UNIVERSITY OF ILORIN

THE ONE HUNDRED AND TWENTY- FOURTH (124th) INAUGURAL LECTURE

"THAT FOOD MAY BE MORE ABUNDANT"

BY

PROFESSOR YEKEEN ABIOLA ABAYOMI
B.Sc.(Hons) Agric. (Ife), M.Sc. (Ilorin), Ph.D. (Wales, UK)
Professor of Agronomy and
Director Unilorin Sugar Research Institute
DEPARTMENT OF AGRONOMY, FACULTY OF AGRICULTURE, UNIVERSITY OF ILORIN, ILORIN, NIGERIA

THURSDAY, 7TH MARCH 2013

This 124th Inaugural Lecture was delivered under the Chairmanship of:

The Vice-Chancellor
Professor AbdulGaniyu Ambali
DVM (Zaria), M.V.Sc., Ph.D. (Liverpool), MCVSN(Abuja)

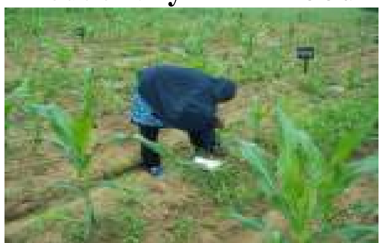
7th March 2013

Published by
The Library and Publications Committee
University of Ilorin, Ilorin, Nigeria

Printed By
UNILORIN PRESS

PROFESSOR YEKEEN ABIOLA ABAYOMI
B.Sc. (Hons)Agric. (Ife), M.Sc. (Ilorin), Ph.D. (Wales, UK)
Professor of Agronomy

Welcome to my Inaugural Lecture on Agronomic Management Practices Towards Improved Crop Productivity That Food May Be More Abundant








Courtesies

In the Name of ALLAH, the Most Beneficent, the Most Merciful

The Vice-Chancellor,
Deputy Vice-Chancellors,
Registrar and other Principal Officers of the University,
Dean of Agriculture and Deans of other Faculties,
Deans of Postgraduate School and Student Affairs,
Professors and Other members of Senate,
Directors and Heads of Departments;
Other Members of Academia,
Members of Administrative and Technical Staff,
My Lords Spiritual and Temporal;
Members of my family, Nuclear and Extended,
Distinguished Invited Guests,
Gentlemen of the Print and Electronic Media,
Greatest UNILORITES,
Ladies and Gentlemen.

Preambles

With profound gratitude to Almighty Allah, I consider it a great honour and privilege to present the 124th Inaugural Lecture of the University of Ilorin, the *Better By Far* University, the 9th in the Faculty of Agriculture and the 2nd in the Department of Agronomy. Mr. Vice-Chancellor Sir, before I go deep into the struggle to release our crops from the clutches of the environmental stresses so that they can attain their potentials in providing food for you, me and our numerous livestock, I will like to appreciate the Almighty Allah for sparing my life to make today a reality through three persons probably sitting here today. These are the angels Allah used to bring hope into my life when many thought that hope had been lost. One of them is a teacher, a physician and an administrator par excellence, in person of Prof. B. J. Bojuwoye who became my personal doctor, putting life back into a walking corpse that I was in the early 2000s. I thank you most sincerely sir. The second person is of course MY JEWEL of inestimable value who graduated from her roles as a dutiful wife and mother to become my personal NURSE AND DRIVER, Olu, you were surely the reason that I survived and live. Finally, my gratitude goes to the immediate past Vice-Chancellor of this great University, Professor Is-haq Olanrewaju Oloyede, who on the 4th March, 2009 (My Birthday) on behalf of the University authority pronounced my appointment as a Professor of Agronomy, thereby paving way for this 2nd Inaugural Lecture of the Department of Agronomy. I thank you most sincerely sir. I will also like to extend my appreciation to the incumbent Vice-Chancellor for giving me the opportunity to present today's lecture, I am grateful sir.

Scope of Agronomy and the roles of Agronomist

Agronomy is a branch of Agricultural science which deals with principles and practices of soil, water and crop management. Agronomy is a dynamic discipline and with the advancement of knowledge and better understanding of plant and environment, agricultural practices are modified or new practices are developed for higher productivity. Agronomist aims at obtaining maximum production with minimum cost. He exploits the knowledge developed by basic and allied applied sciences for higher crop production. In a large sense, agronomist is concerned with the production of food and fibre to meet the needs of growing population. Agronomist carries out research on scientific cultivation of crops taking into account the effects of factors like soil, climate, variety of crop and adjust production techniques suitably depending on the situation. He is a key person with a working knowledge of all agricultural disciplines and coordinator of different subject matter specialists. Consequently, my 31 years of research experience in this great University revolved round getting insights into the effects of soil moisture deficits and nutrients deficiencies on growth and yield of food crops as well as the agronomic management practices that will improve the productivity and yield of the various crops under such environmental stress factors, hence the title of this Inaugural Lecture **"That Food May be More Abundant."**

Introduction

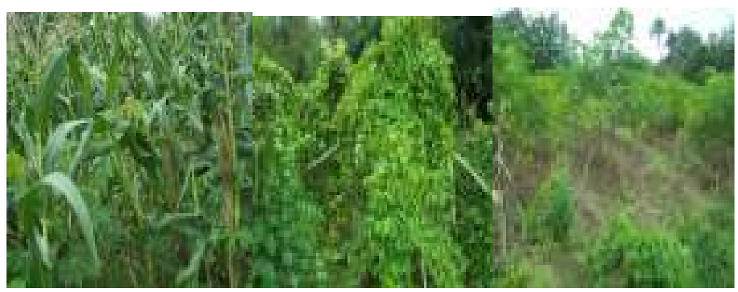
Plants constitute the only source of survival for man, animals and microbes (Amusa, 2010). Our entire lives depend directly on plants and plant products for food, shelter, fibres, clothing and drugs. Some of the commonly used plant species are cereal (maize, rice, sorghum, millet and wheat), legume (cowpea, soybean, groundnut), root and tuber (cassava, yam, potato), fibre (cotton, kenaf, rosette), and tree crops (teak, mahogany) (**Plates 1**). However, the productivity of these various plant species is being constrained by environmental stress factors, resulting from the activities of biotic and abiotic agents. The environmental stress factors such as drought, high temperature, salinity, air pollution, heavy metals, pesticides and soil pH are the major limiting factors in crop production because they affect almost all plant functions

(Hernandez *et al*, 2001; Lawlor and Comie, 2002). Plants, particularly arable crops are subjected to these various environmental stress factors which are nowadays being aggravated by climate changes. Of all these environmental stress factors, soil moisture deficit and nutrients deficiency are two major abiotic factors that limit agricultural crop production (Nemeth *et al*., 2002; Jaleel *et al*., 2009).

Most of the known mitigation strategies for water deficit effects are not attainable in the developing countries of the world, including Nigeria. So for the purpose of crop production, yield improvement and yield stability under water stress conditions, the development of drought tolerant varieties is the best option (Siddique *et al*, 2000). This is also in consonance with an earlier opinion that one strategy to reduce water stress effect on crop yield is to use drought tolerant species and cultivars (Carrow *et al*, 1990). It has earlier been observed that a final solution to drought in Nigeria must involve either the provision of extra moisture, the adaptation of crops to use less water, or to reconstitute crops to tolerate and resist drought (Owonubi and Abdumumin, 1985). However, the provision of extra moisture in terms of irrigation does not seem to be a realizable option for the small scale farmers producing most of the food consumed in Nigeria. The challenge has therefore fallen on the plant breeders, the plant physiologists and the agronomists to reconstitute crops to tolerate and resist drought in order to improve and sustain agricultural production in Nigeria.

Evaluating Crop Species and Genotypes for Drought Tolerance

Improved drought resistance is a major objective in plant breeding and selection programmes for crops grown in semi-arid regions without irrigation. To be successful, selection criteria must be identified that are associated with improved yield under conditions of drought stress, have high heritability, and can be measured accurately in large populations (Schonfeed *et al*, 1988). Many techniques have been suggested for screening for drought tolerance capacity in plants. These include seed germination in high osmotic pressure (Ashraf and Abu-Shakra, 1978; Abayomi, 1992), seedling heat or dessication tolerance (Sullivan and Ross, 1979), water retention or loss of excised leaves (Bayles *et al*,



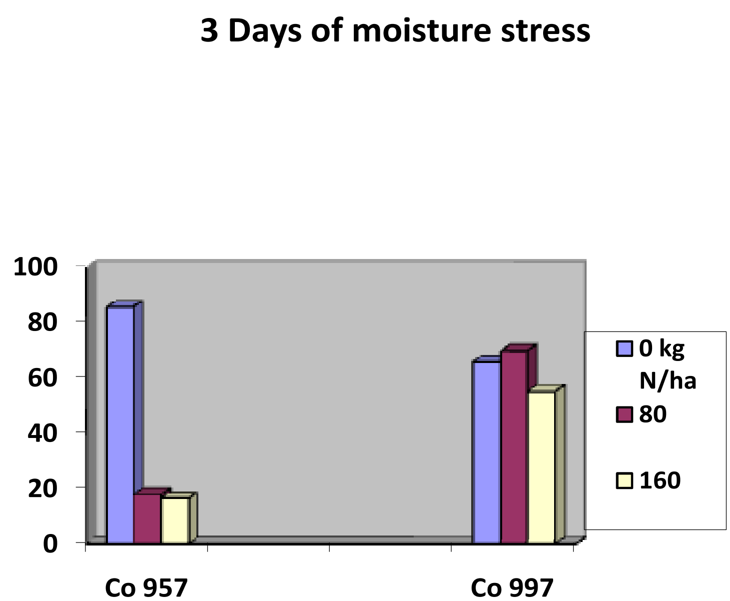
MAIZE (*Zea mays*) YAM (*Dioscorea spp.*) CASSAVA (*Manihot spp.*)

TOMATO **(*Lycopersicon Spp.*** **OKRA** **(*Abelmoschus Spp.*)** **SUGARCANE** **(*Saccharum Spp.)***

Plates 1: Pictures showing maize, yam, cassava, tomato, okra and sugarcane plants

1937; Clarke and McCaig, 1982); leaf conductance or permeability (Fischer and Sanchez, 1979); photosynthetic capacity (Dedio, *et. al* 1976), crop canopy or leaf temperature (Blum, 1979), visual observation of leaf rolling (Begg, 1980; O'Toole et al, 1984). Many biochemical traits have also been used or proposed as drought tolerance indicators in plants. These include accumulation of growth hormones such as abscisic acid (ABA), amino acids such as proline and enzymes such as nitrate reductase. The rate of disappearance of nitrate reductase activity (NRA) and leaf water status are indications of drought tolerance/susceptibility (Naidu *et al*, 1983; Viqueira *et al*, 1983). Thus Abayomi *et al* (1988) used the rate of disappearance of NRA to distinguish between a drought tolerant and susceptible sugarcane genotype. The NRA stability under moisture stress condition has also been indicated to be associated with drought tolerance in plants (Sinha and Rajgopal, 1975; Sairam and Dube, 1984). Abayomi (1999) used NRA stability to confirm the superiority of a sugarcane cultivar, Co 997, as a drought tolerant cultivar in agreement with the earlier observation of Natarajan (1978). (Figure 1).

Figure 1: Effect of nitrogen level on nitrate reductase (NR) enzyme stability under moisture stress (Abayomi,



Seed Germination in High Osmotic Pressure

Soil moisture potential has two contributing components: osmotic potential of the soil solution and the matric potential at which soil water is held. Although, it has been shown that the effect of osmotic potential was less than that of the matric potential of the same magnitude on maize radical growth (Gringrich and Russell, 1957), osmotic potential is easier to handle in the laboratory. It has therefore been used often to compare drought resistance of different crop species and varieties. In a series of publications, we have been able to show the effectiveness of seed germination in high osmotic potential in distinguishing drought tolerant and susceptible crop genotypes such as sugarcane (Abayomi and Mobolaji, 1995), maize (Abayomi and Saliu, 1997), wheat (Abayomi, 1992; Abayomi and Wright, 1999a), Cowpea and maize (Abayomi and Adeniyi, 2005 genotypes **(Table 1; Figure 2**).

Table 1: Interactive effects of osmotically-induced water stress and variety on emergence percent (E%) at the end of stress period in twelve open-pollinated maize varieties.

	Moisture tension (MPa.)			
Variety	**0**	**-0.8**	**-1.2**	**Variety means**
DMR ESR-Y	100a	57.7abc	37.5bc	65.0ab
ACR 89 MDR ESR-W	80a	82.5a	72.5a	78.3a
TZE COMP4 DMR SR BC2	100a	43.8cd	12.5d	52.1cde
TZE COMP3 C1	80a	56.5a-d	28.8bcd	55.0b-e
ACR 90 POOL 16 SR	80a	45.0cd	17.5cd	47.5de
ACR 86 TZ ESR-W	90a	58.8a-d	20.0bcd	56.3bcd
POP 31 DMR SR	75a	52.5bcd	41.3bc	56.3bcd
TZ 9043 DMR SR	80a	65.0abc	46.3ab	63.8abc
SUWAN-1-SR	90a	56.3a-d	42.5b	62.9bc
ACR 90 DMR LSR-W	85a	73.8ab	22.5bcd	60.4bcd
FUN 88 TZ SR-W1	80a	56.3a-d	10.0d	48.8cde
TZL COMP4 C0	75a	33.8d	13.8d	40.8e
Moisture tension means	84.6	56.8	30.4	

Figures followed by the same letter(s) in a column are not significantly different at 5% probability level by the Duncan's Multiple Range Test. To compare moisture tension LSD (0.05) is 22.09%.

Source: Abayomi and Saliu, 1997

Figure 2. Germination response of six sugarcane genotypes to osmotically-induced moisture stress (Low and No stress).

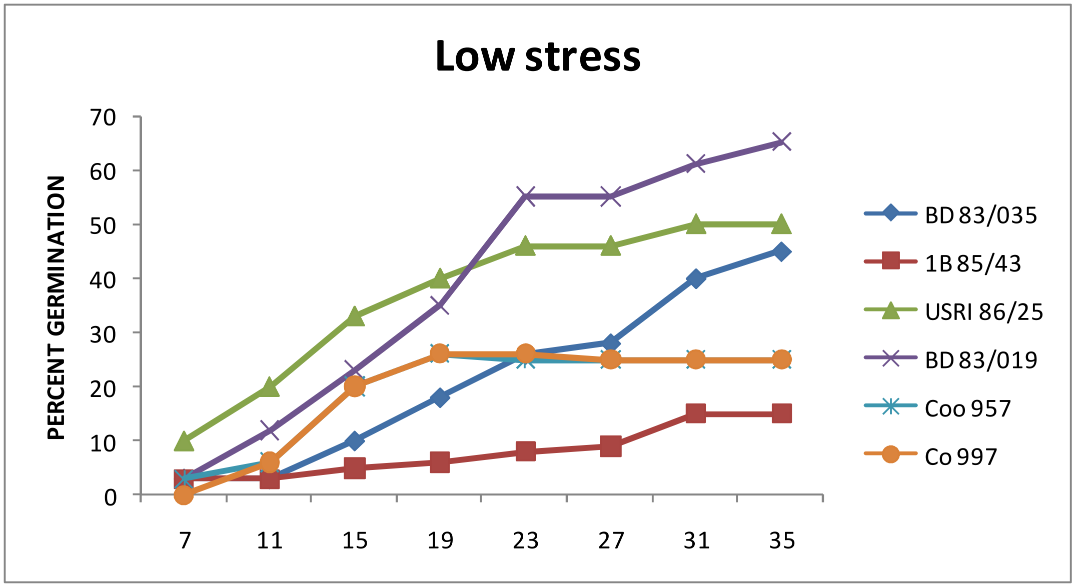


Figure 2 Contd.

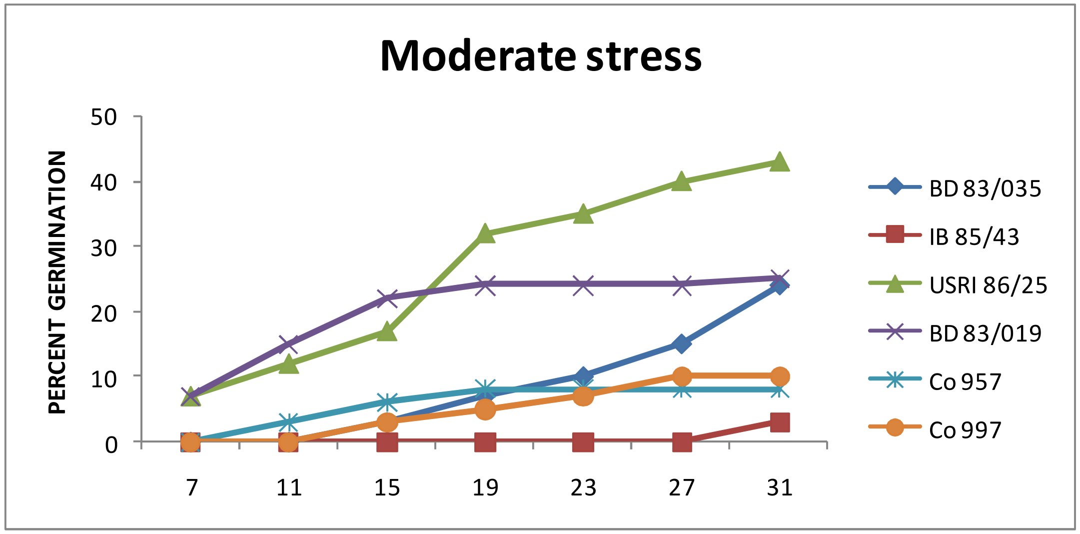
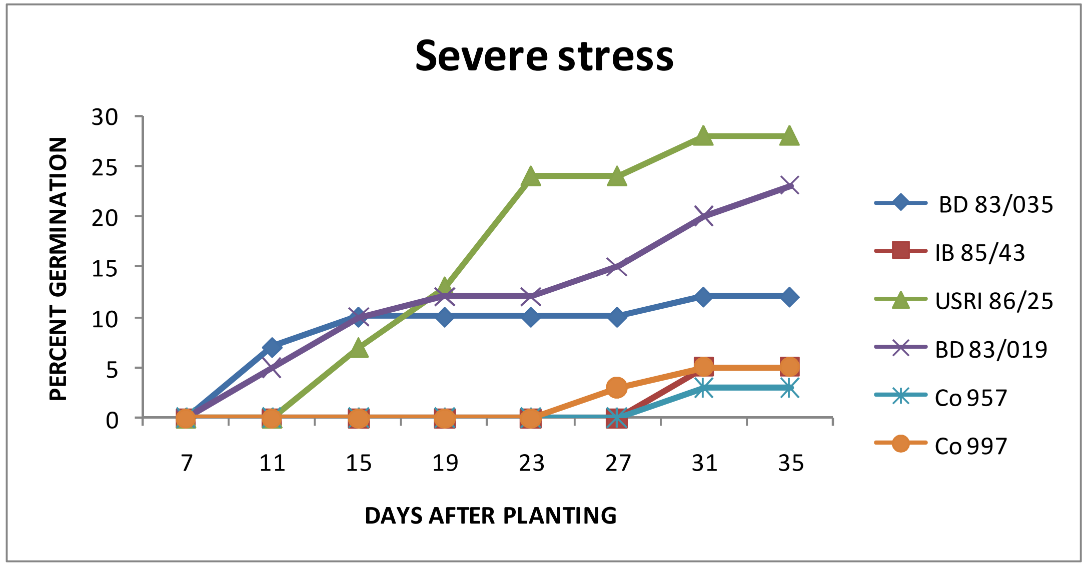
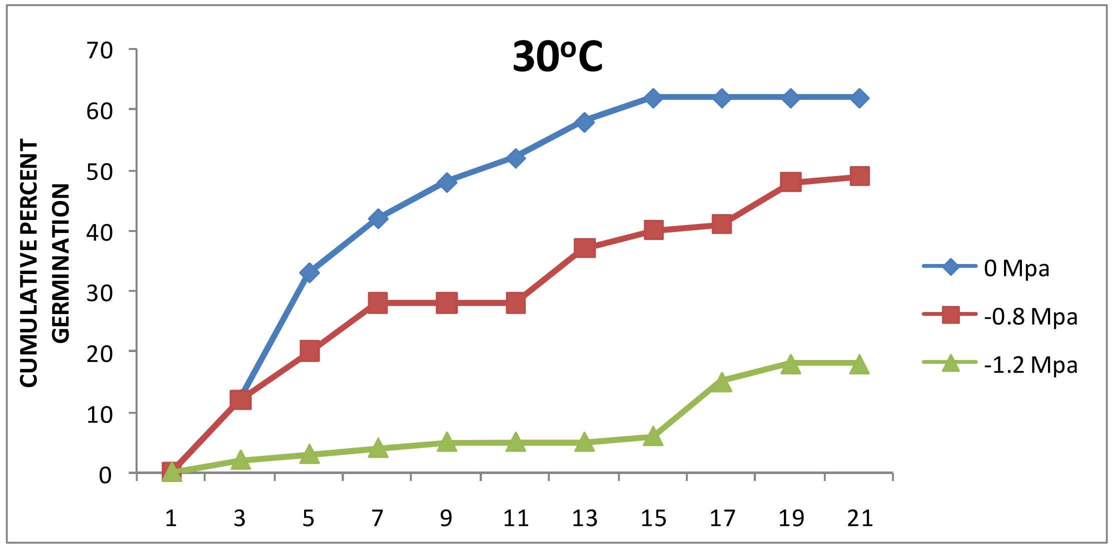


Figure 2 Contd.



Source: Abayomi and Mobolaji, 1995

Figure 3. Interactive effects of osmotically-induced moisture stress and temperature on spring wheat germination.



Source: Abayomi and Wright (1999a)

Figure 3 Contd.

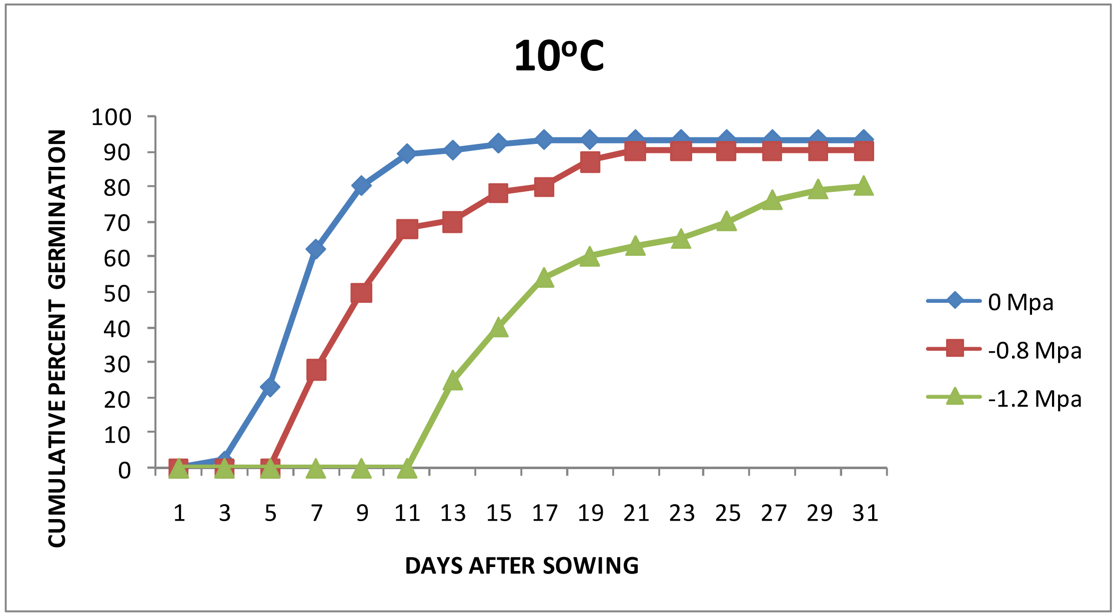


Figure 4. Interactive effects of soil moisture content on germination of cowpea and maize.

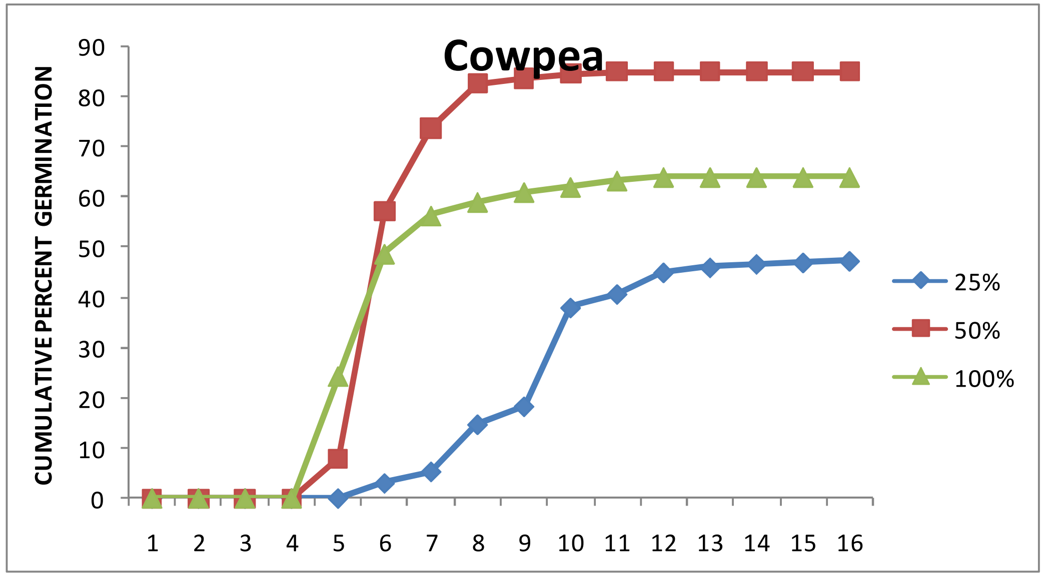
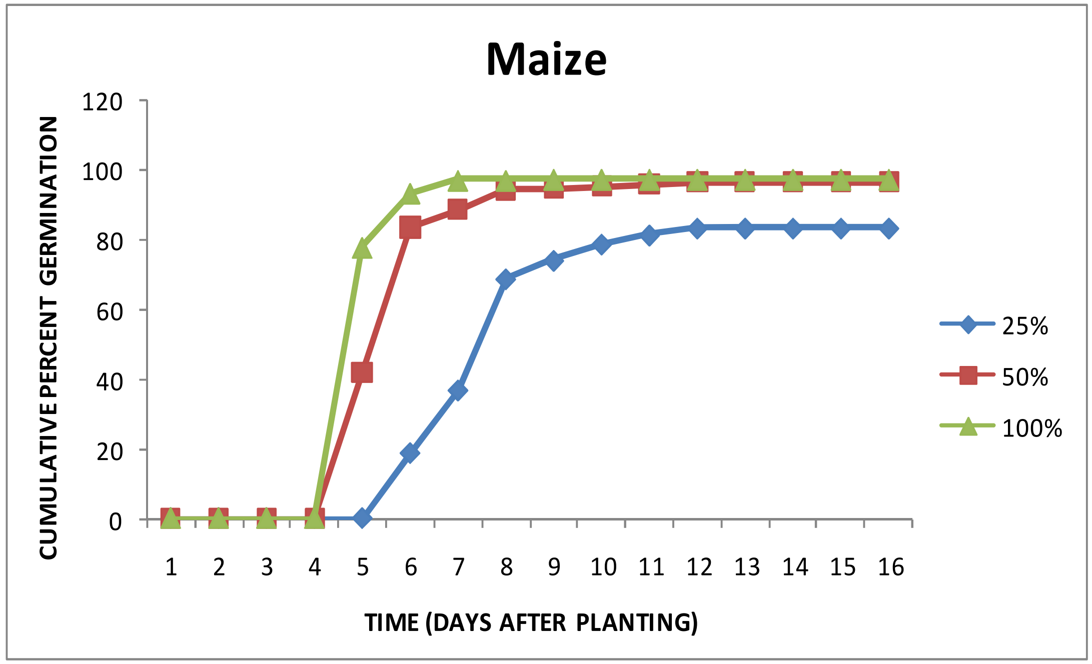


Figure 4 Contd.



Source: Abayomi and Adeniyi (2005).

Moreover, the effect of water deficit on seed germination is sometimes confounded by high or low temperatures (Lafond and Baker, 1986; Smith *et al*, 1989). Abayomi and Wright (1999a) showed that the differences between osmotic potentials increased with temperature (**Figure 3**). In a comparative evaluation study, Abayomi and Adeniyi (2005) reported appreciable differences in seed germination of different crop species (cowpea and maize) at sub-optimal soil moisture content, in favour of maize (**Figure 4**).

Morpho-physiological Growth Characteristics

Expansive growth measurements

- **Leaf Expansion Rate (LER)**

One of the easiest tests for a breeder in selecting for drought resistance (or even water use efficiency (WUE) would be to determine the ability of the plant to maintain expansive growth at reduced tissue water potential. Hsiao and Acevedo (1974) had noted that such a test should be quick and simple since young leaves of any species grow rapidly enough that growth during a fraction of a day can be measured nondestructively, merely with a ruler.

In a series of publications, the lecturer and his colleagues were able to show that leaf expansive growth measurement is the easiest, most simple and inexpensive screening technique with significant variations among genotypes (Abayomi, 1992; Abayomi,1996; Abayomi and Lawal, 1998; Abayomi and Wright, 1999b; Abayomi and Wright, 2002). We also showed that LER response to soil moisture deficit is dependent on the growth stage at which the deficit occurs. Our results on sugar beet showed that water deficit early in the growing season had larger effect on leaf growth, LER, area of individual leaf and leaf area index (LAI), while mid- or late-season soil water deficit showed relatively smaller effects on leaf growth (Abayomi and Wright, 2002) (**Figure 5**). Our results on sugarcane further showed the ontogenetic variations in the responses of leaves at different positions to water stress (**Table 2**).

In another study, Abayomi and Wright (1999b) showed that while the rate of leaf appearance and number of leaves per main stem were not significantly affected by water stress, LER, and hence leaf size and area were significantly reduced to varying degrees by water stress in wheat. The authors thereby suggested that leaf expansion may be more sensitive to water stress than the meristematic process involved in leaf initiation, possibly because the water potential of the shoot meristem and young leaves are maintained at a higher level than the other parts of the plant during the period of water stress (Lawlow and Milford, 1973). However, our results on cowpea showed no evidence of increased senescence with water stress at flowering and pod filing stages.

Table 2: Effect of water stress on Leaf Extension rate (LER in cm day^{-1}) during maximum growth of leaf at positions 8, 10, 12 and 14.

Water stress	BD 83/019	BD 83/035	IB 85/43	USRI 86/25	USRI 86/4
	Sugarcane genotype				
			Leaf 8 (L8)		
No stress	3.8a	5.8a	5.1a	4.7a	5.2a
Moderate stress	3.2a	1.8b	4.5b	3.7a	3.7b
Severe stress	2.7a	1.4b	3.6b	2.5b	2.2c
			Leaf 10 (L10)		
No stress	4.0a	4.8a	9.7a	8.7a	7.1a
Moderate stress	3.9a	3.3a	5.0b	6.5a	2.8b
Severe stress	3.7a	1.9a	2.3b	1.8b	0.3b
			Leaf 12 (L12)		
No stress	10.9a	10.3a	7.5a	4.5a	3.9a
Moderate stress	9.5a	4.9b	5.7a	3.5a	1.6a
Severe stress	2.0b	2.3b	2.6a	2.0a	0.3a
			Leaf 14 (L14)		
No stress	4.4a	5.0a	4.2a	5.0a	3.7a
Moderate stress	3.4a	3.9a	3.1a	3.4a	3.3ab
Severe stress	3.2a	3.6a	2.8a	1.2b	1.84b

Figures followed by the same letter(s) in each column are not significantly different on Duncan's Multiple Range Test at $p<0.05$.

Source: Abayomi and Lawal, 1998

This was probably due to minimal change in plant water potential during stress (Turk *et al*, 1980; Wien *et al*, 1979), indicating that cowpea is an excellent drought avoiding plant. This shows that leaf production is more sensitive to water stress than leaf senescence in cowpea. The reduction in leaf production and leaf area reported by Abayomi *et al* (2001) with water stress at the vegetative stage might also be a drought avoiding mechanism. Shakle and Hall (1983) had earlier shown that cowpea avoid drought by reduction in leaf area, decrease in stomatal conductance and changes in leaf orientation.

Figure 5. Effect of water stress on the ontogenetic changes in final leaf area and maximum leaf expansion rate (LER) during stress period of wheat.

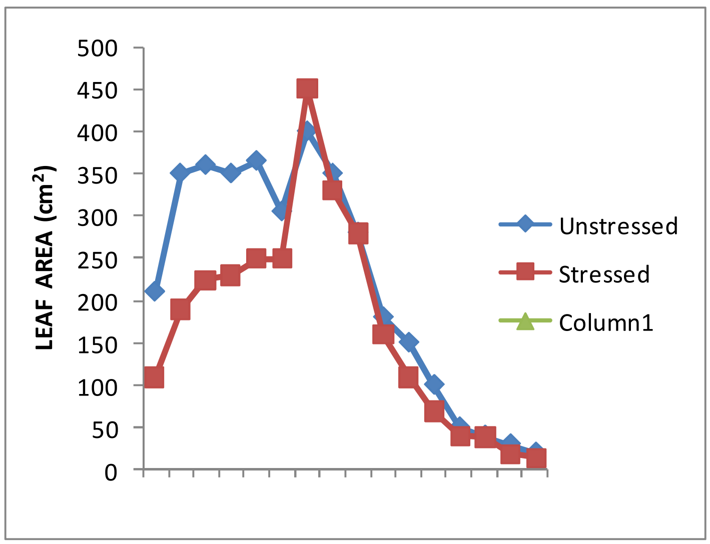
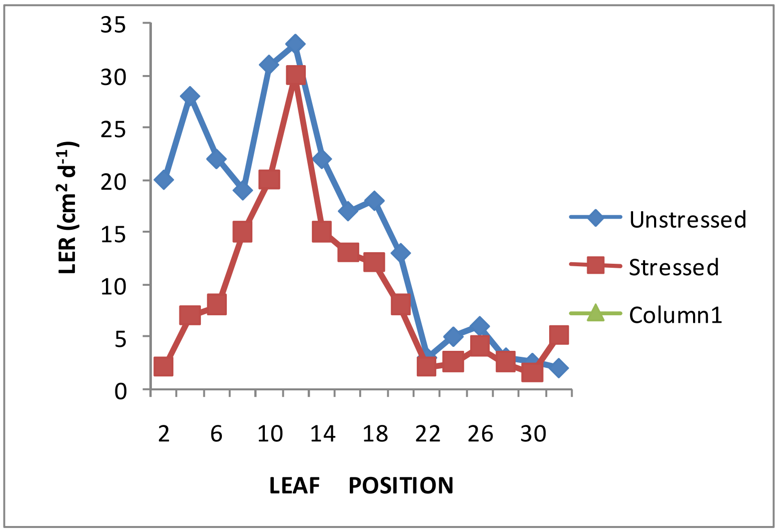


Figure 5 Contd.



Source: Abayomi and Wright (1999b).

- **Stem Elongation/ Plant Height**

It has been suggested that variations in plant height under stress conditions may become one of the causes of variations in grain yield in cereals (Hadjichristodoulou, 1987). In our various studies, we have been able to show that the relative decrease in plant height under water stress as compared to the control (well-watered) was found to be well correlated with grain yield, and therefore concluded that measurement of plant height from the surface of the soil to the tip of the last emerging leaf using a ruler (**Plate 3**) is simple, fast and inexpensive and therefore could be a good selection criterion in large scale selection programme (Abayomi, 1992;

Plate 2. Students measuring leaf length and plant height in okra and maize plants respectively.

Abayomi and Lawal, 1998; Abayomi and Wright, 1999b; Abayomi, 2004; Abayomi, 2008; Abayomi and Adefila, 2008; Abayomi and Abidoye, 2009)`. This view was supported by an earlier report that growth responses in terms of plant height was found to serve well as one component of a multiple selection index for drought resistance in maize (Fischer *et al*, 1983). The results of one of our studies further showed that plant height under water stress as a percentage of the control was positively associated with grain yield (r= 0.48**) and harvest index (r= 0.56**) and significantly varied amongst genotypes. Similar genotypic variation in grain yield in response to relative decreases in plant height under water stress has been reported for grain sorghum (Blum *et al*., 1989).

Physiological Processe

- **Photosynthetic Responses**

Although selection for high photosynthetic rate *per se,* has generally not been a productive approach to increasing yield, the capacity of plant to photosynthesize during and following moisture stress is an important index of drought resistance (Blum, 1979). It has therefore been observed that improvement in crop productivity may be achieved by selecting increased canopy photosynthesis and an efficient utilization of assimilates under unfavourable environmental conditions, such as drought (Fredrick *et al*, 1989). However, Dedio et al, (1976) reported that the use of infrared method did not adequately differentiate between cultivars on their photosynthetic rate. This view was supported by Abayomi (1992) who reported no significant variations in photosynthetic rates of wheat and sugar beet cultivars under moisture stress. The latter author attributed the non-significant genotypic variations to inadequate photosynthetic active radiation (PAR) and thereby stressed the need for saturating PAR if accurate comparisons are to be made using infrared gas analyzer (**Plate 4**). Thus, Abayomi and Wright (2000) reported that the effect of water stress on net photosynthesis (P_n) was greatest between 12.00 and 14.00 hr when the evaporative demand is highest and PAR is at its peak.

Plate 3: Infrared gas Analyzer (IRGA) being used to monitor photosynthetic capacity in a maize field

Mr. Vice-Chancellor, Sir, drought resistance is a complex of many morphological, physiological and biochemical characteristics. It is therefore doubtful that any one criterion will be adequate for selection of drought tolerant genotypes. Thus Sullivan and Ross (1979) have suggested that a combination of desirable factors must be selected.

Evaluation of food crop species for drought tolerance capacity.

Many aspects of food crops growth are known to be affected by drought stress including leaf expansion which is reduced due to the sensitivity of cell to water stress

(Hsiao, 1973). In a series of publications, we showed that water stress applied at the vegetative growth stage of cowpea significantly reduced the number of leaves per plant compared to the control (non-stressed) and plants water-stressed at the flowering and pod-filing stages (Abayomi *et al*, 2001; Abayomi and Abidoye, 2009). Our results further showed that water stress at any growth stage of the crop significantly reduced grain yield with greater effects when the stress occurred at the flowering and pod-filling stages (**Table 3**). In a more recent publication, Abayomi and Abidoye (2009) were able to identify two genotypes, ITA 271 and ITA 352, to have good yield potential and yield stability, while IT99K-1060 and IT97K-598-18 are drought tolerant but have low yield potentials. From the various studies, we concluded that, although it is assumed that cowpea is a water stress tolerant crop species, it was apparent from our results that drought stress during flowering and pod-filling stages may substantially reduce grain yield in cowpea. This has serious implications for planting late in short season cowpeas in the southern Guinea savannah zone, where farmers sometimes plant as late as mid-September, thereby suggesting that rainfall may cease at the period of flowering and /or pod-filling stages. This will definitely result in yield losses in cases where the water available to the root is not substantial. In this case it may be possible to maximize yield by choosing planting dates and varieties that decrease the probabilities of soil water deficit occurring at flowering and pod-filling stages. It was therefore suggested that in this agro-ecology, planting of short season cowpea should be done not later than the 3rd week of August for medium/long duration (>65 days) varieties and 1st week of September for the short duration (<65 days) varieties. From the results of our studies, IT8KD-374-57, TVX L25 and IT87D-941-1 were also identified as promising as drought tolerant varieties which may be successfully cultivated in the zone.

Soybean (*Glycine max* (L) Merrill) is another important edible grain legume in the world due to its high nutritional value and high seed protein content (38-42%) (Nworgu, 1993). The crop which was first introduced to Nigeria in 1908 (Root *et al*, 1985) has gradually become an important crop in the country due to increasing demand for edible oil and protein which has led to the expansion of soybean production to the savannah ecological zone, an area characterized by erratic and low rainfall (Chiezey, 2001). It is known that moisture stress reduces soybean yield (Korte *et al*, 1983b) and this effect is influenced by the timing and severity of stress.

Table 3: Effects of water stress at different growth stages on grain yields of contrasting cowpea genotypes.

		Water Stress applied at			
Variety	**No stress**	**Vegetative**	**Flowering**	**Pod-filling**	**Mean**
			Year 1998		
Ife Brown	3.4	4.01	1.19	1.22	2.48
TVX-L25	4.26	3.90	2.25	2.70	3.28
IT84E-124	4.72	3.15	1.79	3.01	3.17
IT89KD-374-57	3.08	2.85	1.94	2.48	2.59
IT89D-041-1	3.68	2.21	2.11	2.79	2.70
IT90K-102-6	4.53	1.84	2.10	1.28	2.44
IT89KD-256	5.21	1.68	2.03	2.01	2.72
BEWEHE (local)	3.45	1.88	5.52	2.04	3.23
Mean	4.05	2.69	2.37	2.17	-
LSD (0.05)					
Water stress treatment		0.721			
Variety		ns			
WS x V		2.041			

Table 3 Contd.

			Year 1999		
Ife Brown	7.86	7.11	2.23	6.08	5.81
TVX-L25	2.96	2.98	3.47	2.35	2.94
IT84E-124	3.76	1.91	2.70	1.13	2.35
IT89KD-374-57	3.72	2.41	3.70	4.15	3.50
IT89D-041-1	4.07	2.29	1.31	3.20	2.72
IT90K-102-6	7.62	6.31	5.17	2.32	5.46
IT89KD-256	6.92	3.35	5.75	4.32	5.09
BEWEHE (local)	5.25	5.29	3.12	4.98	4.63
Mean	5.26	3.96	3.43	3.75	-
LSD (0.05)					
Water stress treatment		1.69			
Variety		3.407			
WS x V		ns			

Source: Abayomi *et al*, 2001

I conducted various studies on the effects of soil moisture and agronomic inputs on growth and yield of soybean individually or jointly with other colleagues (Abayomi, 2006; 2008; Abayomi and Mahamood, 2009; Mahamood *et al*, 2009; Aduloju *et al*, 2009). In an earlier study, Abayomi (2006) reported that soil moisture stress, especially when it occurred at the vegetative and flowering stages, significantly reduced flower and pod formations, while moisture stress at any growth stage had no significant effect on reproductive efficiency. It was therefore concluded from the study that the decrease in grain yield due to soil moisture stress obtained was due to reductions in the sink sites for dry matter storage, with stress at either the vegetative or flowering stage. This was observed to lead to reduction in the ability to translocate more photosynthate to the appropriate sites when stress occurred at the pod filling stage. Nevertheless, grain yield varied among genotypes due to significant variations in both flowers and pods formation and not due to reproductive efficiency. The results of the study ranked Samsoy 2 and TGX 1817-12E as the most tolerant and TGX 1019-2EN and TGX 536-02D as the least tolerant genotypes to soil moisture deficit.

More recently, Abayomi (2008), concluded that soil moisture stress occurring at any stage of growth could be detrimental to grain yield in soybean depending on the maturity group. He reported that, while the early maturing soybean were mostly adversely affected by a stress at the flowering stage, pod filling stage was the most critical stage for the late maturing group.

Mr. Vice-Chancellor, Sir, rapid decline in the productivity of oil palm (*Elaesis guinensis*, L) and groundnut (*Arachis hypogeal*, L) which have long been the principal sources of vegetable oil in Nigeria has for long been creating problems in meeting the local demand for vegetable oil (Orisamika, 1993). This has therefore necessitated the need to look for alternative sources of oil. Ogunremi (1980) from preliminary investigations and field studies in the late 1970s identified sunflower as a potential source of vegetable oil which can serve as alternative to oil palm and groundnut. The bulk of the agricultural sunflower production is in the Guinea savannah ecology of the country, an area regarded as being prone to drought with low soil fertility (Chiezey, 2001; Adetiloye and Salau, 2002). Consequently, inadequate soil moisture and fertility are the two major husbandry problems reducing sunflower seed (achene) yield, and hence reduced vegetable oil and other products of sunflower in Nigeria. It has been reported that sunflower growth and yield parameters such as number of leaves, leaf area and plant height decreased with severe moisture and nitrogen stresses (Halvorson *et al*, 1999). The water requirement of sunflower has been observed to be higher than those for other crops while water stress symptoms are not easily recognizable in the crop (Nasir, 1994). Therefore, in a study on the interactive effects of soil moisture and fertilizer level on growth and achene yield of sunflower, Abayomi and Adefila (2008) showed that plant growth and achene yield were significantly reduced by low soil moisture contents and this was aggravated by low soil fertility.

In a study on the responses of wheat to soil moisture stress, Abayomi and Wright (1999b) reported that water stress had greater effects on yield and its components when it occurred during the reproductive stage (**Table 4**).

Earlier workers (Doorenbos and Kassam, 1979; Johnson and Kamenrasu, 1982) had suggested that drought tolerance screening in cereals would be more effective during the reproductive stage. In terms of both absolute and relative yield under stress, our results showed that Wembley was the most drought tolerant of the wheat cultivars evaluated. It is interesting to note that Wembley was the only cultivar which produces awns, which in the light of the report that awns increased yield of cereal in dry regions (Evans *et al*, 1972), suggest that awned cultivars of wheat may be more drought tolerant than those that are awnless.

Table 4: Effects of water stress at different growth stages (GS) on grain yield and yield components at harvest.

Yield Components	No stress	Vegetative Stress	Reproductive Stress	SED
Grain yield (g m^{-2})	629.0	506(80.4)	234(37.2)	62.9
Number of ears (m^{-2})	845.0	780(92.3)	830(98.9)	75.10
Fertile spikelet ear^{-1}	12.9	11.5(88.9)	9.2(70.9)	0.56
Infertile spikelet ear^{-1}	1.9	1.7(91.0)	4.7(248.4)	0.42
Total spikelet ear^{-1}	14.8	13.2(89.1)	13.9(93.5)	0.38
No of grains $spikelet^{-1}$	1.35	1.41(101.4	0.56(41.5)	0.091
No of grains ear^{-1}	20.1	18.7(93)	7.9(39.5)	1.38
Grain No m^{-2}	17863.0	14921(85.5)	6910(38.7)	1645.2
Grain weight (mg)	34.62	33.73(97.4)	33.63(97.1)	1.005
Ear weight (g m^{-2})	828.0	648(78.3)	372(44.9)	75.1
Biomass yield (g m^{-2})	1484.0	1030(69.4)	771(51.9)	115.5
Harvest index (%)	41.2	48.7(118.2	28.9(70.1)	3.13

Values in parenthesis are absolute values of stressed plants expressed as percentage of the control values. SED is the Standard Error of the Difference between means.

Source: Abayomi and Wright, 1999b

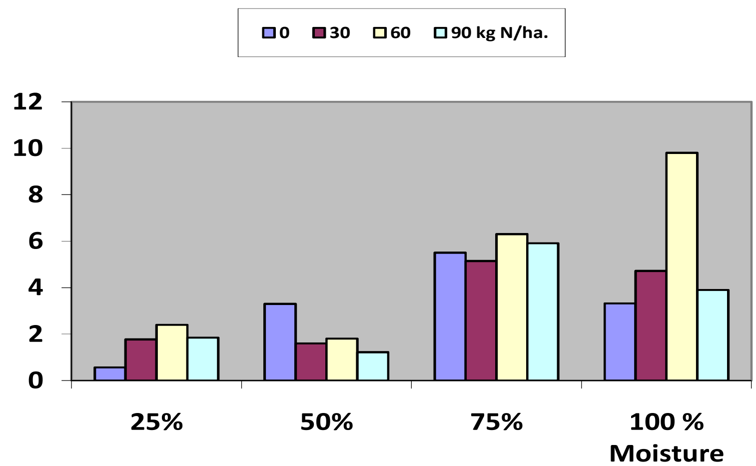
My contributions to studies in other agronomic management practices

Mr. Vice-Chancellor, Sir, my contribution to the agronomy of crop production is not limited to the screening for the drought tolerant genotypes. I wish to inform this august listeners that I have also made ample contributions to other agronomic management practices towards improved crop productivity, **that food may be more abundant.** These include studies on weed management, crop nutrition, intercropping efficiency, adaptability evaluation of crop genotypes to the SGS, soil conservation management practices etc. Sir, I therefore crave your indulgence to allow me to mention some of these contributions in the other areas of agronomic management practices.

Interactive effects of soil moisture content and fertilizer application

Lack of adequate water and improper fertilization of the soil are two of the husbandry problems reducing crops yields in Nigeria. While there have been concerted efforts to address these problems individually, there seems to be little or no study aimed at the interactive effect of fertilization and soil moisture contents. The importance of such study has however been reported (Fernandez *et al*, 1996). This lecturer therefore conducted some studies to determine the interactive effects of fertilizer application and soil moisture content. In his earliest study, Abayomi (1996) reported that adequate water supply and N application are the most critical inputs influencing sugarcane growth and yield. Using prominent and consistent moisture x nitrogen interactions, he showed that the response of sugarcane plant to higher N application will be dependent on the soil available moisture. In a later study, Abayomi (2004) reported significant water stress x N fertilizer application interaction effects on most growth and grain yield parameters of maize. The results showed that application of N fertilizer at any rate has no significant effects on all water stressed plants, while significant positive responses to N application were obtained with adequate soil moisture. More recently, Abayomi and Adefila (2008) working on sunflower, reported significant ($p<0.01$) interactions of soil moisture and fertilizer level, which revealed that application of fertilizer has no significant influence on growth and yield at lower soil moisture levels (25 and 50%), but significantly increased yield components and seed yield at 75 and 100% soil moisture contents (**Fig. 6**). The authors therefore concluded that a factorial combination of 60 kg N ha^{-1} fertilizer level at 75% soil moisture content is optimum for profitable seed yield of sunflower. The results of these studies thereby confirmed the critical interactive effects of N nutrition and adequate soil moisture as they jointly influence growth and grain yield in cereals and other crops.

Figure 6: Interactive effects of soil moisture and N fertilizer appication on achene (seed) yield (g/plant) of sunflower.



Source: Abayomi and Adefila, 2008

Intercropping Efficiency

Studies involving cereal/legume combination have attracted attention in tropical Africa as a way of improving the productivity and quality of food crops and also to maintain and possibly enhance the soil productivity through nitrogen fixation (Adetiloye, 1980). Thus, maize/cowpea intercrop has generated a lot of interest among scientists (including this lecturer) as its advantage under good management indicates that it stands a good chance of becoming a major practice in Nigeria's future agriculture. In a study to determine the influence of maize architecture and nitrogen fertilization on intercropped maize and cowpea, Abayomi and Jatto (1998) reported the need for N application in maize/cowpea intercrop in the SGS (a practice not previously in use). Their results further showed that 80 kg N ha^{-1} is the most renumerative N rate for maize/cowpea intercrop in the zone. The study further revealed that the increased net revenue resulting from N application to the mixture was higher when short maize variety was used. The choice of correct cultivar and agronomic manipulations are the key elements for higher yield in intercropping (Fukai and Trenbath, 1993). A short, less vegetative cereal variety is a better option for cereal/legume intercrop. In a similar study, Abayomi (2000) reported that even though intercropping may result in decreases in yield of one or both of the component crops in a mixture, the productivity of a unit land area is improved by intercropping. The author further showed that the yield advantage is influenced by the architecture of the component cereal crops, being better with a shorter cereal genotype and thereby stressing the need for proper evaluation of the component crops before planting the mixture.

Weed Management and use of herbicides

One of the major factors responsible for reduced crop yield worldwide is uncontrolled weed growth. Results of yield losses resulting from weed competition in many parts of the world varies between 12 and 78% (Zimdahl,1980). In order to establish an individual herbicide and/or herbicides mixture that are selective and would give long-lasting weed control in the crop, a joint effort with other colleagues resulted in series of experiments on weed management and use of herbicides.

In an earlier work, Fadayomi *et al* (1984) recommended the use of Hexazinone-based mixture for longer-lasting weed control in sugarcane over the diuron-based mixture, even though both mixtures were selective on Co 957 than on Co 1001 cultivars of sugarcane. The formulation of an appropriate weed management strategy for any crop requires the knowledge of the critical period of weed infestation in the crop. However, there was limited information in this area with regards to sugarcane crop. Therefore, Fadayomi and Abayomi (1988a) reported that the critical period of weed interference in plant sugarcane crop was between 8 and 20 weeks after planting (WAP), thereby suggesting that any weed management policy for the plant sugarcane must be such that will effectively control weeds between 8 and 20 WAP.

Flowering in sugarcane is one of the most important factors responsible for low sugar production in Nigeria. In an attempt to eliminate flowering in sugarcane, El-Manhaly *et al* (1984) reported that two herbicides, diuron (4.0 kg/ha) and paraquat (0.5 kg/ha) applied to the top leaves of sugarcane reduced flowering up to 45 and 35% respectively. However, these levels of effectiveness and the side effects occasioned by the use of these herbicides, necessitated the need for an alternative. In their search for this alternative, Fadayomi, Abayomi and Olaoye (1995) reported that ethephon (2-chloroethyl phosphatic acid) application reduced the intensity of flowering in all varieties evaluated in the first year, but only in two of the varieties the following year. The authors also showed that acceptable responses can be expected if ethephon is applied between the end of the 1^{st} and 3^{rd} week of July.

Plant nutrition, leaf growth and grain yield of maize

Leaf growth is important in influencing light interception, crop growth and yield in cereals (Gallagher and Biscoe, 1979). The final yield of dry matter has been shown to be proportional to the total amount of radiation intercepted by crop during growth (Scott and Jaggard, 1978), while light interception is largely determined by leaf area index (LAI) (Milford *et al*, 1985). In a much earlier study, Watson (1947) reported that leaf area and leaf area duration were the main causes of yield differences in plants rather than the rate of photosynthesis or net assimilation rate. Thus, low yield of most tropical maize has been attributed to low leaf area index, resulting from low fertility of tropical soils. In our various efforts to use agronomic management practices to improve leaf growth of crops in the SGS zone, Abayomi *et al* (2006) reported grain yield improvement due to enhanced leaf growth with increasing N fertilizer application in both hybrid and open-pollinated maize cultivars, thereby confirming the importance of leaf growth on grain yield of cereals. In an earlier study, Abayomi and Adedoyin (2004a) reported that the increased grain yield resulting from N application was due to improved leaf area production and longer leaf area duration, thereby confirming the critical importance of N to increase LAI and prolong leaf area duration thereby increasing biomass accumulation and grain yield in maize. However, the authors further showed that this expression could be seriously depressed by soil moisture deficit which is largely responsible for yield variations due to different planting dates being experienced in the zone. Abayomi and Adedoyin (2004b) therefore reported that the differences in growth characteristics due to planting date was mainly attributable to inadequate soil moisture, associated with June planting, which did not enhance the efficiency and effective use of the supplied N fertilizer for good growth of leaves and development of maize plants and hence the reduced grain yield. In a subsequent study, Abayomi and Fagbenja (2005) showed that crop growth rate (CGR) and net assimilation rate (NAR) are the two most important physiological characteristics influencing grain yield variations in maize genotypes and in response to N fertilizer application, while plant height and number of leaves per plant are the most important morphological characters in grain yield variations.

Phosphorous nutrition in soybean:

Comparative field evaluation of old and newly developed soybean genotypes in the SGS of Nigeria (Abayomi and Mahamood, 2009) revealed that there have been little but significant genetic gains in soybean development in Nigeria over a period > 50 years of breeding and selection. A possible reason for the low genetic gain is the use of inappropriate growth and/or traits in selection programmes. The authors suggested that more emphasis should be placed on the use of physiological growth characteristics as selection criteria as well as the development of more drought tolerant genotypes. In another study, Aduloju *et al* (2009) were able to identify two new soybean genotypes, TGX 1448-2E and TGX 1844-18E as being better and therefore can replace the old cultivar, TGX 923-2E. The authors further showed that the application of 30 kg P ha^{-1} is beneficial to soybean growth and grain yield in soils with low available P. However, Mahamood *et al* (2009) concluded that even though soybean genotypes responded well to P application, the development of P-efficient technology would benefit the resource-poor farmers more than the development of optimum level(s) of P fertilization which the farmers might not be able to adopt and/or might not have the resources for application.

Soil conservation and weed management using legume cover crops

Land degradation and declining soil fertility leading to decreasing total agricultural productivity is a problem in the Sub-Saharan Africa (SSA) (Okigbo, 1985; Lal, 1989). Integration of legume cover crops into the existing cropping system has been reported to offer potential for overcoming this problem. Legumes have the potential to improve soil fertility thereby boosting subsequent crop yield (Mohammeed-Salem, 1986; Tarawali, 1991). Legumes offer other benefits such as maintenance and improvement of soil physical properties, providing ground cover to reduce soil erosion, increasing soil organic matter, cation exchange capacity, microbial activity and reduction of soil temperature (Vallis and Gardner, 1984; Mulongoy and Kang, 1986; Tarawali et al, 1987). As part of a series of studies in collaboration with the International Institute for Tropical Agriculture (IITA) and the Nigerian Agricultural Research System, Abayomi *et al* (2001) evaluated the potentials of selected legume species for establishment, growth characteristics, biomass and seed production, soil fertility improvement and weed suppression at the Unilorin Teaching and Research Farm, Bolorunduro, southern Guinean savanna. Using the rank summation index (RSI) (**Table 5**), the authors showed that the order of adaptation of the legume species evaluated to the study location on the basis of their ground cover, biomass production, seed yield, dry season survival and N contribution to the soil was: *Cajanu cajan* > *Aeschynomene hisrix* > *Stylosanthes guinensis* > *S. scabra* > *Crotolaria ochroleuca* > *C. verrucosa* > *Clitorea tarnatea* > *Pseudovigna argentea* > *Centrosema pascuorum* > *Pueraria phaseoloides* > *Lablab purpureus* > *Psophocarpus palustris* > *Chamecritea rotudifolia* > *Macroptilium atropurpureum.*

In a subsequent study, Ekeleme *et al* (2003) reported that velvet bean, lablab, pigeon pea, (DS, SGS), sun hemp (NGS) and Centurion (SGS) could contribute significantly to weed management in the derived and Guinea savanna of Nigeria. These cover crops were shown to be more effective in reducing weed density than the other legumes. In an inter-cropping and residual effects study, Fadayomi *et al* (2005) concluded that the integration of legume cover crops in a maize-based system increased maize grain yield and reduce weed infestation; and that *Centrosema pascuorum* is the most promising species in the SGS region. Nevertheless, the authors were of the opinion that *Lablab purpureus, Mucuna pruriens and Cajanus cajan* could also be potentially useful species if introduced about 4 weeks after planting of cereals or used as short rotation crops.

Table 5: Species ranking and rank summation index (RSI) showing the performance of legume species at the trial location.

Legume species	Ground Cover Yr 1	Ground Cover Yr 2	Biomass yield Yr 1	Biomass yield Yr 2	Seed yield	Residual N	Persistence	RSI*	Final Rank
Aeschynomene hisrix	15	4	12	4	8	3	1	47	2
Cajanu cajan	5	1	1	1	2	2	5	17	1
Stylosanthes guinensis	17	1	11	2	18	1	1	51	3
S. scabra	18	9	8	3	9	11	4	62	6
Crotolaria ochroleuca	7	18	3	17	4	4	11	64	7
C. verrucosa	16	12	6	10	11	6	6	67	8
Clitorea tarnatea	11	10	9	9	7	10	14	70	10
Pseudovigna argentea	9	3	16	7	16	12	8	71	12
Centrosema pascuorum	4	14	7	15	5	15	16	76	13
Cenrosema brasilianum	10	5	10	8	10	9	9	61	5
Lablab purpureus	3	17	5	16	6	18	15	80	14
Psophocarpus palustris	6	16	15	14	15	5	10	81	15
Chamecritea rotudifolia	18	8	13	11	13	16	13	82	16
Macroptilium atropurpureum.	12	11	14	12	14	17	12	92	17
Mucuma pruriens (black)	2	15	4	18	3	8	17	67	8
Mucuna pruriens (white)	1	13	2	13	1	7	18	55	4
S. harmata	14	7	18	5	12	13	1	70	10

* The smaller the figure, the better the performance.

Source: Abayomi *et al* (2001)

Conclusion and Recommendations

Conclusion

The survival of mankind depends on the abundant supply of food by crop plants. Plant growth and productivity however, are adversely affected by nature's wrath in the form of various biotic and abiotic stress factors (Sade *et al*, 2011). Water deficit is one of the major abiotic stress factors, if man would continue to exist, then we have to ensure the continued existence of green plants, by either providing the extra moisture required and/or reconstitute the genetic composition of plants to tolerate moisture stress and maintain productivity **that food may be more abundant.** Prior to now, plant breeders depended on conventional approach for selecting drought tolerant species and genotypes of crops. However, such approach has been found to be laborious and time consuming and less effective. The reductionist approach is an attempt to reduce time lags in breeding and selecting drought tolerant genotypes using morphological, physiological and biochemical characteristics of plants. Most of these methods are fast, inexpensive and amenable to large scale selection programmes. Evidences from our various studies show that considerable differences exist among crop genotypes in their ability to endure drought stress. Out of several evaluation techniques proposed and/or being used to select drought tolerance genotypes, germination at high osmotic pressure and expansive growth measurement techniques were found to have merit as inexpensive, simple and fast methods of screening large populations for drought tolerance and predicting the response of the whole plant in the field. They are therefore useful to breeders in evaluating first and second generations of breeding materials. Nevertheless, other methods such as the measurements of photosynthetic capacity, using potable and commercially available instruments (Infrared Gas Analyzer) can be used for smaller populations such as the advanced lines and parent stocks in germplasms.

Recommendations

Current observations suggest that increasing the level of stress tolerance by reinforcing the plants' defense systems with new genes is an attainable goal. In the light of this, I wish to make the following recommendations that:

- Nigerian scientists, particularly the plant breeders, crop physiologists and agronomists should intensify their efforts at reconstituting crops genes, using new approaches, particularly the physiological and molecular approaches, which would be the most attractive ways to develop new varieties rapidly, so that they will be able to tolerate drought stress better;
- adequate genetic banks of crop species should be maintained and constantly updated with new materials to expand the genetic diversity of each food crop species;
- adequate research funds should be made available for the scientists by the various governments and other stakeholders to enable the scientists to execute the above recommendations;
- we are now in the era of large scale commercial farming when irrigation of farms is inevitable, Federal and State Governments are hereby called

upon to reorganize and re-energize the various River Basin Development Authorities to be able to expand their equipments, construct more dams to be able to cater for more farmers in their areas of jurisdiction for irrigation farming;

- farmers all over the country should take adequate advantage of the Fadama projects of the various Agricultural Development Programmes in various states to produce more crops during the dry season and to plant crop species that will use less water; and
- farmers in Nigeria in general and in the savanna ecologies in particular should choose varieties and planting periods that will decrease the probabilities of soil water deficit occurring at flowering and grain-filling stages for optimum crops yields **that food may be more abundant**.

Acknowledgements

Mr. Vice-Chancellor, sir, distinguished Ladies and Gentlemen I would like to seize this opportunity to thank Almighty Allah (SWT) for His mercy, faithfulness in putting all plants and animals at the disposal of man, and the gift of life that I am here today to deliver the 2nd Inaugural Lecture of the Department of Agronomy of this great University against all odds; and to appreciate all the people who have contributed one way or the other to my life. These people are too numerous to mention their names individually, but they are all covered in the following groups:

My parents (both of blessed memory, May Allah grant them Alijana Fridaus); my brothers and sisters and

the entire Abayomi and Tijani families; my teachers at all levels of education; my colleagues at the Unilorin Sugar Research Institute, at the Department of Crop Production, at the Department of Agronomy; Colleagues at the Faculty of Agriculture, including the current and all past deans, all Heads and staff of other Departments, past and present Sub-Deans of Agriculture, past and present Faculty Officers and Faculty Accountants; my students, undergraduates and graduates, past and present; the unknown reviewers of my manuscripts as well as the assessors of my publications; friends of the family; my in-laws including Arokoto and Areosegbe families; Unilorin Muslim Community under the leadership of the Chief Imam, Prof. AbdulGaniy AbdulSalam Oladosu; my nuclear family members including my Darling wife, friend and excellent partner in progress, Deaconess Olufemi Arike Abayomi for her commitment to the marriage, standing by me during various trying periods, her relentless prayers for the family and above all for giving me brilliant, obedient and God-fearing children and to the "ABAYOMI BOYS", Babatunde, Obafemi and Olalekan ('Twin brothers'), Abiodun and Olwuwapelumi, I say bravo to you for giving me rest of mind and being reliable and dependable research assistants whenever I needed one, I am proud of you all; my special appreciation to the University of Ilorin, under the leadership of our amiable Vice-Chancellor, Prof. AbdulGaniyu Ambali, for giving me the opportunity to present this lecture; my profound gratitude to the members of the "Editorial Board" comprising of Professors K. L. Ayorinde, who modified the original title, A. A. Adeloye, who reviewed the text and Y. A. Quadri, who proof-read the final text and finally my deepest appreciation to all of you seated, for your kind attention and patience. To all of you I say *gracia, merci,* thank you**, and God Bless.**

References

Abayomi, Y.A. (1987). Growth, Yield and Quality performance of sugarcane cultivar Co 957 under different rates of application of nitrogen and potassium fertilizers. *Journal of Agricultural Science, Cambridge* 109: 285 – 292.

Abayomi, Y. A.; Etejere, E.O. and Fadayomi, O. (1988). Effects of nitrogen level and water deficit on nitrate reductase activity (NRA) from leaves of two commercial sugarcane cultivars Co 957 and Co 1001. *Turrialba* 38(4): 352 – 358.

Abayomi, Y. A. (1989). Nitrogen use efficiency and drought tolerance capacity evaluations of two commercial sugarcane cultivars. *Nigerian Journal of Agronomy* 4(1): 7 – 14.

Abayomi, Y. A.; Etejere, E.O. and Fadayomi, O. (1990).Effects of stalk section, coverage depth and date of first irrigation on seed cane germination of two commercial sugarcane cultivars in Nigeria. *Turrialba* 40(1): 58 – 62.

Abayomi, Y.A. (1992). Comparative effects of water stress on wheat and sugar beet. Ph.D. Thesis, University of Wales, Bangor, UK.

Abayomi, A. and Mobolaji, G. O. (1995). Germination responses of six sugarcane (*Saccharum officinarum,* L) lines to osmotically induced water stress. *Bangladesh Journal of Sugarcane* 17: 23 – 30.

Abayomi, Y. A. (1996). Interactive effects of moisture, nitrogen and phosphorus fertilizers application on growth and biomass yield of a commercial sugarcane cultivar Co 957. *Biosciences Research Communications* 8(1): 57 – 67.

Abayomi, Y. A. and Saliu, L. O. (1997). Emergence and seedling vigour responses to simulated sub-optimal moisture conditions in twelve open pollinated maize (*Zea mays,* L) varieties. *Biosciences Research Communications* 9(1): 21 - 28.

Abayomi, Y. A and Jatto, F. D. A. (1998). Performance of intercropped maize (*Zea mays,* L) and cowpea (*Vigna unguiculata* (L) Walp.)as affected by maize architecture and nitrogen fertilizer application. *Biosciences Research Communications* 10(3): 185 – 196.

Abayomi, Y. A. and Lawal, O. J. (1998). Effect of water stress on growth and biomass yield of contrasting genotypes of sugarcane (*Saccharum officinarum* L). *Ghana Journal of Agricultural Science* 31: 73 – 80.

Abayomi, A. (1999). Interactive effects of variety and water stress induced at different stages on grain yield and yield components of spring wheat (*Triticum aestivum* L). *Nigerian Journal of pure and applied Sciences* 14: 877 – 888.

Abayomi, Y. A. and Wright, D. (1999a). Osmotic potential and temperature effects on germination of spring wheat (*Triticum aestivum* L) genotypes. *Tropical Agriculture* (Trinidad). 76(2): 114 – 119.

Abayomi, Y. A. and Wright, D. (1999b). Effects of water stress on growth and yield of spring wheat (*Triticum aestivum* L) genotypes. *Tropical Agriculture* (Trinidad). 76(2): 120 – 125.

Abayomi, Y. A. (2000). Influence of maize variety height on productivity of intercropped maize (*Zea mays,* L) and cowpea (*Vigna unguiculata* (L) Walp). *Ghana Journal of Agricultural Science* 33: 199 – 206.

Abayomi, Y. A. and Wright D. (2000). Effect of water stress at different growth stages on photosynthesis, stomatal conductance, evapotranspiration and water use efficiency in wheat. *Nigerian Journal of Botany* 13:13 – 22.

Abayomi, Y. A.; Afolabi, E. S. and Aderolu, M. A. (2001). Effects of water stress at different stages of growth, on growth, grain yield and seed quality of cowpea genotypes. *Nigerian Society for Experimental Biology Journal* 1: 87 – 97.

Abayomi, Y.A.; Fadayomi, O.; Babatola, J. O. and Tian, G. (2001). Evaluation of selected legume cover crops for biomass production, dry season survival and soil fertility improvement in a moist savannah location in Nigeria. *.African Crop Science Journal* 9(4): 615 – 627.

Abayomi, Y. A. and Wright, D. (2002). Sugarbeet leaf growth and yield response to soil water stress. *.African Crop Science Journal* 10(1): 51 – 66.

Abayomi, Y. A.; Alabi, J. O. and Mustapha, W.O. (2003). Comparative growth responses of field- and pot- grown open pollinated maize varieties to N fertilizer application. *African Scientist* 4(4): 171 – 189.

Abayomi, Y. A and Adedoyin, G. A. (2004a). Effects of Planting dates and nitrogen fertilizer application on growth and yield of contrasting genotypes of maize (*Zea mays* L) I: Leaf growth and its relationship with grain yield. *Journal of Agricultural Research and Development* 3: 83 – 98.

Abayomi, Y. A. (2004). Interactive effects of water stress and nitrogen application on growth yields of hybrid maize varieties. *Plant Scientist* 4(4):66 – 80.

Abayomi, Y. A and Adedoyin, G. A. (2004b). Effects of Planting dates and nitrogen fertilizer application on growth and yield of contrasting genotypes of maize (*Zea mays* L) II:

Morpho-physiological growth characters and their contributions to grain yield. *Nigerian Journal of Pure and Applied Sciences* 19: 1641 – 1652.

Abayomi, Y. A. and Fagbenja, O. (2005). Morpho-physiological basis for yield variation in varieties of maize (*Zea mays* L) at different levels of nitrogen fertilizer application. *Journal of Agricultural Research and Development* 4(1): 31 - 57.

Abayomi, Y. A. and A. M. Adeniyi (2005). Comparative germination responses of cowpea and maize genotypes to soil moisture content. *Agrosearch* 7(1): 29 – 36.

Abayomi, Y.A. (2006). Effects of soil moisture stress on floral and pods abortion, reproductive efficiency and grain yield in soybean genotypes (*Glycine max* (L) Merrill). *Moor Journal of Agricultural Research* 7(1):9-17.

Abayomi, Y. A., A. Arijenja-George and I. A. Kolawole (2006). Comparative leaf growth and grain yield responses of hybrid and open-pollinated maize genotypes to nitrogen fertilizer application.

Abayomi, Y. A. (2008). Comparative growth and grain yield responses of early and late soybean maturity groups to induced soil moisture stress at different growth stages. *World Journal of Agriculture* 4(1):71-78.

Abayomi, Y. A.; Ajibade, T. V.; Samuel, O. F. and Sa'adudeen, B. F. (2008). Growth and yield responses of cowpea (*Vigna unguiculata* (L) Walp) genotypes to fertilizer (NPK) application in the southern Guinea savanna zone. *Asian Journal of Plant Sciences* 7(2):170-176.

Abayomi, Y.A. and E.O. Adefila (2008). Interactive effects of soil moisture level and fertilizer application on growth and yield of sunflower (*Helianthus annus,* L). *Journal of Agronomy* 7(2):182-186.

Abayomi, Y.A. and T.O. Abidoye (2009). Screening of cowpea genotypes for soil moisture stress tolerance. *African Journal of Plant Science* 3(10):229-237.

Abayomi, Y. A. and J. Mahamood (2009). Comparative field evaluation of old and newly developed soybean (*Glycine max,* L. Merrill) genotypes in the southern Guinea savanna of Nigeria. *Crop Research* 38(1,2&3):43-50.

Adetiloye, P.O. (1980). Growth, development and yield in sole and intercrop cowpea (*Vigna unguiculata* (L) Walp) and maize (*Zea mays* L). Ph.D. Thesis, University of Nigeria, Nsukka, Nigeria. 385pp.

Adetiloye, P.O. and A.W. Salau (2002). Response of soybean to inoculation with Rhizobium in South Western Nigeria. *Tropical Oilseeds Journal*, 7:1-11.

Aduloju, M.O.; J. Mahamood and **Y. A. Abayomi** (2009). Evaluation of soybean (*Glycine max,*(L). Merrill) genotypes for adaptability to a southern Guinea savanna environment with and without P fertilizer application in north central Nigeria. *African Journal of Agricultural Research* 4(6): 556-563.

Amusa, N. A. (2010). Man and microbes in continuous battle. 53rd Inaugural Lecture, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria.

Ashraf, C.M. and S. Abu-Shakra (1978). Wheat seed germination under low temperature and moisture stress. *Agronomy Journal*, 70:135-139.

Bayle, B.B., J.W. Taylor and A.T. Bartel (1937). Rate of water loss in wheat varieties and resistance to artificial drought. *J. Amer. Soc. Agron.* 29:40-52.

Begg, J.E. (1980). Morphological adaptations of leaves to water stress. In "Adaptation to water and high temperature stress". (Eds. N.C. Turner and P.J. Kramer) pp. 33-42. Wiley: New York.

Blum, A. (1979). Genetic improvement of drought resistance in crop plants: A case for sorghum. In "Stress Physiology in Crop Plants". (Eds H. Mussell and R.C Staples) pp. 429-445. Wiley Interscience: New York.

Blum, A., J. Mayer and G. Golan (1989). Agronomic and physiological assessments of genotypic variationfor drought resistance in sorghum. *Aust. J. Agric. Res.*, 40:49-61.

Carrow, R.N., R.C. Shearman and J.R. Watson (1990) .Turfgrass. In irrigation of agricultural crops Agon. Monogr. 30, ASA, CSSA and ASSA (ed. B.A. Stewart and D.R Nielson). Madison, W1. Centre for ClimateChange Research, School of Environmental Sciences, University of Change Scenarios for United Kingdom. The UKCIP02 Scientific Report, Tyndall, pp. 889-919.

Chiezey, U.F. (2001). Pod abortion and grain yield of soybean (Glycine max, (L) Merrill) as affected by nitrogen, phosphorous nutrition in the Northern Guinea savanna zone of Nigeria. *Tropical Oilseed Journal*, 6:1-10.

Clarke J.M. and T.M. McCaig (1982a). Excise-leaf water retention capacity as an indicator of drought resistance in triticum genotypes. *Can. J. Plant Sci.* 62:571-578.

Cortes, P.M. and T.R. Sinclair (1986). Water relations of field-grown soybean under drought. *Crop Science* 26:993-998.

Dedio, W., D.W. Stewart and Green (1976). Evaluation of photosynthesis measuring methods as possible screening techniques for drought resistance in wheat. *Can. J. Plant Sci*. 56:243-247.

Doorenbos, J. and A. H. Kassam (1979). Yield response to water. FAO Publication, FAO Rome.

Ekeleme, F., Akobundu, I. O.; Fadayomi, R.O.; Chikoye, D. and **Abayomi, Y. A.** (2003). Characterization of legume cover crops for weed suppression in the moist savannah of Nigeria. *Weed Technology* 17: 1 – 13.

El-Manhaly, M. A.; Fadayomi, O.; **Abayomi, Y. A.** and Olofinboba M. O. (1984). Control of flowering in two commercial sugarcane varieties. *Journal of Agricultural Science, Cambridge* 103: 333 – 338.

Evans, L.T., J. Bingham, M.A. Roskams (1972). The pattern of grain set within ears of wheat. *Aust. J. Biol. Sci*., 25:1-8.

Fadayomi, O.; **Abayomi, Y. A.** and El-Manhaly, M. A. (1984). Efficacy of selected herbicide mixtures for weed control in sugarcane. *Journal Of Agricultural Science, Cambridge* 103: 503 – 510.

Fadayomi, O. and **Abayomi, Y. A.** (1988a). Weed control in sugarcane with Asulam and Actril DS. *Ife Journal of Agriculture* 10: 29 – 38.

Fadayomi, O. and **Abayomi, Y. A.** (1988b). Effects of varying periods of weed interference on sugarcane (*Saccharum officinarum,* L) growth and yield. *Nigerian Journal of Weed Science* 1:65 – 70.

Fadayomi, O. **Abayomi, A.** and Olaoye, G. (1995). Evaluation of ethephon for the control of flowering in sugarcane at the Bacita Estate, Nigeria. *Sugar Cane (The International Magazine of Cane Agriculture)* 1995 (Jan/Feb) (1): 9 – 17.

Fadayomi, O.; **Abayomi, Y. A.**; Ajayi, A.S. and Tian, G. (2005). Effects of six legume cover crops on yield and soil properties in southern Guinea savanna of Nigeria. *Journal of Tropical Biosciences* 5(1): 51 – 56.

Fischer, R.A., E.C. Johnson and G.O. Edmeades (1983). Breeding and selection for drought resistance in tropical maize. Int. Maize and wheat improvement centre, p.21

Fischer, R.A. and M. Sanchez (1979). Drought resistance in spring wheat cultivars II: Effects of plant water relations. *Aust. J. agric. Res*.30:801-814.

Fredrick, J.R., J.D. Hesketh, D.B. Peters and F.E. Below (1989). Yield and reproductive trait responses of maize hybrids to drought stress. *Maydica* 35:319-328.

Funkai, S. and B. R. Trenbath (1993).Processes determining inter-crop productivity and yields in component crops. *Field Crop Research* 34:247-271.

Gallagher, J.N. and P.V. Biscoe (1979). Field studies of cereals leaf growth III: barley leaf extension in relation to temperature, irradiance and water potential. *J. Exptl. Bot.* 30:645-655.

Gringrich , J.R. and M.B. Russel (1957). A comparision of effects soil moisture tension and osmotic stress on root growth. *Soil Science*, 48:185-194.

Hadjichristodoulou, A. (1987). Stability performance of cereals in low rainfall area as related to adaptive traits. In *Drought Tolerance in winter cereals* (ed. J.P. Strivastava, E. Porceddu, E. Acevedo and S. Varma), pp 191-200. New York, Wiley Interscience for ICARDA.

Halvorson, A.D., A.L. Black, J.M. Krupinsky, S.D. Merrill and D.L. Tanaka (1999). Sunflower response to tillage and nitrogen fertilization under intensive cropping in a wheat rotation. *J. Agron.* 91:637-642.

Hanson, A.D., C.E. Nelsen and E.H. everson (1977). Evaluation of free proline accumulation as an index of drought resistanceusing two contrasting barley cultivars. *Crop Science* 17:720-726.

Hernandez, J.A., M.A. Ferrer, A. Jimenez, A.R. Barcelo and F. Sevilla (2001). Antioxidant system and O_2/H_2O_2 production in the apoplast of *Pisum sativum* L. leaves: its relation with NaCl-induced necrotic lesions in minor veins. *Plant Physiol*. 127:817-831.

Hsiao, T.C. and E. Acevedo (1974). Plants responses to water deficits, water use efficiencies and drought resistance. *Agric. Meteorol*. 14:59-84.

Hsiao, T.C. 1973). Plant responses to water stress. *Ann. Rev. Plant Physiol.* 24:519-570.

Hulse, J.A. (1989). Forward. *In Drought resistance in cereals* (Ed F.W.G. Baker) CAB International for ICSU Press.

Jalee, C. A., P. Manivannan, A. Wahid, M. Farooq, H. J. Al-Juburi, R. Somasundram and R. Panneerselvam (2009). Drought stress in plants: A review of morphological characteristics and pigments composition. *Int. J. Agric. Biol.*, 11: 100-105.

Johnson, D.A., R.A. Richards and N.C. Turner(1983).Yield, water relations, gas exchange and surface reflectances of near-isogenic wheat lines differing in glaucousness. *Crop Science* 23:318-325.

Johnson, R.C. and E.T. Kamenrasu (1982). The influence of water availability on winter wheat yields. *Can. J. Plant Sci*. 62:831-838.

Korte, L.L., J.E. Specht, J.H. Williams and R. C. Sorensen (1983b). Irrigation of soybean genotypes during reproductive ontogeny II: Yield components responses. Crop Science, 23:528-533.

Kramer, P.J. (1983). *Water Relations of Plants*. AcademicPress: New York

Lafond, G.P. and R.J. Baker (1986). Effects of temperature, moisture stress and seed size on germination of nine spring wheat cultivars. *Crop Science,* 26:563-567.

Lal, R. (1989). Agroforestry systems and soil surface management of a tropical Alfisol II: Changes in soil chemical properties. *Agroforestry System* 8:113-132.

Lawlor, D.W. and G. Comie (2002). Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant Cell Environ*. 25:275-295.

Lawlow, D.W. and G.F.J. Milford (1973). The effect of sodium on the growth of water-stressed sugar beet. *Annals of Botany*, 37:597-604.

Milford, G.F.J., T.O. Pocock, J.Riley and A.B. Messem (1985). An analysis of leaf growth in sugar beet III: Leaf expansion in field crops. *Ann. Appl. Biol.* 106:187-203.

Mohammeed-Salem, S.A. (1986). The ecology, vegetation and land use of sub-humid Nigeria. In Livestock system research in Nigeria's sub-humid zone. Proceedings of second ILCA/NAPRI Symposium held in Kaduna, Nigeria, 29 October – 2 November1984. Von Kaufmann, R., S. Chater and R. Belneh (Eds.). ILCA (International Livestock Entre for Africa), Addis Ababa, Ethiopia.

Mahamood, J.; **Y. A. Abayomi** and M. O. Aduloju (2009). Comparative growth and grain yield responses of soybean genotypes to phosphorus fertilizer application. *African Journal of Biotechnology* 8(6): 1030-1036.

Moss, D.N., J.T. Woolley and J.F. Stone (1974).Plant modification for more efficient water use: the challenge. *Agric. Meteorol.* 14:311-320.

Mulongoy, K. and B.T. Kang (1986). The role of potential forage legumes in alley cropping, live mulch and rotational systems in Humid and sub-humid tropical Africa. In Potential of forage legumes in farming system of sub-saharan Africa. Hague, I., S. Jutzi and P.J.H. Nestle (Eds.), pp.212-231. Proceeding of workshop held at ILCA

(International Livestock Entre for Africa), Addis Ababa, Ethiopia.

Naidu, K.M., S. Venkataramana and P.N. Gururaja Rao (1983).Varietal variation in stomata inductance and diffusion resistance during moisture stress and recovery in sugarcane. ISSCT Proceedings 18:567-584.

Nasir, S. (1994). Crop Production. In Oil seed crops, Bashir, E. and R. Bantol (Eds.) National Book Foundation, Islamabad, pp.348.

Natarajan , B.V. (1978). Breeding of improved cane varieties for Nigeria Sugar Industry. Proceedings of International Symposium on Sugarcane in Nigeria (August 28 – September 1, 1978) organized by National Cereal Research Institute, Nigeria. Pp. 73-79.

Nemeth, M., T. Janda, E. Horvath, E. Paldi and G. Szalai (2002). Exogenous salicyclic acid increase polyamine content but may decrease drought tolerance in maize. *Plant Science*, 162:569-574.

Nworgu, F.C. (1993). Effect of plant growth regulators on soybean growth and yield. Ph.D. Thesis, Moscow Agric.Academy, Russia; pp.56-75.

Root, W.R., P.O. Oyekan, and K.E. Dashiell (1985). West and Central Africa: Nigeria set example for expansion of soybean. In Singh *et al.* (eds). Soybean for the Tropics. John Wiley and Sons Ltd.

Ogunremi, E.A. (1980). Response of sunflower to NPK fertilizer in Southern Nigeria. *East Afr. J. Agric. For.* 45:264-268.

Okigbo, B.N. (1985). Land use productive potential of Africa savanna. In Ecology and Management of the world's savanna. Tothill, J.C. and J.J Moh (Eds.), pp.95-106. Australian Academy of Science, Camberra, Australia/CAB

(Commonwealth Agricutural Bureau), Farham Royal Bucks, UK.

Orisamika, V.A. (1993). Effect of nitrogen on the growth, yield and seed oil percentage in some accessions of sunflower. M.Sc. Thesis, University of Ilorin, Nigeria.

O'Toole, J.C., N.C. Turner, O.P. Namuco, M. Dingkuhn and K. A. Gomez (1984). Comparision of some crop water stress measurement methods. *Crop Science* 24:1121-1128.

Owonubi, J.J. and Abdumumin, (1985). Forecasting drought in Nigeria. An invited paperpresented at the first National Workshop on Ecological Disasters. Sponsored by the Federal Ministry of Education, Science and Technology. Kano, 9-12 December, 1985.

Root, W.R., P.O. Oyekan and K.E. Dashiell (1985). West and Central Africa, Nigeria set example for expansion of soybeans. In Singh *et al* (Eds). Soybean for the Tropics. John Wiley and Sons Ltd.

Sade Bayram, Suleyman Soylu and Elif Yetim (2011). Drought and oxidative stress. *African Journal of Biotechnology,* 10(54): 11102 – 11109.

Sairam, R.K. and S.D. Dube, (1984). Effect of moisture stress on nitrate reductase activity in rice in relation to drought tolerance. *J. Plant Physiol.* 27(3):264-270.

Schonfeed, M.H., R.C. Johnson, B.F. Carver and D.W. Mornhinweg (1988). Water relations in wheatas drought resistance indicators. *Crop Science*, 28:526-531.

Scott, K. and K. Jaggard (1978). How the crop grows: from seed to sugar. British Sugar beet Review, Winter 1978: 19-22.

Shackle, K.A. and A.E. Hall (1983). Comparision of water relations and osmotic adjustment in sorghum and cowpea under field condition. *Aust. J. plant Physiol*. 10:423-435.

Siddique, M. R. B., A. Hamid and M. S. (2000). Drought stress effects on water relation of wheat. *Bot. Bull. Acad. Sin* 41(1):35 – 39.

Sinha, S.K. and V. Rajgopal (1975).Effect of moisture on nitrate reductase activity and accumulation of protein in sorghum. Proceeding of the symposium “Crop plant responses to environmental stresse” held at Vivekanda Parvatya Krishi Amusandham Shala Almora (U.P) on July 4, 1975. Pp.36-44.

Smith, R.L., C.S. Hoveland and W.W. Hanna (1989). Water stress and temperature in relation to seed germination of pearl millet and sorghum. *Agronomy Journal*, 81:303-305.

Stance, A.M., M. Odoardi, P. Martiniello, L. Cattivelli, C. Lorenzoni and N. Marmiroli (1987). Biochemical and physiological response to heat and water stress. In *Drought tolerance in winter cereals*. (Eds: J.P. Srivastava, E. Porceddu, E. Acevedo and S. Varma) pp. 115-122. Wiley Interscience : New York. (For ICARDA).

Sullivan, C.Y. and W.M. Ross (1979).Selecting for drought and heat resistance in grain sorghum. Pp 447-464. In H. Mussell and R.C. Staples (eds.) *Stress physiology in crop plants*. John Wiley and Sons, New York.

Tarawali, G. (1991). Residual effects of Stylosanthes fodder banks on grain yield of maize. *Tropical Grassaland*, 25:26-31.

Tarawali, G., M.A. Mohammed-Saleem and R. Von Kaufmann (1987). Comparision of labour requirements for cropping maize on land previously used for Stylosanthes fodder banks and an adjacent fallow in the sub-humid zone of Nigeria. ILCA Bulletin 26:36-39. ILCA (International Livestock Entre for Africa), Addis Ababa, Ethiopia.

Turk, K.J., A,E. Hall and C.W. Asbell (1980). Drought adaptations of cowpea I: Influence of drought on seed yield. *Agronomy Journal*, 72:413-420.

Vallis, J. and C.J. Gardner (1984). Nitrogen inputs into agricultural system by *Stylosanthes*. In *The Biology and Agronomy of Stylosanthes.* Stance, H.M. and L.A. Edye (Eds.), pp.359-380. Academy Press: Australia.

Viqueira, L., L. Goniez and C. Rodiriguez (1983).Effect of water deficiency on two sugarcane varieties. 18th Congress, ISSCT Proceedings: 539-565.

Watson, D.J. (1947). Comparative physiological studies on the growth of field crop II: The effect of nutrient supply on net assimilation rate and leaf area. *Annals of Botany,* 11:375-407.

Wien, H.C., E.J. Littleton and A. Ayanaba (1979). Drought stress of cowpea and soybean under tropical conditions. In "Stress Physiology of Crop Plants" (Eds. H. Mussell and R.C. Staples), pp. 283-301. Wilet Interscience: new York.

Winter, S.K., J.T. Musik and K.B. Porter (1988). Evaluation of screening techniques for breeding for drought resistant winter wheat. *Crop Science* 28: 512-516.

Zimdahl, R.L. (1980). *Weed-Crop Competition, a review*, 196pp. Corvallis, Oregon: International Plant Protection Centre.