ratoon crops; ++; Mean of Plant crop; N/A; Figure not available
Source: Olaoye (1999).

Plate 2: Drought tolerant sugarcane varieties with high cane yield and sucrose content developed at the Unilorin Sugar Research Institute (USRI)

Search for parental genotypes for developing drought tolerant sugarcane varieties

The local sugarcane farmers who serve as out-growers to the sugar plantations lacked facilities for supplemental irrigation to supply moisture during the long dry spell (5-7 months) and so depend on natural rainfall to grow their canes. This necessitated the search for genes that could be incorporated into existing cultivars in order to develop sugarcane varieties with features that enhance crop productivity under conditions of low available soil moisture. Data from earlier studies on inheritance of characters that determine sugar yields in moisture stress and non-moisture stress environments (**Olaoye,** 1987; 1999) revealed that progress in breeding of productive sugarcane genotypes for cultivation under strict upland conditions was achievable through selection under upland conditions (Table 6). Another long term study which evaluated 48 foreign and local sugarcane accessions under upland conditions at the USRI Research farm (**Olaoye,** 2005; 2006), revealed that heritabilities of yield and related traits under such conditions ranged from high to moderate and were comparable with values obtained under non-moisture deficit condition (Table 6). These studies showed that progress could be made from selection for cane yield and related traits as well as ratooning ability under upland conditions. They also identified suitable varieties for cultivation under low soil moisture regime typical of the savanna ecologies of Nigeria.

Table 6: Broadsense heritability (H^2B) estimates (with standard errors) for cane yield and related traits under different cropping situations in Nigeria

Trait	Moisture deficit	Non-moisture deficit	+Long term experiment	+Ratooning ability Method I	Method II
Cane yield	0.51±0.20	0.65±0.19	0.51 ±0.20	0.76±0.21	0.64±0.21
Sucrose content	0.12±0.5	a	0.12±0.23	0.82±0.21	0.64±0.22
Stalks/Stool	0.25±0.25	0.47±0.23	0.25±0.25	a	0.67 ±0.27
Stalk length	A	0.78±0.02	0.39±0.21	a	a
Stalk diameter	0.39±0.21	0.33±0.24	a	0.63 ±0.22	0.53±0.22
Millables canes	-	-	0.61±0.21	0.57±0.22	0.64 ±0.21
Kg-Brix	-	-	0.66 ±0.17	0.41±0.23	0.56 ±0.22

Source: Olaoye (1987; 1999; 2005 & 2006); a = negative variance estimates due to negative/zero variance components. Method 1= Formula proposed by Milligan et al, (1996). Method II is a generalized formula based on annual yield of plant cane and first ratoon crop as the reference yield + = Four cropping cycles.

Additional screening of sugarcane germplasm accessions under well-watered and moisture stress imposed by withdrawing water for 10 weeks at the vegetative stage of growth (10 weeks after emergence) in the screenhouse (Ishaq, **Olaoye** and Akinsanya, 2008) identified drought tolerant (DT) varieties (for example

KD-01, USRI 24, Bida Local & F141) which remained relatively unaffected throughout the period of induced moisture stress and could therefore serve as parents for transferring DT genes into future varieties.

Further studies (Ishaq & **Olaoye**, 2006; 2008; 2009) which evaluated progenies derived from bi-parental crosses – KD-01 x F141 (drought resistant x drought resistant), KD-01 x Co331 (drought resistant x drought susceptible), Co453 x F141 (drought susceptible x drought resistant) and Co453 x Co331 (drought susceptible x drought susceptible) under well-watered and moisture deficit conditions for two years (Table 7) showed that:

- Estimates of additive genetic variance (δ^2A) were larger in magnitude than dominance genetic variance (δ^2D) for almost all the traits investigated.
- Progenies derived from DT parents (KD-01 x F141 and Co453 x F141) exhibited significant mid-parent (MP) heterotic effects for higher sugar yields (commercial cane sugar) and cane yield than either parents under moderate drought stress confirming the presence of non-additive gene action for the traits in the population. These progenies had higher cane yield than progenies derived from other crosses as well as higher sugar yields (commercial cane sugar) than either parents.

Indeed, four (4) of the 10 sugarcane varieties currently undergoing pre-release evaluation across sugarcane growing ecologies in Nigeria are from these populations.

Table 7: Cane yield (kg/plot), heterosis (%) and narrow sense heritability for cane yield and related traits in sugarcane bi-parental crosses under well-watered and moisture deficit condition.

	Well-Watered (202)		+Moisture deficit (2002 &2003)		%Heterosis (Moisture deficit)			
	Cane yield		Cane yield		Cane yield		°Brix	
Parents		°Brix		°Brix	Mid-Parent	Better Parent	Mid-Parent	Better Parent
Females								
KD-01 (DS)	15.60	19.43	13.23	16.53				
Co453 (DS)	13.70	16.87	10.78	17.26				
Males								
Co331 (DT)	13.00	16.43	13.62	17.08				
F141 (DT)	15.47	17.33	17.62	18.33				
*Crosses								
KD-01 X F141	15.00	16.11	15.89	16.83	12.34	-9.34	-3.20	-5.51
KD-01 X Co331	10.00	16.68	13.34	16.97	14.78	10.14	-1.07	-3.65
Co453 X F141	11.91	17.12	13.82	17.41	8.05	-17.95	-1.27	-9.86
Co453 x Co331	10.92	18.08	9.47	17.03	-16.27	-25.11	-6.64	-3.39
LSD@0.05	ns	ns	3.87	ns				
Narrow sense heritability (Moisture deficit)								
Cane yield	0.60+0.027							
Brix	0.16+0.0							
Purity (%)	0.45+0.08							
Polarity(%)	0.33+0.01							
Fibre (%)	0.06+0.							
Dry Matter (%)	0.36+0.00							
Commercial cane sugar (%)	0.39+0.027							

+; Data combined over plant and first ratoon crops; *; First parent in a cross is female, DT= Drought tolerant; DS= Drought susceptible. *Source: Ishaq & Olaoye (2006; 2008, 2009)*

Maize Breeding for Stress Tolerance Capacity in Nigeria

The need to extend maize cultivation to Nigeria's guinea savannas (NGS) where crops such as guinea corn and sorghum were the main cereal crops and for late maize production in the south eastern (SE) Nigeria, culminated in the search for genes for tolerance to *striga* and nitrogen use efficiency (NGS) as well as stem borer (SE Nigeria). It is important to mention here that the achievements made in the development of maize genotypes which have the capacity to combine high yield with stress tolerance cannot be adequately discussed without due reference and acknowledgement of the pioneering works of maize scientists at the IITA, Ibadan. They include Drs. S. K. Kim (Striga and Downy mildew disease), J. M. Fajemisin (Downy mildew and other leaf diseases), J. G. Kling (Striga and Low-N), A. Menkir (Drought stress and Striga), S. O. Ajala (Stem borer/Low-N) and B. Badu-Apraku (Drought escape/tolerance and Striga). These activities along with those of colleagues based in CIMMYT, Mexico provided information on the genetic mechanism underlying the inheritance of tolerance/resistance to the stress factors as well as the traits that are used as index of selection. Through collaboration with scientists at the Institute of Agricultural Research (IAR), Zaria, Institute of Agricultural Research and Training (IAR&T), Ibadan and relevant Faculties of Agriculture in Universities including University of Ilorin, many varieties with capacity to exhibit their yield potentials were developed, tested and released for cultivation and commercialization. Again, Plant Breeders have come to rescue mankind from hunger and lack that could have resulted if these crops were allowed to grow and produce based on the dictates of their environments.

Drought tolerance in Maize

Empirical evidence has shown that soil moisture deficit especially if it occurs during the reproductive phase do result in drastic yield reduction in maize grain yield with an estimated yield loss of more than 15% of well-watered condition in susceptible varieties (Basseti and Westgate, 1993; 1994). Mid-season drought with its adverse consequence on crop growth (Plate 3) and productivity is one of the peculiarities of the SGS agro-ecology. Therefore development of DT maize varieties was critical for this zone that is drought-prone with its characteristic erratic rainfall and soils with poor water holding capacity in order to stabilize maize yields.

Plate 3: Morphological attributes of maize varieties during a prolonged drought-stress (43days) at the T&R Farm, University of Ilorin in 2013. The susceptible variety already showed signs of temporary wilting as early as 9.30am.

Although major research on drought tolerance occurred in IITA, modest activities were also conducted at University of Ilorin. For example, **Olaoye** (2009), screened four maize populations and their reciprocals which were derived by intercrossing two DT inbred parents (DT-S_3-W & DT-S3-Y) obtained from the IITA, Ibadan and two adapted open pollinated varieties (OPVs) of maize (DMR-LSR-Y & AFO-W) under soil moisture deficit imposed at vegetative, pre- and post-anthesis phase compared with well-watered condition for two weeks. Findings from the study showed that although grain yield under full irrigation was superior to pre and post-anthesis by 66 and 33%, crosses involving AFO-W (local variety) and the DT-inbred parents exhibited better heterosis for grain yield than crosses involving DMR-LSR-Y.

In a related study which used a combination of screening methods including moisture withdrawal at specific growth stages and field screening using sequential planting dates beginning from April to August over a three-year period, post-anthesis moisture deficit significantly reduced grain yield by 25-73.5% (OPVs) and 20-64% (hybrids) under screenhouse condition. Under field conditions, grain yield ranged from 2.48-4.26 tons/ha (full-growing season) and 2.03-2.5 ton/ha (late season) with hybrids as a group showing superiority for grain yield over OPVS under moisture deficit condition either in the screen house studies or field conditions (**Olaoye** *et al*., 2009c).

Another study (**Olaoye** *et al*., 2009b) evaluated 14 local maize varieties collected from different parts of Burkina Faso, under well-watered and soil moisture deficit conditions imposed prior to anthesis, for two years (1999 & 2000) at the Ikenne sub-station of the IITA. The study identified three local varieties (Bondokuy-1, Dogona-1 and Douana-1) with comparable or higher grain yields than the hybrid check (Oba Super) under well-watered and moisture deficit, which could serve as potential major sources of alleles for developing high yielding varieties targeted towards drought-prone ecologies in WCA.

Striga Research

The parasitic plant *Striga species* (Plate 4) is a weed of economic importance with different strains that parasitize specific crops. Yield loss due to *striga* infestation especially in maize fields has been put at more than 70 percent of maize yields in *striga* free-environments and many farmers have either abandoned *striga*-infested fields or adopted cultivating non-susceptible host crops. The severity of the effects depends on many factors, such as nitrogen availability and host genotype (tolerance), *Striga* species and ecotype (determining virulence), as well as infection time and level (Gurney *et al.*, 2006).

Plate 4: Flowering striga plants in a farmer's field in Bauchi State (left) and striga infested maize plot at Mokwa in Niger State (right)

Research into the development of *striga* tolerant (STR) maize varieties was actually pioneered by maize scientist at IITA (Kim *et al*., 1986; Kim, 1991; Efron, 1993; Kim & Adetimirin, 1997). These research efforts have resulted in the development and release of several STR maize varieties (OPVs and hybrids). However, another *striga species* with debilitating effects on maize production in the derived savanna is *S. lutea*. Consequently, studies were initiated in collaboration with the IAR&T, Ibadan to elicit information on control methods and nature of inheritance of resistance to the *species* (Olakojo and **Olaoye**, 2003; 2004; 2006; 2007; 2011). Findings showed that:

- Hybrids were superior to their inbred parents by 27% reduction in *striga* emergence count and a corresponding >124% yield advantage, indicating a promising future for the development of *striga lutea* resistant maize varieties (open pollinated and hybrids) for the *S. lutea* endemic ecologies of the SW Nigeria.
- Four inbred parents were also found to possess good sources of genes for higher grain yield which could be used to produce hybrids for cultivation in *S. lutea* endemic zone of the Southern Guinea savanna zone (SGSZ) or for extraction of *S. lutea* tolerant inbreds.

Stem Borer Research

Stem borers *(Lepidopterous species)* are among the most important insect pests of maize in Africa. Two of the four borer species -*Sesamia calamisti* and *Eldana sacahrina* reduce maize yields in the lowland of West and Central Africa. Almost all plant parts - leaves, stems, tassels and ears are attacked (Plate 5) and crop losses may result from death of the growing point (dead hearts), early leaf senescence, reduced translocation, lodging and direct damage to the ears. Available information from various studies have shown that severity and yield losses (10 -100%) depend upon borer species, the plant growth stage, number of larvae feeding on the plant, and plant's reaction to borer feeding.

Plate 5: Symptoms of infestation of African maize stalk borer on maize stem and leaves (left); stalk borer (app.8mm) feeding inside the maize stem, with brown frass deposit (middle) and maize cobs damaged by Buseola fusca (right). (Source: Anne Bruntse, Bio vision, 2011.

Studies conducted in Nigeria and elsewhere (Ajala, 1993; Schulthess & Ajala, 1999; Ajala *et al*., 2002; Ajala, Odiyi, Thé and **Olaoye**, 2008; Ajala, Aroga, Odiyi and **Olaoye**, 2009), have shown preponderance of additive gene action in the control of stem borer such that breeding approaches such as half-sib, S_1 or S_1 testcross selection that utilize gene action can be effectively used to develop varieties with better levels of resistance.

Deployment of Stress Tolerance Genes for Enhanced Maize Productivity

The ultimate outcome of plant breeding is mainly improved cultivars which are expected to be released for cultivation by the end users. In the early years of varietal development in Nigeria (and probably elsewhere), the job of the Plant Breeder terminates with the development of improved varieties which were then handed over to Extension Specialists for testing in farmers' fields prior to release. However, many of these varieties were never really adopted by the end users probably because they failed to fit into the farmers' cropping systems or lack other attributes which farmers and/or their households desired. However, the practice of plant breeding has evolved into a multidisciplinary approach where plant breeders now work in conjunction with specialists in Agricultural Extension and Agricultural Economics to test newly developed varieties on farmers' fields. This is referred to as *Participatory Plant Breeding* (PBB) or *Participatory Variety Selection* (PVS) in which scientists work with farmers in selection of their preferred varieties (Ceccarelli, 2012). These approaches have been used to identify superior crop genotypes with farmer-preferred attributes elsewhere (Sthapit *et al*., 1996; Witcombe *et al*., 1999) and in Nigeria (**Olaoye** *et al*., 2009a). Few of the PVS activities on the deployment of stress tolerant varieties in which University of Ilorin has been privileged to participate, will be highlighted here.

African Maize Stress (AMS) Project

The *Lepidopterous* stem borer is a late season maize production constraint in south eastern (SE) Nigeria and other borer endemic ecologies of Nigeria particularly Kogi and Ondo states. Yield loss due to borer infestation may be as high as 46% in high yielding environments and 58% in lower yield environments even when chemicals are used for protection. Adoption of stem borer resistant (SBR) maize varieties was therefore promoted among the farmers in Abia State (Figure 4). The project which was funded by the African Maize Stress (AMS) Project, coordinated by the WECAMAN/IITA with fund from IFAD and UNDP through the IITA, Nigeria was conducted in collaboration with the Faculty of Agriculture, University of Ilorin and the National Rice Maize Centre, Ibadan. Over 205 field demonstrations were conducted either as sole maize (early season) and/or intercropped with cassava (late season) between 2000 – 2002 and later in 2005. Highlights of the studies showed that apart from superiority for cob yield (Plate 6), plant aspect, borer damage rating, higher grain yield and higher economic returns over farmer's variety under sole cropping, the two SBR varieties (Ama TZBR-W & Eldana 3) also had a yield advantage of 39 and 68% over farmer's varieties in intercropped situation (Table 8) during the late season cropping (**Olaoye** *et al*., 2009a).

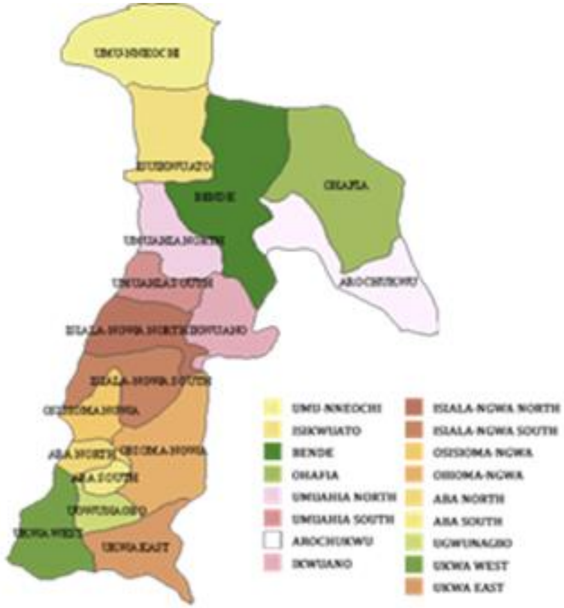

Figure 4: Map of Abia state, South Eastern Nigeria.

Plate 6: Fresh Cob characteristics in TZBR Eldana 3 (left) farmer's variety (middle) and Ama-TZBR-W in 2001 early season on-farm trials in Umuahia (Abia State, Nigeria).

Table 8: Plant, ear and yield characteristics of AMA-TZBR WCl and farmers' varieties intercropped with cassava in late growing season (Abia State, Nigeria).

Technology	Cob aspect	Stem borer rating	Overall preference	Damage (%)	Rating	Cob size Big	Cob size Small	Cumulative cob yield
Ama – TZBR W C1 + Cassava (intercrop)	4.40	4.30	4.45	34.45	2.48	31.30	10.61	41.91
Ama – TZBR W C1 + Cassava (Relay)	4.45	4.30	4.20	38.70	2.61	35.78	12.52	48.30
Local variety + Cassava (Intercrop)	2.75	2.10	1.60	69.09	4.04	17.00	6.35	23.35
LSD α 0.05	0.43	0.40	0.38	7.79	0.40	4.35	3.10	6.28

Source: Olaoye, Ajala, Adedeji (2009).

Further activities of the AMS project which included promotion of other ST maize varieties (*striga*, drought and low-N use efficient) were conducted among resource-limited farmers in Kwara State between 2005 and 2006. In executing the project activities, the state was delineated into four agricultural zones (Figure 5) and relevant maize varieties were deployed to each zone. Three varieties -TZE Comp 3 DT Syn (drought), LNTP-W (Low-N) and TZL Comp 1 Syn-W (Striga) along with the farmers' practice (control) were promoted over the two-year period among more than 50 farmers. Each of the ST maize varieties demonstrated superiority over the farmers' variety with respect to yield parameters. The drought tolerant variety (TZE Comp 3 DT Syn) had 44 percent (%) yield advantage over farmers' variety while the low-N variety (LNTP-W) also had 26% yield advantage over farmers' variety. The highest yield advantage of 65% was however obtained in respect of striga resistant variety -TZL Comp 1 Syn-W (Table 9).

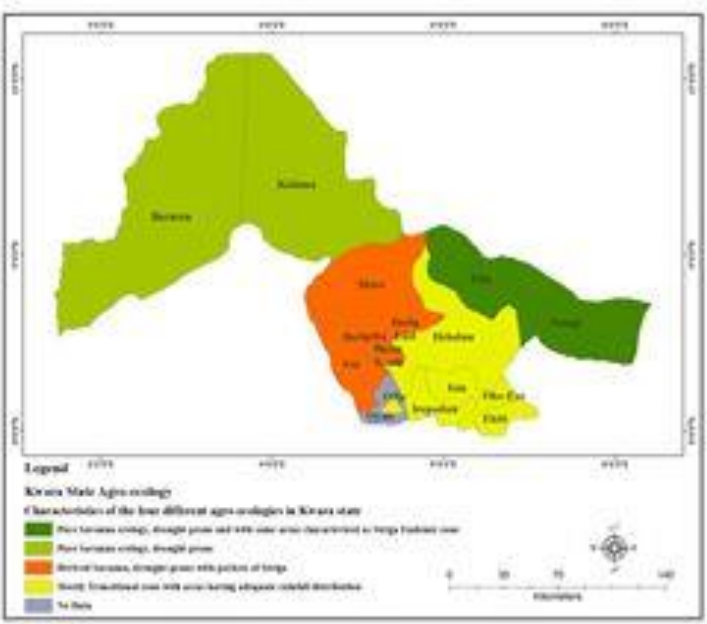

Figure 5: Map of Kwara State showing the different ecologies

Table 9: Ear number (ENO) and grain yield in stress tolerant maize variety compared to farmers' variety in Kwara State (Late season, 2006)

Variety	ENO	Grain Yield		% Gain over farmer's variety	
		Grain yield (kg/ha)	20 random cobs (kg/ plot)	Grain yield	20 random cobs/plot
	Drought tolerance				
TZE Comp 3 DT Syn	459a	2208a	6.48a	43.8	47.3
Farmer's variety	294b	1536b	4.40b		
Mean	376	1874	5.41		
SE±	54.23	3.13	0.64		
	Low-N Tolerance				
LNTP-W	314a	1896a	6.63a	26.1	42.6
Farmer's variety	253b	1504b	4.65b		
Mean	284	1704	5.64		
SE±	28.7	1.72	0.58		
	Striga tolerance				
TZL Comp 1 Syn-W	363a	2036a	6.82a	46.4	64.7
Farmer's variety	210b	1390b	4.14b		
Mean	287	1714	5.48		
SE±	34.33	3.11	0.50		

AMS project activity was later extended to all parts of SE Nigeria and parts of the Middle Belt under the Presidential Initiative on Doubling Maize Production (PIDOM) in Nigeria, funded by the Obasanjo regime between 2008 and 2010. Additional SBR maize varieties were included in the promotion exercise. The performance of the SBR varieties both in the early cropping season when the insect pest is not a problem to maize production as well as in the late season cropping followed similar trend as reported for Abia State. This activity popularized late season maize production in borer endemic ecologies of Nigeria consequent upon which four stem borer resistant maize varieties - Ama TZBR-W, TZBR Eldana 3, BR 9943 DMRSR-W and BR 9928 DMRSR-Y were registered and released for cultivation.

Plate 7: Ceremonial field day of maize stem borer adoption technology in a Catholic Seminary, Orji River, Anambra State (2008). Participating farmer (Rev. Father) displayed the cob of Ama-TZBR-W to other participants and visitors during the field trip.

Drought Tolerant Maize for Africa (DTMA) Project

The Drought Tolerant Maize for Africa (DTMA) project funded by Bill and Melinda Gates Foundation commenced in eight African countries in 2007. The project has the major goal of development and promotion of appropriate varieties for expanding and sustaining maize production in Africa. The project activities in the SGS of Nigeria which is housed in the Faculty of Agriculture, University of Ilorin, was based on research proposal which I submitted in 2007. In recognition of the multi-stress factors prevalent in the different SGS agro-ecologies (Figure 6), many of the drought tolerant (DT) maize varieties promoted among farmers also had genes for *striga* tolerance, low-N tolerance and endosperm quality attributes referred to as quality protein maize (QPM) varieties.

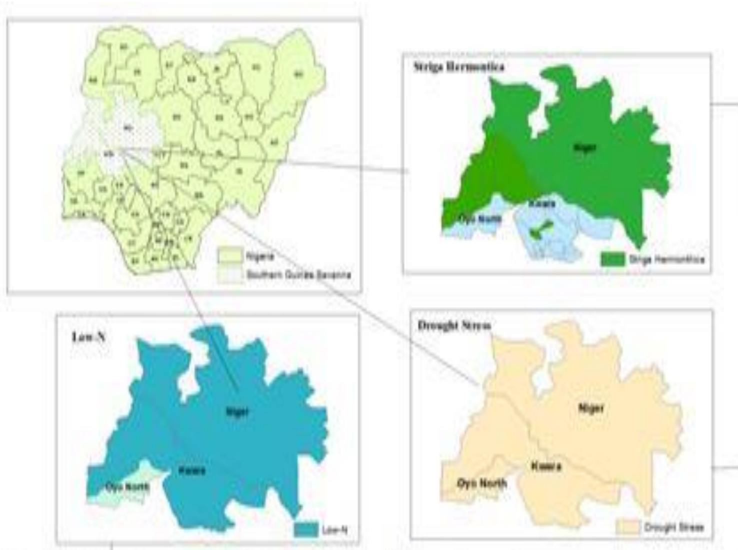

Figure 6: Major biotic and abiotic yield limiting factors in the southern guinea savannas.

Over 200 DT maize varieties (OPVs and Hybrids) of different maturity groups (extra-early, early, medium and late) have been tested in multilocational trials between 2007 and 2015 in different ecologies of the SGS while more than 50 varieties identified from these trials have been tested in farmers' fields between 2008 and 2015, using complementary crop management practices (intercrop/relay) that are compatible with farmers' cropping systems. Two features of the DTMA technology promotion are

- Field days – provide opportunities for participating and non-participating farmers to rate improved varieties/technology with their own practice (Plates 8 & 9) and
- Community Based Seed (CBS) Production Scheme - farmers are organized into groups and exposed to the techniques of producing good quality and unadulterated seeds of their preferred varieties (Plate 10). The CBS ensured availability

of improved seeds of farmer-preferred varieties at affordable price and led to the emergence of 'Farmer groups' are being linked with Seed Companies to ensure the take-up of seeds produced and sustainability of the project beyond its life span.

Plate 8: Female participation in DTMA activities: Left – Ranking new set of DT varieties with the assistance of a collaborating scientist (T&R Farm, Ilorin) Right: Participating female farmers during a ceremonial field day in Mokwa, Niger State.

Plate 9: District Head of Alapa Community (Kwara State) addressing members of his community during a ceremonial field day (left), a participating farmer in DTMA promotion technology at Ndagbachi Community (Niger State) addressing fellow participants on the quality of "ogi" content in two DT-maize varieties (TZE-Y DTSTR QPM CO & TZE-W POP DT STR QPM CO) during the field day in 2010 (Right).

Plate 10: Cobs of DT Maize varieties – TZE-Y DT STR QPM C_0 (left) and White DT STR SYN-W (Right) harvested from Community Based Seed Production Project (Mokwa, 2011).

Apart from other farmer-preferred attributes, findings from these studies (**Olaoye** *et al*., 2014; Gbadamosi, **Olaoye** and Akinwale, 2014) showed that majority of the DT varieties (OPVs or Hybrids) demonstrated superiority over farmers' variety ranging from >20 to 75% depending on the variety, year of evaluation or agro-ecology (Table 10).

Table 10: Comparison of grain yield in DT maize varieties and farmers' practice in On-farm trials in different farming communities in the SGS agro-ecologies (2009-2012).

Open pollinated varieties			**Hybrids**		
Variety	**Grain yield (t/ha)**	**% Superiority over farmer's variety**	**Variety**	**Grain yield (t/ha)**	**% Superiority over farmer's variety**
			Kwara State		
EVDT-Y 2008 STR C0	4.25	74.12	M1026-10	5.50	18.18
2004 TZE-W DT STR	4.50	75.56	M1026-13	5.85	23.01
2004 TZE-Y DT STR	2.50	56.04	Farmers' Variety	4.50	
Farmers' Variety	1.10		LSDα 0.05	2.96	
LSDα 0.05	2.32				

			Niger State		
2011 EVDT-W 99	5.22	50.58	M1026-10	5.15	65.53
EVDT-W 99 QPM	5.14	49.81	M1026-13	4.63	61.66
99 TZE-Y STR	5.27	51.00	Farmers' Variety	4.55	
Farmers' Variety	2.58		LSDα 0.05	2.53	
LSDα 0.05	1.09				
			Niger State		
TZE-W DT STR C4	5.01	48.45	TZEI 21 X TZEI 29	5.09	29.50
White DT STR SYN	5.02	48.75	TZEI 39 X TZEI 90	5.19	30.92
Farmers' Variety	2.58		Farmers' Variety	3.59	
LSDα 0.05	1.05		LSDα 0.05	2.18	
			Oyo North (Oyo State)		
DT-SR-W C2	5.67	27.29			
TZL Comp4 C3 DT	5.72	27.97	TZEEI 29 X TZEEI 37 X TZEEI 14	6.00	49.56
TZL Comp1-W6/DT Syn-1	4.56	9.65	TZEEI 82 X TZEEI 79 X TZEEI 95	4.80	36.94
Farmers' Variety	4.12		TZEEI 29 X TZEEI 90	5.23	42.09
LSDα 0.05	ns		Farmers' Variety	3.03	
			LSDα 0.05	1.34	
			Oyo North (Oyo State)		
			TZEEI 29 X TZEEI 137 X TZEEI 14	5.86	27.11
			Ife Hybrid 1	5.33	18.00
			Farmers' Variety	4.47	
			LSDα 0.05	1.75	

Consequent upon these, a total of 22 DT varieties (12 OPVs and 9 hybrids) many of which are also fortified with genes for Low-N, *Striga* tolerance/resistance and quality protein have been released for cultivation in the Nigeria's savannas (Table 11). Beginning from 2012, attention has being focused on greater women participation in cultivating DT varieties as well as in enhancing their capacity in utilization of DT maize products. Female farmers especially in Arandun (Kwara State) and Mokwa (Niger State) now enjoy the benefit of cultivating DT maize varieties like their male counterparts (Ayinde, Abdoulaye, **Olaoye,** and Akangbe, 2013).

Other Research Activities

(i) Community Based Agricultural Research and Development (CBARD) Project

The project which was funded by the African Development Bank (AfDB) has the goal of reducing poverty through the improvement of livelihoods and living standards of the rural poor. The agricultural component of the project was implemented in five States of Nigeria (Adamawa, Bauchi, Gombe, Kaduna, and Kwara). The maize component in Kwara state was conducted in Edu and Ifelodun Local Government Areas (LGAs) where performances of three improved open pollinated varieties (OPVs) of maize -2000 Syn EE-W STR, TZL Comp 1 STR Syn-Y1 and TZL Comp 1 STR Syn-W1 were compared with farmers' varieties over a two year period. Results (Table 12) showed that var. 2000 Syn EE-STR-W exhibited superiority for grain yield over others including farmers' variety with a yield advantage of 0.84, 1.27 and 1.69t/ha respectively at Edu LGA, and 0.14, 0.69 and 1.67t/ha respectively at Ifelodun LGA (Table 12). Consequently, var. 2000 Syn EE-STR-W (superiority of performance) and var. TZL Comp1 STR Syn Y1 (yellow grain colour) were recommended for cultivation in the state.

Table 11: Attributes of DT maize varieties released under DTMA in Nigeria (2009-2013).

Release name	Year of release	Hybrid/ OPV	Maturity Range	Suitable agro-ecologies	Grain yield	Additional traits/remarks
Sammaz 15	2008	OPV	Medium-late	Moist savannas	High	STR with good nitrogen use efficiency
Sammaz 18	2008	OPV	Early	Guinea & Sudan savanna	High	Striga tolerant
Sammaz 19	2009	OPV	Medium-late	Moist savannas	High	Striga tolerant
Sammaz 20	2009	OPV	Early	Guinea & Sudan savanna	High	Striga tolerant
Sammaz 22	2009	Hybrid	Medium-late	Moist savannas	High	3-way cross
Sammaz 23	2009	Hybrid	Medium-late	Moist savannas	High	3-way cross
Sammaz 24	2009	Hybrid	Medium-late	Moist savannas	High	Top cross
Sammaz 25	2009	Hybrid	Medium-late	Moist savannas	High	Top cross
Oba Super 7	2009	Hybrid	Medium-late	Moist savannas	High	Striga tolerant
Oba Super 9	2009	Hybrid	Medium-late	Moist savannas	High	Striga resistant
Sammaz 26	2009	OPV	Medium-late	Moist savannas	High	Striga resistant
Sammaz 27	2009	OPV	Early	Guinea & Sudan savanna	High	Striga tolerant
Sammaz 28	2009	OPV	Extra-early	Guinea & Sudan savanna	Medium	Striga tolerant
Sammaz 29	2009	OPV	Extra-early	Guinea & Sudan savanna	Medium	Striga tolerant
Sammaz 32	2011	OPV	Extra-early	Guinea & Sudan savanna	Medium	Striga tolerant, drought escaping & QPM
Sammaz 33	2011	OPV	Extra-early	Guinea & Sudan savanna	Medium	Striga tolerant, drought escaping & QPM

Sammaz 34	2011	OPV	Early	Guinea & Sudan savanna	High	Multiple cob bearing
Sammaz 35	2011	OPV	Early	Guinea & Sudan savanna	High	Striga tolerant
Sammaz 38	2011	OPV	Extra-early	Guinea & Sudan savanna	Medium	Striga resistant & QPM
Ife hybrid 5	2013	Hybrid	Extra-early	Guinea & Sudan savanna	High	Low soil nitrogen tolerant, striga resistance, single cross
Ife hybrid 6	2013	Hybrid	Extra-early	Guinea & Sudan savanna	High	Low soil nitrogen tolerant, striga resistance, single cross
Sammaz 40	2013	OPV	Late	Southern & Northern guinea savannas	Low	Striga resistant

Note: Sammaz = Code name for maize released through IAR, Samaru, Zaria. Source: Drought Tolerant Maize for Africa-Nigeria Fact Sheet 3.

Table 12: Comparison of grain yield (t/ha) of improved maize varieties and farmer's variety in mother and baby trials in two Local Government Areas (LGAs) of Kwara State (2011 & 2012)

	Mother trial					
	Edu LGA		Ifelodun LGA		+Baby trial (Pooled data)	
Variety	Grain yield	% Superiority over farmer's variety	Grain yield	% Superiority over farmer's variety	Grain yield	% Superiority over farmer's variety
TZL Comp1 STR Syn-Y	3.07	27.69	4.87	31.41	2.41	0.83
2000 Syn EE-W STR	3.91	43.22	5.00	33.20	2.71	11.81
TZL Comp1 STR Syn -W	2.64	15.91	4.31	22.51	3.38	29.29
Farmers' Variety	2.22		3.34		2.39	
Mean	2.96		4.38		2.70	

+ = *Average of 7 sites.*

(ii) West African Agricultural Productivity Project (WAAPP)

The West African Agricultural Productivity Project (WAAPP) adopts the concept of technology transfer at the village level (i.e. "Adopted Village") in which researchers and extension agents work in collaboration to provide solution to identified problems in farmers' fields. The project focuses on economic empowerment of resource poor farmers, creating job opportunities for youths as well as enhancement of food security. The Faculty of Agriculture, University of Ilorin was one of the beneficiaries of this project based on a proposal submitted in September, 2013 by a team of researchers led by me. Under the maize-based aspect of the project, two stress tolerant (ST) maize varieties –EVDT 99 STR-W and LNTP-W are currently being promoted among the farmers in seven adopted villages in Kwara State –Lajiki, Jimba-Oja, Ballah, Omupo, Arandun, Efue and Amodu. Apart from the maize-based technology, poultry and fishery production have been established in adopted secondary schools in three communities -Omupo, Jimba-Oja and Ballah (Plate 11) while Agricultural Research Outreach Centre (AROC), fully equipped with viewing equipment and relevant books, has also been established in secondary schools at Omupo and Ballah

(iii) Support for Agricultural Research Development for Strategic Crops (SARD–SC) Maize

This project is funded by the AfDB and has the objective to improve the productivity of maize-based systems and utilization across four African countries (Nigeria, Ghana, Mali and Zambia) in order to raise farmers' income and contribute to poverty reduction. The uniqueness of the project is its grass root approach referred to as the "Innovation Platform" (IP) which brings several stakeholders some of who are outside target communities together. The Faculty of Agriculture, University of Ilorin was approved as the backstopping Institution for Kwara and Oyo IP consequent upon the approval of the proposal which I submitted in 2013. The maize-based system has been promoting adoption of relevant ST maize varieties among the resource-poor farmers in two Local Government Areas of Kwara (Asa and Moro) and Oyo (Saki West and Saki east) since 2013. Two varieties- LNTP-Y, BR 9928 DMRSR were promoted in Oyo state while EVDT-W-99 STR and LNTP-W were promoted in Kwara state. Our results revealed that the improved ST maize varieties were superior to farmers' varieties by over 2.0t/ha with yield advantage of between 32.70 and 58.31% in Oyo State. In Kwara state where there was terminal drought, majority of the farmers' varieties failed while the ST varieties still had between 16 and 23% yield advantage (Table 13).

Plate 11: Cross section of resource persons and participants at Lajiki Community during pre-season planning meeting (Upper left); Broiler production by students of Omupo Grammar School (Upper right); Field of LNTP-W at Omupo (Bottom left) and Fishery production at Jimba Oja Community secondary School (bottom right).

Table 13: Comparison of grain yield (t/ha) in ST maize varieties and farmers' variety in four LGAs of Kwara and Oyo States (2014)

Variety	Grain yield	% Superiority over farmers' variety	Grain yield	% Superiority over farmers' variety
		Seed Drop (Oyo State)		
	Saki West		Saki East	
BR9928 DMRSR-Y	6.81	39.21	5.73	36.47
LNTP-Y	6.71	38.30	5.41	32.72
Farmers' variety	4.14		3.64	
LSDα 0.05	ns			
		On-farm trials (Oyo State)		
BR9928 DMRSR-Y	4.30	51.86	4.39	58.31
Farmers' variety	2.07		1.83	
LSDα 0.05	ns			
		On farm trials (Kwara State)		
	Asa LGA		Moro LGA	
LNTP-W	4.29	19.81	4.53	22.96
EVDT-W 99 STR	4.39	21.64	4.16	16.11
Farmers' variety	3.44		3.49	
LSDα 0.05				

Community Service

Restructuring of Courses in Plant Breeding and Introduction of New Ones

The contents of the Introductory course on Genetics and Breeding at the Undergraduate level in the Faculty of Agriculture, University of Ilorin, at the time I got involved in lecturing in 1992 was loaded with several topics which could not be covered in a semester. In addition, majority of the students admitted into the B. Agric. programme had vague ideas of chromosome behaviour while the contents relating to plant genetics could hardly be covered effectively. Consequently, final year students in my Department avoided offering the plant breeding course or offered it because their project supervisors (Awopetu/Oluleye/Olaoye) are Plant Breeders. Working in conjunction with Professor Ayorinde of Animal Production Department, the plant aspect of the course was fashioned out as a separate course. This has yielded the dividend of having many of our graduates returning to pursue their careers (M. Sc., Ph D) in Plant Breeding. At the Postgraduate level, the existing course in plant breeding has also been properly restructured and additional courses mounted to give Plant Breeding students a strong background in both the qualitative and quantitative aspects of plant breeding. These courses also satisfy the requirements of the minimum benchmark for Postgraduate programmes up to Doctoral level in plant breeding.

Apart from several Undergraduate Students' Projects, I have also supervised many Postgraduate students either at the M. Sc. or Ph. D level and currently supervising more than 10 M. Sc. and five (5) Ph. D students.

Conclusion

Man requires food everyday but its production has become a big challenge especially due to the dictates and influence of the environment. Changes in the factors of environment have continued to impact negatively on crop growth, survival and productivity. The impact of these constant changes is often felt more by millions of resource-poor rural dwellers in the sub-Saharan Africa, whose main source of livelihood depends directly on agricultural activities. One principal solution provider is the Plant Breeder. However, for Plant breeders to remain relevant in an agrarian society such as ours and to ensure survival of mankind worldwide, newer and more productive varieties must be made available for cultivation in relevant target ecologies. There is no doubt that achieving this objective requires commitments from government and the private sector in funding plant breeding activities, which include qualitative training programmes especially for emerging plant breeders and geneticists.

The Way Forward

(i) Need for improved funding of Basic Research into high yielding and adaptable crops

Breakthroughs in research can only be achieved through adequate funding of basic research. Recognizing this fact, Governments in developed countries either solely or on conjunction with the Private Sector and non-governmental organizations (NGOs), have continued to fund research in areas that pose challenges to their developmental capacities or breaking new grounds. The situation is different in Nigeria where Universities and/or Research Institutes are not adequately funded to carry out meaningful research. It is pertinent to mention that external bodies rarely fund basic research since they fall within the domain of activities that should be funded by the home government. Private companies on the other hand who are the beneficiaries of research findings prefer to support short term activities that bring quick returns rather than long term research which create new products and break new frontiers of knowledge. Consequently, governments at Federal and State levels need to do more in funding basic research in their respective institutions (Universities, Polytechnics and Research Institutes) in order to enhance the capacity of new graduates to effectively compete with their colleagues both nationally and internationally.

(ii) Need for greater collaboration between Research Institutes and Relevant Faculties in Nigerian Universities

Multidisciplinary approach to conducting research especially when it involves collaboration among researchers across institutions (International, National and Universities) has been credited with success stories, few of which have been enumerated in my lecture today. Such studies have always enhanced collaboration between scientists in the National Agricultural Research Institutes (NARIs) and their colleagues in the Universities thereby improving the quality of their research output. However, majority of the scientists in NARIs except those presently affiliated with Universities (for example, IAR, NAPRI, IAR&T, NISER), rarely relate with their colleagues in the Universities. Governments (Federal and States) should therefore adopt measures that integrate research centres with relevant Faculties in the Universities such that resources of the institutions can be pooled together to achieve greater success in teaching and solving common research problems.

(iii) Upgrading existing Facilities in Nigerian Universities for Research in Trending areas in Plant Genetics and Breeding

Mr. Vice Chancellor sir, in my presidential address to delegates at the Annual Conference of Genetics Society of Nigeria which held inside this Auditorium in October 2009, I referred to the discipline of Genetics and Breeding as “endangered”, based on enrollment for graduate programmes in the discipline as well as the poor background of students admitted into the B. Agric. Degree Programme in Biology, who might eventually opt for higher degrees in Plant Breeding and/or Genetics. The situation today has changed with improvement in enrollment of Postgraduate students into higher degree programmes in the discipline and also additional enrollment through externally funded projects (DTMA, AGRA) which focused on enhancing the capacity of women in Plant Breeding. However, it is also important for Universities to create an enabling environment for practitioners in this discipline to function effectively upon completion of their programmes. This requires conscious efforts in acquisition of ‘state of the art’ equipment in our laboratories to carry out research especially in new areas of Plant Breeding and Genetics, including molecular techniques that aid faster understanding of genetic basis of quantitative traits. The IITA, Ibadan, has played a leading role beyond the universities on research in this discipline.

(iv) Restructuring of USRI to attain its Objectives

At the time I assumed duty in USRI in 1990, the future of the institute was not certain because of the reluctance of University Administration to promote academic staff of the institute to the Professorial Rank on the premise of “lack of teaching and supervision experience” despite the fact that some of them were teaching courses in other departments in the University. Consequent upon the movement of USRI to the Faculty of Agriculture as a semi-autonomous unit, the erstwhile academic staff of the institute joined their colleagues in the old Department of Crop Production, with dual status of Lecturers and Research Associates of the institute. Although the USRI has undergone series of metamorphosis depending upon the disposition of successive Administrations, it has continued to maintain the status of the proverbial ***"Kokumo"*** – a Yoruba terminology for a child that has refused to die.

Mr. Vice-Chancellor sir, permit me to state that even in the face of dwindling funds, the institute has recorded many achievements through the dedication of the existing research associates. These include development and release of sugarcane varieties, training of students at Undergraduate and Postgraduate levels (M. Sc. and Ph. D), execution of consultancy services for the Nigerian sugar industries, attracting funds from external bodies (NSDC, ARCN) to conduct research which address issues germane to the sugar industries as well as active participation in the activities of Nationally Coordinated Research Projects on Sugarcane being funded by the NSDC, Abuja. At present, the institute is coordinating activities of the West African Sugarcane Development Project in the sugarcane growing ecologies of the southern Nigeria. The project which is funded by the Common Funds for Commodity (CFC) with International Sugar Organization (ISO) as the supervisory body has the NSDC as the Project Executing Agency. These activities have projected the image of the institute beyond its base at the University and outside the shores of Nigeria. Based on the performance of the institute and its credibility through well conducted research and articulated reportage of the institute's research activities, the NSDC is currently establishing a Sugarcane Biofactory at the institute's permanent site opposite ARMTI.

Having enumerated these achievements, it is pertinent to emphasize the fact that the number of Research Associates in the Institute has been greatly depleted and majority of the remaining members are essentially "good brains with tired legs". This underscores the need to inject young academics into the system to have a blend of old with "good brains" and young people who have the zeal and energy to execute the ideas. I therefore plead with the University Administration to come to the aid of the institute to sustain the present level of achievements, surpass it so as to achieve the stated objectives and vision of the founding fathers of the Institute. Prominent among the assistance required is the restructuring of the academic component of the institute - i.e. combination full time Research Fellows whose activities will be complemented by Research Associates drawn from relevant Faculties/Departments in the University. This document was presented to the USRI Management Board during my tenure as the Institute's Director in 2012. Implementation of the model will provide the necessary blend of academics to execute the Institute's project activities while sustaining the commitment of the remaining foundation staff of the institute. The second and equally important issue is the need for Administration to redeem the outstanding pledge made at the time the institute moved to its permanent site which includes construction of earth dam for irrigation during the long dry spell, equipping the laboratories to carry out relevant quality analyses, increase in the annual subvention to enable Research Associates conduct meaningful research and hiring of additional technical and field staff to complement the existing one.

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