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WEEDS: DISPENSABLE COMPANION OF FARMERS

By

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Professor of Weed Science

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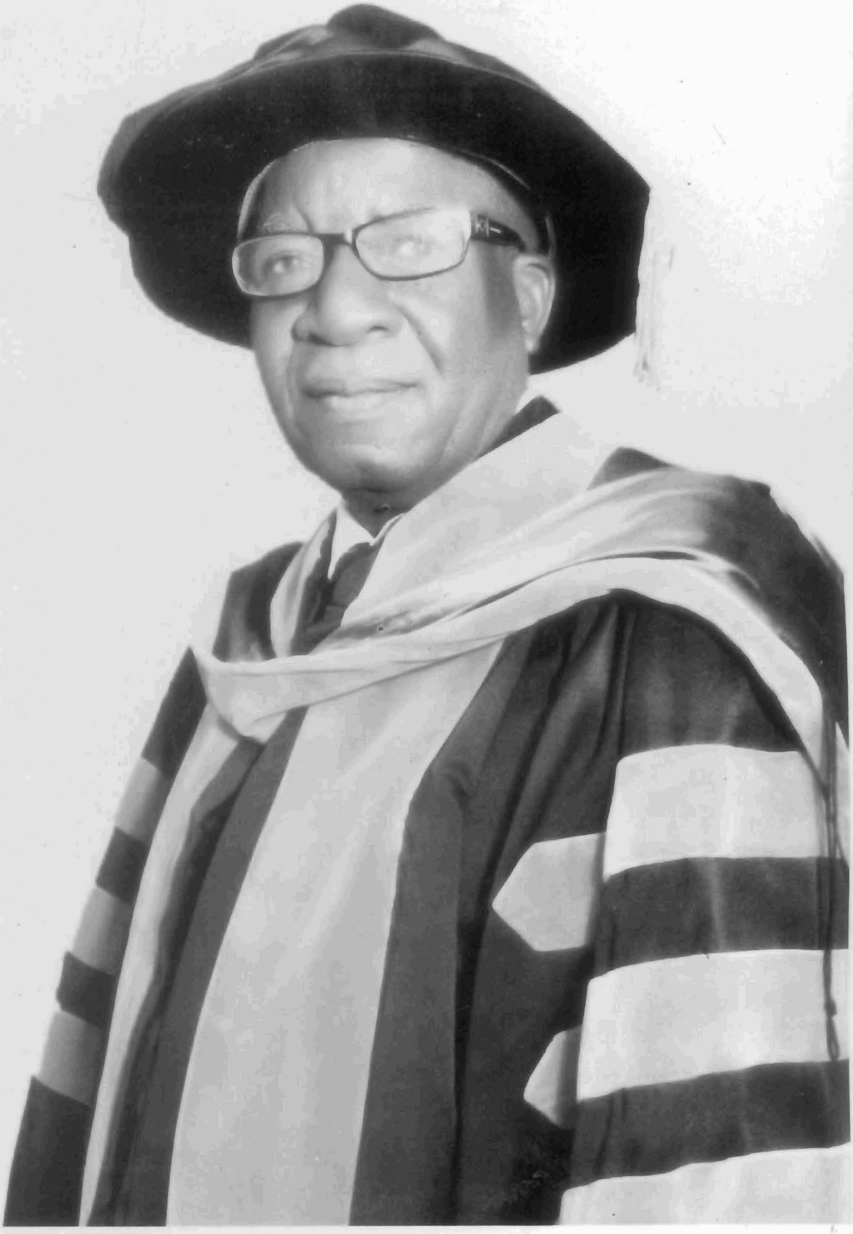

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INTRODUCTION

Weeds: Concept and Definition

Weeds evolved as a consequence of human activities. For most of the time the ancestors of modern humans diverged from the ancestors of living great apes, around 7 million years ago, all humans on earth fed themselves exclusively by hunting wild animals and gathering wild plants until within the last 11,000 years that some peoples turned to what is termed food production i.e. domesticating wild animals and plants and eating the resulting livestock and crops (Diamond, 1999). Among wild plant and animal species , only a few are edible to humans, by selecting and growing those few species of plants and animals that we can eat, we obtain far more edible calories per ha, as a result one ha can feed many more farmers. In order to allow the selected plant species grow and produce to its potential, unwanted vegetation have to be removed hence the concept of weeds.

The word 'weed' was first used in its present form by Jeffry Toll in 1731 (Klingman, 1996), invariably the beginning of agriculture. Different names were given to these unwanted vegetation which may be herbs, shrubs or trees; such names include 'plants growing where it is not wanted', plants growing out of place', 'plants for which uses have not been established' etc. It was not until the International Weed Control Congress jointly held by the International Weed Science Society (IWSS) and the European Weed Research Society (EWRS) in Copenhagen, Denmark, 25-28 June 1996 that the nomenclature was resolved and a common definition of weeds was adopted. At the Conference, Weed Scientists agreed and defined weeds as *'Any plant which grows spontaneously in a managed ecosystem, and which has negative impact on human activity'*. Thus, at the center of this definition is the human factor: negative impact on human activities. It is this human factor that makes the study of weeds obligatory if not compulsory.

Mr. Vice-Chancellor sir, the title of this inaugural lecture is *WEEDS: DISPENSABLE COMPANION OF FARMERS*. This is the first inaugural lecture on Weed Science at the Obafemi Awolowo University (OAU) Ile-Ife and the third in Nigeria. It is my honor and privilege to address you. But first let me provide the perspective for a digest of the inaugural.

Advocacy of Weed Science

Weed Science Societies

As human beings evolved, moving from the Hunter-Gatherer state to food production and sedentary life, weeds continue to be a troublesome companion to the farmers. However, it is not until 1956 that a group of Scientists working on various aspects of weeds got together to establish the Weed Science Society of America (WSSA). The objectives of the society were and still are to study the biology, ecology, control and related issues of weeds and evolve ways to dislodge this troublesome companion. This Society publishes the **Journal of Weed Science**, **Weed Technology, Weeds Today** and holds an annual conference. Shortly after this, Weed Science Societies sprang up in many areas of the world. In 1971, a group of scientists at Ife, Professor W. W. Sanford of Botany Department, Professor A. M. A. Imevbore of Zoology Department, Dr. A.C. Adebona of Botany Department, Dr. B.E. Onochie of Plant Science (now Department of Crop Production and Protection), and Professor Ajibola Taylor of the Institute of Agricultural Research and Training, Ibadan, came together to establish the Weeds Group which later transmuted to the present day Weed Science Society of Nigeria (WSSN) with similar objectives as the WSSA.

The activities of the WSSN were initially very low until a few people who had just returned from study abroad joined the Society and by 1985 organized the first international Conference on weeds in Nigeria. At the end of the conference held at the University of Ibadan (UI), I was elected National Secretary of the Society with Dr. N.J. Usoro as National President. Some life came into the Society and annual conferences became regular. At the annual Conference held at the Tafawa Balewa University, Bauchi in 1987 at the age of 40 years and barely three years of my membership of the Society, I was elected the National President of the WSSN. The Executive of the society, under my leadership, hype the activities of the Society including the appointment of an Editor-in- Chief in person of Professor R.O. Fadayomi and the funding for the publication of the Nigerian Journal of Weed Science (NJWS). At the November 1988 Conference held at the Obafemi Awolowo University, my Executive launched the first edition, Volume 1, No 1 of the Nigerian Journal of Weed Science (NJWS). I later served as Editor- in- Chief of the NJWS for 10 years from 1997 to 2007 and was at the top leadership position, present at every annual meeting and conferences continuously for the next 28 years. Since its first publication in 1988 the NJWS has continuously been published even as of today without missing a year, just as the Society has continuously held its annual conferences unbroken since 1985. In November 2008 at the annual Conference held at the Federal University of Technology, Akure, at a brief but impressive ceremony, I was conferred with the Fellowship of the Weed Science Society of Nigeria, the first Fellowship to be so awarded by the WSSN, in recognition of my contribution to the growth of the Society.

National Advisory Committee on Weed Control

Sometime in 1979, the Federal Government of Nigeria was alerted to a plan by some foreign nationals to import unwholesome agrochemicals, essentially herbicides, to Nigeria. In response to the threat, the Federal Ministry of Agriculture and

Rural Development (FMARD), Department of Agriculture put together some experts on herbicides and named the committee 'National Advisory Committee on Weed Control' (NACWC) at the submission and acceptance of the report of the expert committee. The Committee was domiciled in the Department of Agriculture of the FMARD. As the name suggests the scope of the committee was extended to cover advisory on weed control. The Chairman of the Committee was Dr I.O. Akobundu, then of the International Institute of Tropical Agriculture (IITA), Ibadan. Membership of the Committee was 12 comprising of only those with training in core weed science. In 1983, barely two years of my joining the staff of the University, I was invited to the membership of this committee. The Committee commissioned studies in various parts of the country and periodically publishes an advisory pamphlet on weed control. The last publication of this very important document was '*Weed Control Recommendations for Nigeria: Series 3*' of 1994 with Honorable Mallam Adamu Ciroma, as then Minister of Agriculture. This comprehensive document covers all agro- ecological zones of Nigeria both in terms of crops and weeds, and laid out weed control recommendations for arable and plantation crops of each region. The contents of this document are still relevant today and the Committee continues to serve the nation.

WEED CONTROL

Weeds are generally annuals or perennials, climbing or erect; they can be herbaceous, shrubs or trees. Many weeds possess underground parts that impose special problem of control. Seeds longevity, dormancy and depth in soil all combine to make control a complex issue. Thus,today there is no single method to completely control or restrict the growth of unwanted vegetation. Yet, if the farmer must grow his food to the full potential of the crop he must dispense with weeds; he cannot prevent or eradicate weeds. Some selected methods of weed control will be briefly discussed.

Methods of Weed Control

The first known method of weed control is manual, and this has been practiced from the beginning of agriculture, as the farmer decided for a sedentary life away from Hunter-Gatherer, and domesticated plants for food production. This method involves the physical removal of unwanted vegetation, with bare hands or the use of small tools as civilization progresses. This method is efficient for house hold and home garden use but it limits the area of land that a farmer can cultivate. In order to derive full benefit, the Nigerian farmer acquires several wives and children for help on the farm to increase his farm holdings. The drudgery of the exercise, bending down from dawn to dusk in a full season year- in year- out, invariably makes the farmer acquire a permanent stooping posture. Manual weed control is still practiced today by our farmers who are mostly 55 years in age, cropping less than 2 ha of land, producing barely one ton per ha of maize for example , but still feeding the nation.

Mechanical control of weeds began with the development of the plow and disc. The blade cuts deep into the soil and turns the sod thereby burying the weed. The weeds so buried are starved of sunlight and hence unable to photosynthesize and dies of starvation. The weeds are dead within two weeks; the harrow pulverizes the soil and shred any remaining stubble. Initially the plow and harrow were animal driven but with the development of the tractor, mechanical cultivation became a routine practice on farms. Mechanical cultivation allows large tracks of land to be cultivated without the drudgery of manual weeding, however, with time it soon became apparent that some adverse ecological effects are inadvertently associated with mechanical cultivation of plow and harrow. Such adverse effects include predisposal of soils to erodibility and erosivity forces.

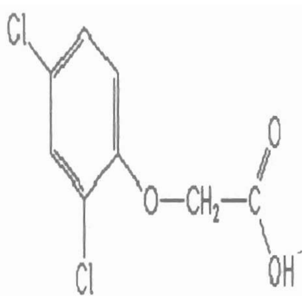
Also, while mechanical cultivation has become routine practice in the developed economies, most developing economies have limited access to the technology due largely to cost outlay. Thus while a farmer in the United States has an average of 2 tractors to himself allowing him to cultivate over a hundred hectares at a time, statistically over 1000 farmers in Nigeria share one tractor thereby severely limiting his capacity to farm beyond 2 ha at a time.

Major advances in chemical control of weeds, chemical energy, to replace or reduce mechanical energy began in the mid twentieth century shortly after the end of the second world war,1944/1945. At this time, for the first time since the beginning of the century, scientists from America and Europe were able to meet and exchange findings. At one of such meetings it was revealed that 2,4-D (***2,4-dichlorophenoxyacetic acid***) had been discovered and tested in USA as a selective herbicide, a couple of years earlier while a variant , MCPA ***(2-methyl-4-chlorophenoxyacetic acid***) (Fig 1) was developed and tested in England (Klingman, 1966). Before this period, however, isolated tests of potential herbicides were carried out in both Europe and America.

Weed-killing chemicals are called herbicides. There are three major types of herbicides depending on their effects on plants: contact, growth regulators, and soil sterilants. Contact herbicides kill plant parts that are covered by the herbicide; the chemicals are directly toxic to living cells. These group of chemicals have limited translocation in the phloem but may move upwards in the non- living xylem with transpiration stream. Effects of contact herbicides are acute, the plant dies quickly after contact making it more effective on annual plants. Contact herbicides can be selective, killing some plants with little or no injury to others, or non- selective, toxic to all plants. Most contact herbicides are non- selective. Growth regulators are systemic herbicides, absorbed by either the roots or above-ground parts and translocated, apolastic or symplastic, through the plant system, upsetting the plants' growth and metabolic processes especially the enzyme system. The effects of systemic herbicides are chronic, the full effect showing up several days, weeks or months after application. Systemic herbicides may be selective or non-selective. However, an overdose on the leaves may kill the plant and prevent effective translocation and may injure all plants. Any chemical which prevents the growth of green plants when present in the soil is considered a soil sterilant. When a chemical sterilises the soil for less than 48 hours it is said to have no residual toxicity, if for 4 months or less, it is considered a temporary soil sterilant, four months to 2 years as semi-permanent and for more than 2 years as a permanent soil sterilant. The rate and frequency of herbicide application, soil and climatic conditions determine the length of time that a chemical remains in the soil or its persistence.

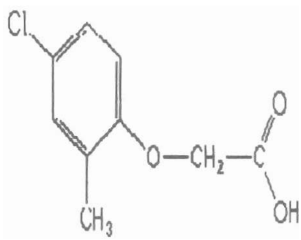
The time of application of an herbicide may be given with respect to the crop or the weed. Pre-planting treatment is any treatment made before the crop is planted. Pre-emergence refers to treatment made prior to emergence of a specified crop or weed but more technically to weeds. The treatment may be applied to both the crop and weeds or just to the weeds. Post emergence treatment is any treatment made after emergence of a specified crop or weed. Often, the chemical may be applied post-emergence to the crop, but pre-emergence to the weeds. Chemicals are applied broadcast, band, directed spray or as spot treatment. Broadcast application is uniform application to the entire field; band application usually means treating a narrow strip or crop row. In band application the space between the rows is not chemically treated but usually cultivated for weed control with comparative savings in chemical cost and reduced soil residue. Directed sprays are applied to particular part of the plant, usually the lower part of the stem or trunk just above the soil level. Spot treatment is restricted to small spots on the field where particular weed species require special treatment. Appropriate equipment exist for the various applications.

Some other methods of weed control exist that are of limited application. Such methods include biological control where biotic agents are deployed for the control of weeds; the use of flames and water level to check the growth of unwanted vegetation. Integrated weed control or management has been given some new impetus in recent time as a result of cries of environmental pollution from the use and abuse of herbicides. The broad objective of integrated control is to minimize use of synthetic chemicals in the environment in order to reduce the adverse effects. This entails where appropriate the integration of manual, mechanical and chemical control options. Crop rotation and use of weed free seeds are other approaches to enhance weed control.



2, 4-Dichlorophenoxyacetic acid

(2, 4-D)



2-methyl-4-chlorophenoxyacetic Acid

(MCPA)

Fig. 1: Structure of 2, 4-D and MCPA (Phenoxy Compounds)

Mr. Vice-Chancellor, Sir

CONTRIBUTIONS TO WEED SCIENCE

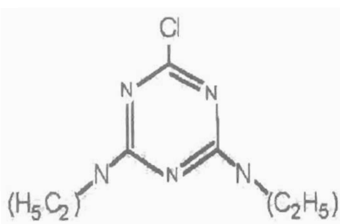
The Beginning

In the mid seventies, in North America, Scientists were faced with the demand for more fibre for the manufacture of paper from an unusual source, the fast growing *Populus* species mainly *Populus tremuloides* L., commonly called poplar. The demand was to make poplar produce more fibre per unit land space. Grants were then being provided to investigate the cultivation of Poplar in a short rotation intensive culture (SRIC) (borrowing from the agronomy of arable crops) to meet the expanding demand for the paper industry. Thus in 1978 in my second year at the graduate school, I was awarded a graduate fellowship grant by the Department of Forestry at the Michigan State University, East Lansing Michigan (MI), United States of America (USA), to develop a weed control prescription for the large scale cultivation of Poplar in SRIC. Poplars are deciduous, sometime semi-evergreen forest trees with a wide distribution in Northern Hemisphere. Stem form is characteristically tall and straight (excurrent), they are short lived but of fast growth rate often enabling them to reach large size. Establishment of clonal poplar plants with hard wood stems, anthropogenic form of vegetative reproduction, employs 20-to 30- cm long sections of dormant, 1 year old woody shoots as planting stock; when planted early spring they quickly produce roots from existing primordia in the inner bark and new shoots from the buds; the resultant clonal plants often grow several meters tall in the first growing season; the wood of poplar is very versatile and widely used in the industry for pulp and paper, (Dickmann *et. al.* 2001). The above attributes predisposes poplar to SRIC for which the grant was awarded. A series of studies were then conducted in the field, greenhouse and laboratory between 1978 and 1980.

The studies investigated the effect of tillage, clone, herbicides Simazine ***(2-chloro-4,6-bis(ethylamino)-s-triazine***) and Diuron ***(3-(3,4-dichlorophenyl urea***) (Fig 2) and their interaction on the establishment of poplar plantation in different parts of Michigan; the influence of simazine on total nitrogen concentration in foliage of field-grown poplar clones; the dose response of selected poplar clones treated with varying rates of simazine or diuron in the greenhouse and variation in photosynthesis, leaf conductance and leaf morphology of poplar clones identified as tolerant and intolerant clones. Results of the series of investigations provided empirical evidence that tillage and herbicides at the beginning of the season benefitted all clones tested ; high doses of each herbicide were toxic to all clones except H 47 which appeared to be relatively tolerant; in a 21 clonal screening, Tacamahaca (Section) hybrids and interaction crosses between Tacamahaca and Aigeiros (Section) were relatively intolerant whereas Aigeiros clones were relatively tolerant; addition of 5 mg of simazine had no deleterious effect on NC 5328 (Section Aigeiros) but reduced the rate of co2 fixation, increased co2 compensation concentrations and lowered specific leaf weight of clone NE 388 (Section Tacamahaca); deleterious effects of simazine on NE 388 were detected ca. 48 hr after exposure and generally became more pronounced thereafter etc. (Akinyemiju, 1980; Akinyemiju and Dickmann, 1982a, b, c; Akinyemiju et. al. 1983). These results were the first set of empirical data to support the cultivation of Poplar in Short Rotation Intensive Culture (SRIC) and with similar results elsewhere form the basis for the adoption of SRIC of Poplar in North America in current use today.

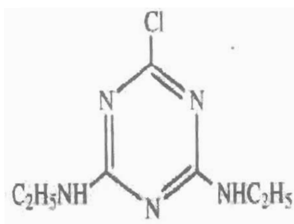
At the North America Poplar Council Conference held in Detroit ,Michigan, February, 1980, I presented a paper titled *'The Influence of Tillage and the Herbicides Simazine and Diuron on establishment of Poplar Clones in Lower Michigan'*, one of the several papers from the above study. The paper was received with ovation and at the end of the presentation, the Director, Forestry Sciences Laboratory (Forest Genetics Lab), one of the foremost research stations of the Department of Agriculture of the United States Government, offered me a post-doctoral position of one year duration in the research laboratory in Rhinelander, Wisconsin even though my Ph.D. defense was still some 7 months away. After my graduation I accepted the Post-Doctoral Fellowship.

Between January and September of 1981, I screened in the greenhouse several of the Poplar clones produced by the breeders in the Forest Genetics Laboratory at Rhinelander, to glyphosate ***(N-(Phosphono-methyl) glycine***) (Fig3), a systemic broad spectrum foliar applied herbicide. Field studies were also conducted to complement the greenhouse studies. The results of the studies also confirm for the first time that glyphosate can be used successfully for weed control in SRIC poplar plantations if no chemical is allowed to contact green tissue or if applied in the dormant season (Akinyemiju et. al. 1982). Some of these results form the basis for a later work in the Forestry Sciences Laboratory to identify the shikimic acid parthway (Amino acid synthesis) of the enzymatic system of glyphosate activity which led to the pioneering work on genetic engineering of tree species, the forerunner of current day genetic engineering of crops.



2-chloro-4-ethylamino-6-isopropyl-amino-s-triazine

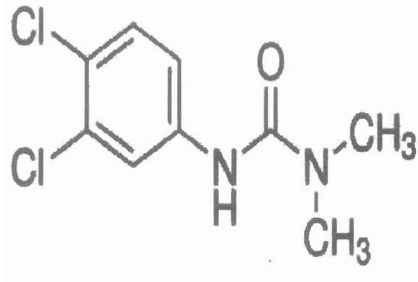
(Atrazine)



2-chloro-4, 6-bis(ethyl amino) -s-triazine

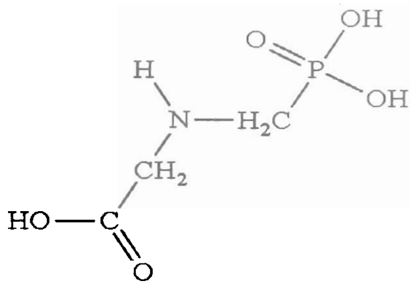
(Simazine)

Figure 2: Structure of Atrazine and Simazine



3-(3,4-Dichlorophenyl)-1,1-Dimethylurea

(Diuron)



N-(phosphonomethyl)glycine

(Glyphosate)

Fig. 3: Structure of Diuron and Glyphosate

Weed Science Domestication at Ife

The Department of Plant Science (now Department of Crop Production and Protection) OAU, which I joined in October 1981, already had a suitable academic undergraduate and post-graduate programme in Weed Science which my predecessor Dr R.O. Fadayomi (now Professor Fadayomi) prepared; it is a Senate approved programme of international standard which is now being updated in the Department. However, at the research level I was confronted with a notion of ineffectiveness of common arable crop herbicides from a belief that weeds have grown resistant to these products. At that particular period, herbicide use have become routine in the developed economies, having solved these type of problems decades earlier. Having worked in one of the most sophisticated herbicide physiology laboratories in the world in the previous 5 years or so, I was confronted with a most rudimentary of weed control issues. I needed to domesticate weed science.

Two approaches readily came to mind; to demonstrate convincingly that herbicides were not being properly applied at the Teaching and Research Farm of the Faculty of Agriculture, O.A.U hence its seemingly ineffectiveness and to document the persistence of herbicides in this environment. To achieve the first goal, I calibrated a boom- sprayer and a knapsack-sprayer, did the routine herbicide calculation and personally applied the herbicide, mounting the boom-sprayer and using the knapsack- sprayer one after the other on different pieces of land at the Farm, with the technical staff of the farm in attendance. Observations after 7 days confirmed clearly that application of herbicides were not being efficiently done hence the observed ineffectiveness.

Consequently, the staff of the Teaching and Research Farm were trained on environmentally safe and effective application of pesticides. To document the persistence of herbicides in our environment, the persistence of atrazine ***(2-chloro-4-(ethylamine)-6-(isopropylamino-s-triazine))*** in a humid tropical soil was studied at the Teaching and Research Farm, using spectrophotometry. At 64 days after application, 75% of atrazine at the usual recommended weed control rate of 3.0 kg a.i. /ha had disappeared; weed control assessment at this period showed a relatively inadequate control of weeds due to the loss of applied atrazine showing that adequate control of weeds cannot be expected beyond eight weeks (56 days) after application of 3.0 kg a.i./ha in the humid tropics (Akinyemiju et. al. 1986).

In a similar study the persistence of hexazinone ***[3-cyclohexyl-6-(dimethylamino)-1,3,5triazine-2,4-(1 H,3 H)-dione]*** was evaluated in cassava cultivation using a plant bioassay and a UV/Spectrophotometery in collaboration with colleagues in the Chemistry Department of this University. At the end of the studies, which I conducted with my first Ph.D. student, Dr Adetoyese Oyeniyi, (now HRM The Olufi of Gbogan, in Osun State), the results showed that hexazinone at 1.0 kg a.i./ha, the usual recommended weed control rate for cassava, persisted for 14 weeks after application in the early season and 10 weeks in the late season; the longer persistence in the early season is desirable for cassava whose critical period of weed competition is the first

12 weeks after planting (Oyeniyi, 1989). Residue studies were also conducted on several other herbicides, showing similarly the short persistence of herbicides in the humid environment (Evbuomwan *et. al.* 1993a,b). Having established from these series of residue/ persistence studies that a season long control of weeds at the usual recommended rates may not always occur, as is the case in the temperate environment, and given the fact that our farmers do not always plant optimally to improve weed control, supplementary weeding was recommended, in order to achieve an adequate season long control of weeds in the humid tropics. This recommendation has been adopted by the Federal Government through its Ministry of Agriculture and incorporated in the recommendations of the NACWC.

Weed control prescriptions were later developed routinely at the Teaching and research Farm for the common arable crops of southwestern Nigeria with particular reference to those being studied in the University: Maize (***Zea mays*** L.) (Akinyemiju, 1988, 1993a,b), Cowpea (***Vigna unguiculata*** Walp.) (Akinyemiju and Echendu, 1987; Akinyemiju, 1987; 1988; Makinwa and Akinyemiju, 1990; Akinyemiju *et. al.* 1990), Tomato (***Lycopersicum esculentum*** Mill.),Rice (***Oryza sativa*** L.,) (Akinyemiju and Igori, 1986; Evbuomwan and Akinyemiju,1995), Soybean (***Glycine max*** *(L) Merr.*) (Adesina *et. al.* 1998), Plantain (***Musa*** spp) (Akinyemiju *et. al.* 2009).

In addition to weed control prescriptions, bioassays were developed for the humid tropics for routine herbicide persistence studies (Oyeniyi and Akinyemiju, 1990; Evbuomwan *et. al.* 1993a,b); economic analysis were also carried out for crop production under different weed control methods (Akinyemiju and Alimi, 1989; Alimi and Akinyemiju, 1990). These prescriptions have become routine recommendations for this agro-ecological zone and incorporated into the national agricultural recommendations for agrochemicals. Thus, today OAU has become a reference center, among Weed Scientists, for standard plant bioassay on herbicide persistence studies and weed control prescriptions for common arable crops of southwestern Nigeria, (Fig 4,5,6,7; Table 1).

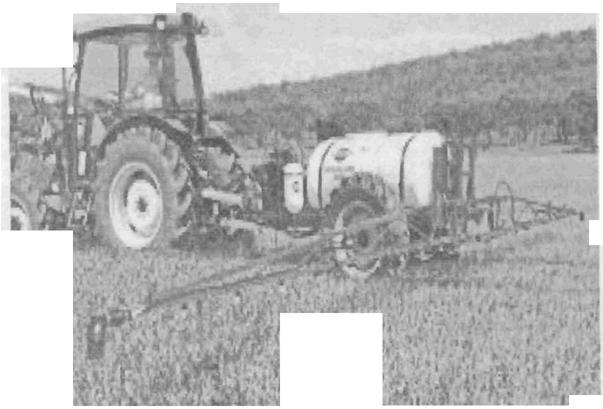
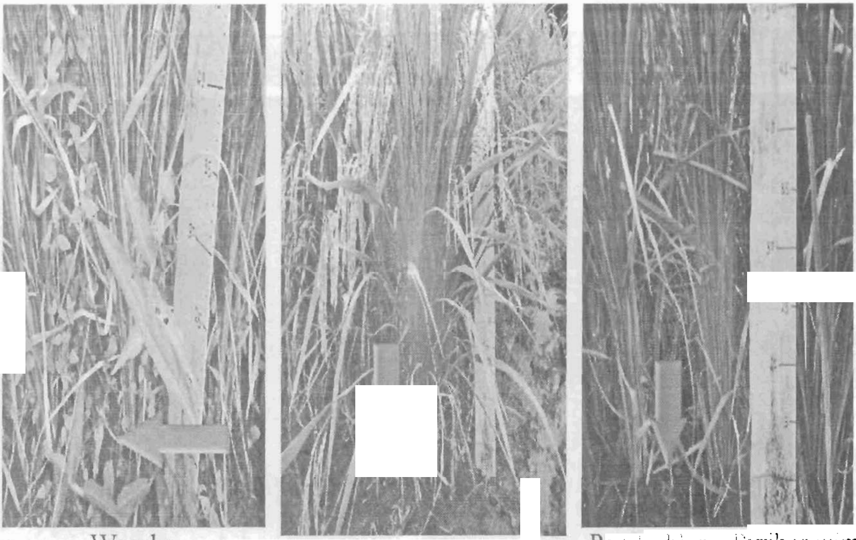


Fig. 4: A boom sprayer applying herbicide for weed control

Fig. 5: Application of herbicide by Knapsack sprayer for weed control on a rice field



Weedy

Hand weeded

Pretilachlor + Pyribezoxim (Solito®) at 0.4 kg a.i/ha.

Fig. 6: Weed Control Efficacy of Pretilachlor + Pyribezoxim (Solito®) at 12 Weeks After Transplanting.

Hand Weeded

Pretilachlor + Pyribenzoxim (Solito®) at 0.4 kg a.i/ha.

Yield Performance of Pretilachlor + Pyribezoxim (Solito®)
at 12 Weeks After Transplanting.

Table 1:Herbicide recommendations for selected arable and plantation crops at different agro-ecologies in Nigeria

Crop	Agro-ecology	Herbicide	Rate (kg a. i./ha)	Time of application	Weeds controlled
Maize	Forest	Atrazine+metolaclor	2.5	PE	Most annual weeds
	Southern guinea savanna	Atrazine+alaclor	2.5	PE	Most annual weeds except itchgrass and sedges
	Northen guinea savanna	2,4-D	2.0	POE,	Most annual weeds except itchgrass and sedges
	Sudan savanna	Atrazine+butylate	1.5+2.0	PPI	Most annual weeds
Cowpea	Forest	Metolachlor+metobromuron	2.5	PE	Annual weeds except milk weeds
	Savanna	Metolaclor+prometryne	2.0	PE	Most annual weeds
Cassava	Forest	Fluometuron+metolaclor	2.0-3.0	PE	Most annual weeds
	Southern guinea savanna	Atrazine+metolachlor	3.0	PE	Most annual weeds
Upland rice	All ecologies	Butachlor	1.5	PE	Most annual weeds
Soybean	All ecologies	Metolachlor+metribuzin	2.0	PE	Most annual weeds
Oil palm	Nursery	Diuron+paraquat	1.0	PPI	Most annuals
	Forest	paraquat	0.8	POE	Most annual weeds
Cocoa	Forest	paraquat	0.8	POE	Most weeds
Plantain	Forest	glyphosate	2.5-3.0	POE	All emerged weeds
Rubber	Forest	Asulam	2.4	POE	Most annuals weeds

PE – pre-emergence, POE- post-emergence, PPI- pre-plant

Aquatic Weed Control

Water hyacinth ***(Eicchornia crassipes*** L.), a major aquatic weed, is an invasive species that was introduced into Africa as an ornamental plant, and which thrives in polluted environments. The weed has the capability to completely clog the waterways in which it grows, making it nearly impossible to navigate fishing boats; it chokes out both sunlight and oxygen to the aquatic organisms that live there; it competes with native species for sunlight, diminishing energy resources thereby creating a threatened environment. In addition to the loss of energy, water hyacinth also takes up and depletes the water of oxygen which is essential to the livelihood of all aquatic organisms.

I was on my way out of the country for an international conference in 1986 when a national daily carried a headline on the invasion of Nigeria coastal waters by water hyacinth. I reviewed literature on the weed and its implication on Nigerian waters and provided some guidelines on the approach to its national control (Akinyemiju, 1987). This was the first scientific publication on the weed at the time in Nigeria. Based on the response to this publication and interactions with the Federal Ministry of Science and Technology, an international workshop/seminar was organized on water hyacinth, in Lagos August 7-12, 1988. At the conference Professor A.M.A. Imevbore led the water quality team while I led the control team. The impact of the OAU team was significant and provided the first set of scientific data, based on studies in Nigeria, on the control of water hyacinth and its implication on water quality (Badejo *et. al.* 1990; Akinyemiju et. al. 1990a, b; Akinyemiju and Bewaji, 1990).

About 6 months after the conference, the Presidency invited Professor Imevbore and I to the Tafawa Balewa office in Lagos for an opinion on the weed. The Presidency awarded us a grant to conduct a pilot control program and to develop a national control strategy for water hyacinth in Nigerian waters. The pilot study was conducted at Kofawei Creek, near Igbokoda in Ondo State, one of the water hyacinth endemic locations in Nigeria at the time. Shortly after this, the Shell Petroleum Development Company (SPDC) commissioned the Weed Control Research Team to conduct a pilot control programme at Abiala Creek near Koko town in Delta State; the Ogun State Government commissioned the team for a similar study at the Ere Fishing Creek, Yewa, Ogun State; another study was conducted at the instance of the Ogun-Oshun River Basin Development Authority, at the Rice Irrigation Canal, Itoikin, near Lagos. At the end of the series of studies a body of data was produced on water hyacinth biology, control and water quality implications.

Results show that water lettuce, water spinach, water primrose and water lily were often associated with water hyacinth at initial invasion but associated weeds soon disappear when water hyacinth finally establishes covering nearly 100% of invaded water bodies; several morpho-types of water hyacinth can occur in same location; water hyacinth reproduces vegetatively and can double its number within a period of 3 months where nutrient is not limiting; 2,4-D at 2.0 kg a.i./ha, diquat at 3.0 kg a.i./ha, ioxynil + 2,4-D at 3.0 kg a.i./ha, paraquat at 2.0 kg a.i./ha, terbutryn at 2.0 kg a.i./ha and glyphosate at 3.0 kg a.i./ha when foliarly applied killed water hyacinth and associated aquatic weeds within 2 weeks of application and by 6 weeks after application the dead weeds had sunk to various depths in the water column; water quality following the application of herbicides showed that there was a variation in the concentration of the major ions, K^+, Na^+, Mg^{++}, Ca^{++}, Cl^{-}, and SO_4^{--} following the decay of the weed; the concentration of these ions increased from 2 WAT and reverted to pre-treatment levels 14 WAT; the alteration in the chemical balance was more due to decomposing vegetation rather than to applied herbicides; no noticeable changes in the value of other ions, PO_4^-P. NO_3^-N,Fe^{++} and pH; oxygen concentration dropped sharply after herbicide application due to dead, decaying weeds but recovered to pre-treatment level by 16 WAT confirming that the low oxygen situation was for a temporary period; the population of planktons monitored increased between 4 and 6 WAT and remain more or less same till the end of the study 6 months after treatment; residue analysis of applied herbicides decreased with time, the value being highest 4 WAT when all plants have been killed and are decaying; no residue of these herbicides were detected in water 12 WAT; the residue values obtained (0.01-0.07 mg/l) are within the internationally permissible residue level in portable water and indeed are within the recommended safety limits. Glyphosate had no detectable residue. It was then concluded authoritatively, for the first time in Nigeria, that herbicides can effectively control water hyacinth in Nigerian waters without any permanent adverse effect on non-target organisms; when used as recommended, herbicides are safe and effective for aquatic weed control in Nigeria (Akinyemiju, 1989; Akinyemiju and Imevbore, 1990; Akinyemiju, 1993; Akinyemiju and Imevbore, 1994).

Comprehensive reports including recommendations for routine control of water hyacinth in their waters were given to the various organizations that commissioned the studies, the Shell Petroleum Development Company (SPDC), Warri; Ogun State Government, Abeokuta and the Ogun-Oshun River Basin Development Authority, Abeokuta; our recommendations were adopted and have become routine practices in these various organizations.

A comprehensive report and detailed strategy for the national control of water hyacinth were presented to the Federal Government by Professor A.M.A. Imevbore and I, with pop and pageantry. It is however sad that till date the Federal Government has not had the courage and political will to implement the recommendations for the national control of water hyacinth in Nigeria even when the assignment was commissioned by the Federal Government in the first place, (Fig 8,9,10,11,12,13,14).

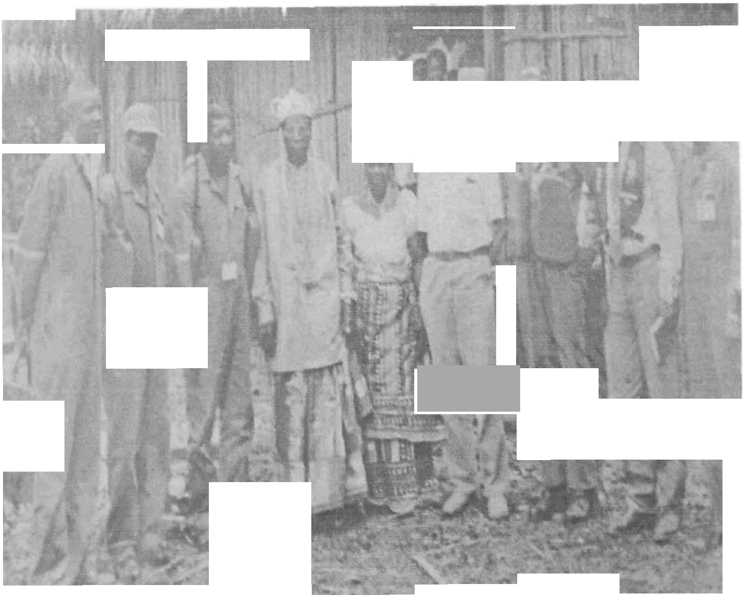


Fig. 8: Some members of the Obafemi Awolowo University (OAU) Weed Control Research Team with the Shell Petroleum Development Company (SPDC) Staff.

Fig. 9: A complete water hyacinth plant

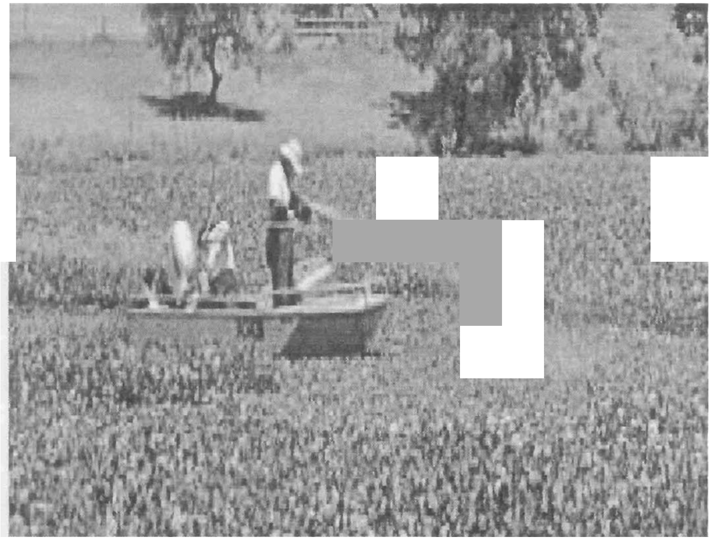
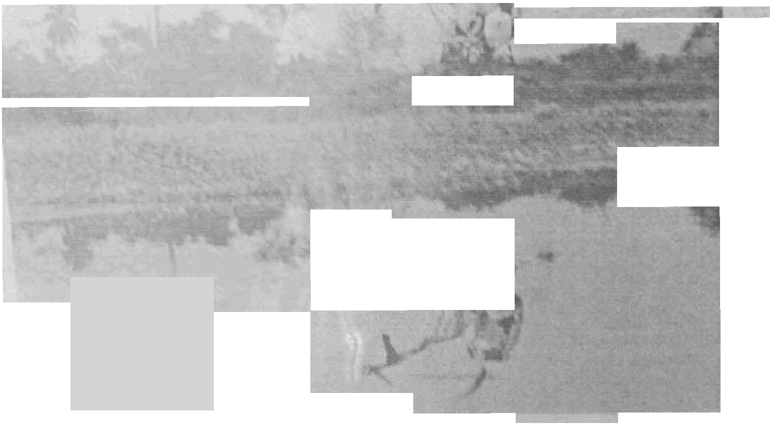


Fig. 10: Herbicidal control of water hyacinth

Fig. 11: Herbicidal control of water hyacinth



... MANOEUVRABILITY ARE IMPORTANT
... APPLICATION OF HERBICIDE

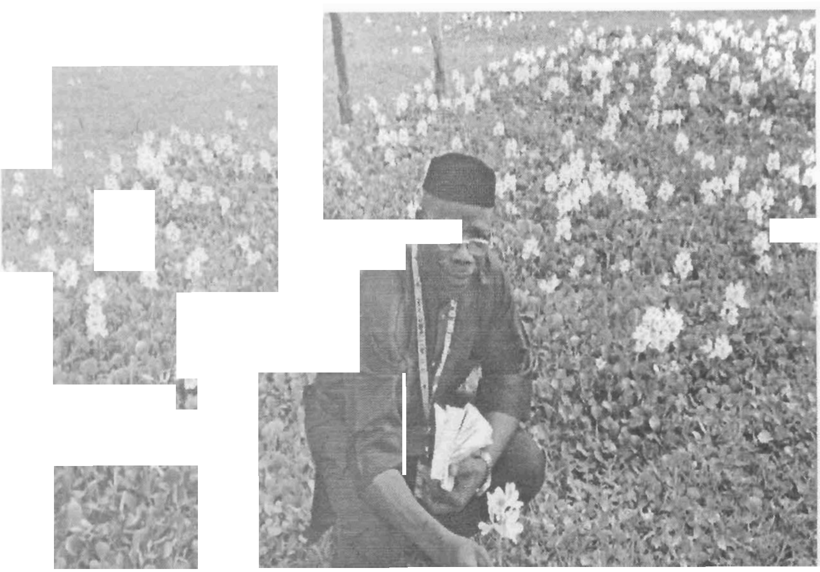


Fig. 13: Water hyacinth at a location on the Adamawa state border with Cameroun

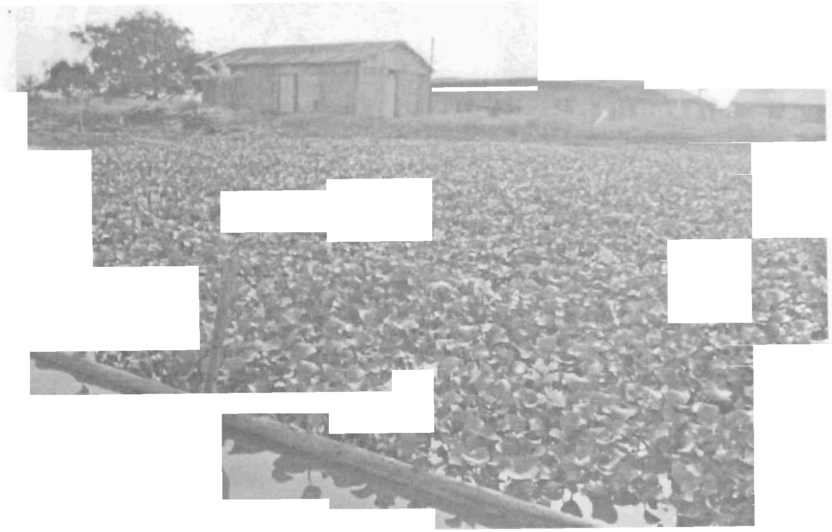


Fig 14a: Fresh water hyacinth in the waterways of Ondo State.

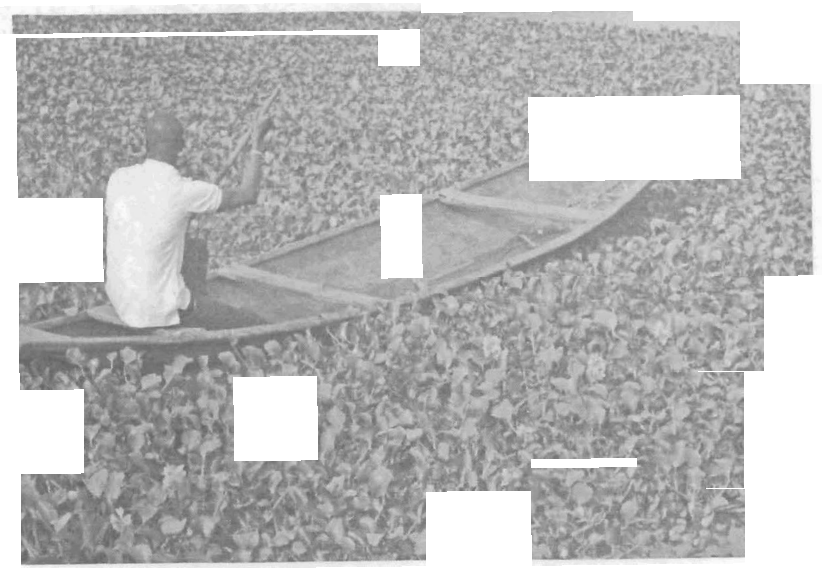


Fig 14b: Fresh water hyacinth in the waterways of Ondo State

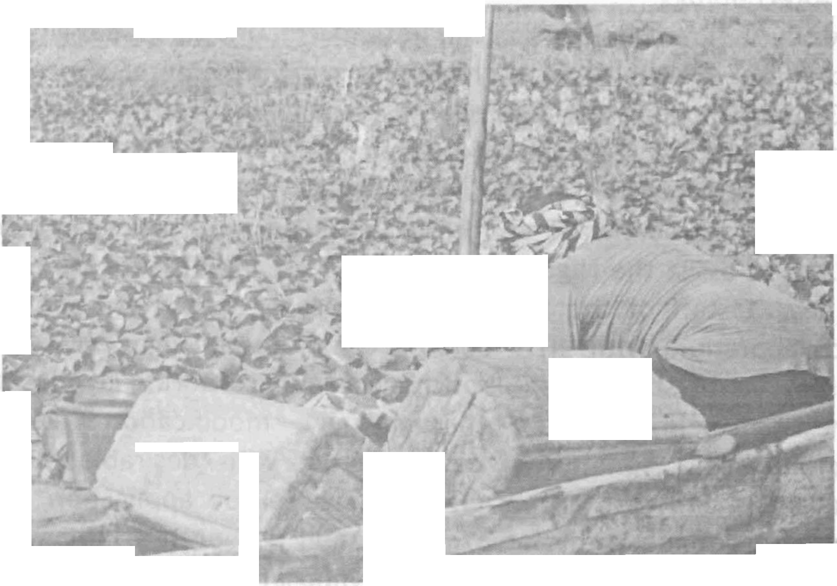


Fig 14c: Fresh water hyacinth in the waterways of Ondo State

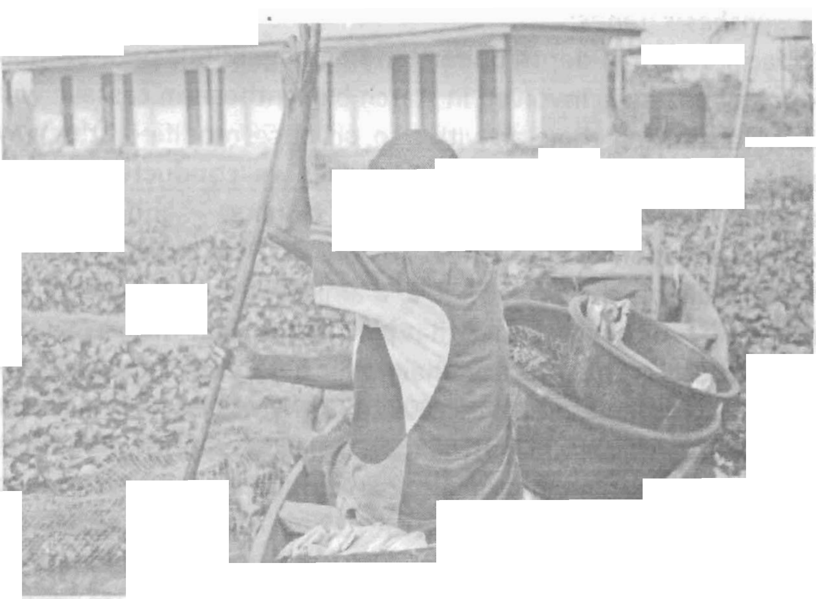


Fig 14d: Fresh water hyacinth in the waterways of Ondo State

Biotechnology

Modern biotechnology has the potential to bring about dramatic changes related to food, health and environmental concerns. Genetic modification procedures have been used to produce crops that are resistant to diseases (and therefore require less pesticides), resistant to herbicides, plants that produce fibres of specific characteristics etc. In line with global practice and the urge to assist the Nigerian farmer, one of my graduate students (now a staff of the Department, Dr Jelili Opabode) and I, in collaboration with IITA embarked on research activities to improve the starch content of cassava and incorporate glyphosate resistance in the crop through gene modification thereby producing a commercial cassava crop, with desirable starch qualities and resistant to glyphosate herbicide application. The progress made with starch modification is reported here while work is still on-going on glyphosate resistance gene modification,(Fig 15).

Isolation, molecular cloning and characterization of starch biosynthesis genes:

To facilitate an in-depth understanding of genomic organization of four key enzymes involved in starch biosynthesis in cassava with a view to altering their activities to produce modified starch with wide food and industrial applications, we conducted extensive studies on isolation, molecular cloning, sequencing and characterization of the genes. For the first time, our works have made available the nucleotide and amino acid sequences of genes encoding four key enzymes that play major roles in cassava starch biosynthesis in the international public database, *Gen Bank,* under the accession numbers **HM038439**, **HM038440, HM046981, HM046982, HM046983, HM046984, HM046985, HM046986** and **HM046987** (Table 2). We also developed a transgenic cassava plant, **TME 12-2010**, from TME 12 as an intermediate bio-engineered cassava plant towards the final development of genetically modified cassava plants with ability to produce modified (low-amylose) starch with a wide industrial application (Opabode *et. al.* 2011; Opabode *et. al.* 2012).

Table 2: Accession number, plasmid and function of isolated starch biosynthesis genes from cassava

s/n	Gene	Accession	plasmid	Length (bp)	function
1	gbss I	HM038439	pOPA303-1	731	amylose synthesis
2.	gbss II	HM038440	pOPA303-4	1690	Amylopectin structure
3.	gbss II	HM046981	pOPA303-5	1689	Amylopectin structure
4.	sbe I	HM046982	pOPA303-6	502	Starch branching
5.	gwd	HM046983	pOPA308-1	561	Starch phosphorylation
6.	gwd	HM046984	pOPA308-2	566	Starch phosphorylation
7.	gwd	HM046985	pOPA308-3	561	Starch phosphorylation
8.	sbe I	HM046986	pOPA308-11	573	Starch branching
9.	sbe I	HM046987	pOPA308-12	570	Starch branching

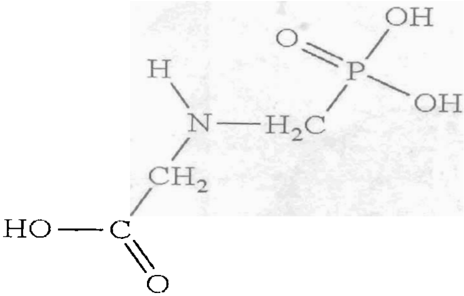
***Discovery of new starch genes in cassava*:**
To expand and enrich our understanding of starch biosynthesis and degradation in cassava, we applied bioinformatic tools and analysis on molecular data from arabidopsis and rice genomes to discover and isolate a new gene encoding glucan water dikinase, which is responsible for phosphorylation activities in cassava. This discovery has opened another avenue of modifying and regulating cassava starch metabolism through increasing phosphate content of starch. We produced three genomic clones encoding a fragment of an α-glucan, water dikinase (GWD), the primary

enzyme required for starch phosphorylation. Phylogenetic analysis of the cassava GWD sequences with other plants GWDs revealed that the cassava GWD belongs to the same group as that of castor bean, potato, tomato and tobacco. These resources add to the current knowledge base of starch metabolism in cassava and expand the molecular tool box for starch modification in this important tropical root crop (Opabode *et. al.* 2013).

Somatic embryogenesis, in vitro regeneration and genetic modification:

Production of somatic embryos is crucial for development of *in vitro* regeneration and gene transfer systems. For the first time, our investigation has produced primary somatic embryo from axillary meristem of some cassava cultivars. We also investigated the influence of age of the cotyledons, cut from primary somatic embryos developed from shoot meristems or immature leaf lobes, on secondary somatic and cyclic embryogenesis of two cassava cultivars. This study further concluded that cyclic embryos should be discarded after the 4th CSE cycle and fresh starting material should be used to restart the somatic embryogenic process (Opabode, *e.t al.*201;,2014)

Funds from the OAU Research Committee (URC) and the National Biotechnology Development Agency NABDA, Abuja in addition to training a Biotechnologist, have been deployed to establish a Plant Tissue Culture Laboratory at the Department of Crop Production and Protection, the first and only one in the Faculty and a foundation for a full fledged Biotechnology Laboratory in the University, (Fig 15,16,17).



N-(phosphonomethyl)glycine
(Glyphosate)

Fig. 15: Structure of glyphosate herbicide

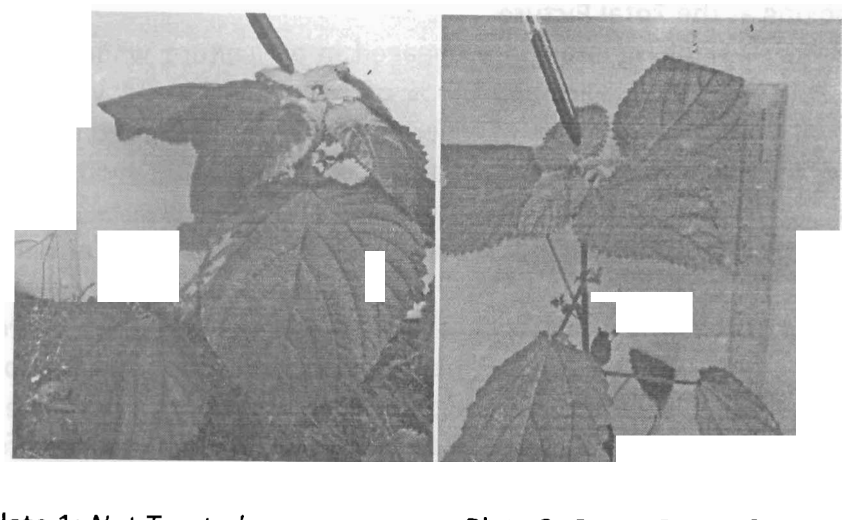


Plate 1: *Not Treated*

Plate 2: *Seven Days After Glyphosate Application*

Fig. 16: Phytotoxic effect of glyphosate on weeds

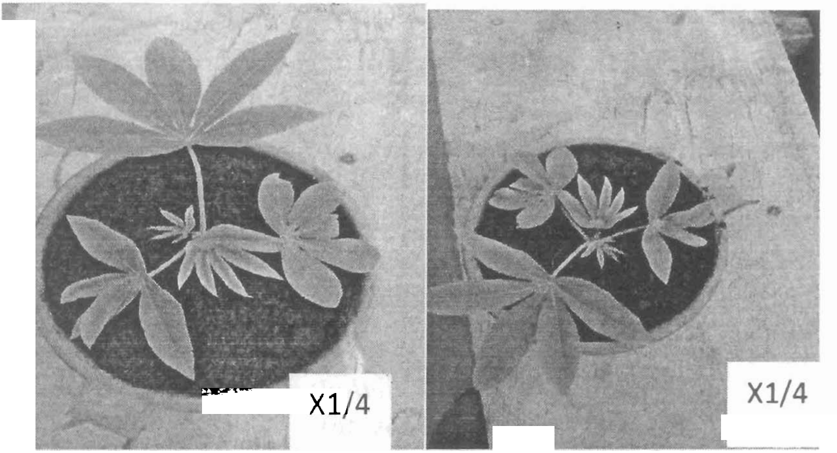


Fig. 17: Non-transgenic cassava TME 12 plant with regular starch traits — Transgenic cassava **TME 12 -2010** Plant with starch improvement traits

AGRICULTURAL PRODUCTIVITY IN NIGERIA

Looking at the Total Picture

About 70 % of Nigerians are engaged in agriculture while about 60% are full time farmers, 60 % of Nigerians are 24 years or younger; the average age of Nigerian farmer is 50. Productivity of the Nigerian farmer is very low, producing for example about 1 ton per ha of maize; his production tools are poor; he cultivates 2-3 ha of land, there is average of a tractor to more than 1000 farmers, has poor management of soil or fertilizer application, control weeds with hoe and cutlass because of poor knowledge of modern weed control technology and therefore does not use herbicides or other pesticides appreciably; Nigeria does not produce pesticides and has low consumption of pesticides (FAO, 2015) (Table 3); life expectancy in Nigeria is between 47-48. However, in spite of the obsolescence of tools of the Nigerian farmer, he still feeds the nation and to make matters worse, government at various levels still rely on him. This situation has not changed appreciably in the last 50 years. In contrast to Nigeria, in 1980 about 5% of Americans were farmers, today only 3% are engaged in agricultural production and they can feed the entire world; an American farmer cultivates about 150 ha of land producing 7-8 tons of maize per ha, with two tractors to a farmer. America produces about 80% of world pesticides with herbicides accounting for about 60% and consumes nearly all of what it produces; its life expectancy is 70 or better. Yet agricultural research in Nigeria dates back to several decades with the establishment of Agricultural Research Institutes in Ibadan, Benin, Zaria etc and the establishment of the University of Ibadan in 1948, with its Faculty of Agriculture and subsequent Universities and their faculties of Agriculture in the sixties and seventies etc.

Table 3: SOME NIGERIAN AGRICULTURAL PRODUCTION STATISTICS

S/N	Item	value
1.	Total Population (2014)	181.4M
2.	Population Growth	3.2%
3.	Agricultural Population (2011)	98M
4.	Agricultural Population Growth	-0.43%
5.	Total Land Area (2007)	92.0M
6.	Agricultural Land	78.0M
7.	Arable Land	46.5%
8.	Forest Area	11.3%
9.	Unemployment (2014)	25.1%
10.	GDP (US$ 2014)	573.5
11.	GNI per capita (US$ 2014)	2,943.0
12.	Agric GDP on Total GDP (%)	20.24%
13.	National Budget Spent on Agriculture (%, 2008)	07.0%
14.	Extension Agent (EA) to Farm Family (Nigeria)	1:9000
15	Extension Agent (EA) to Farm Family (FAO)	1:350
16.	Tractor in use (2007)	1:4,100 Farmers

Source: United Nations Food and Agricultural Organization (FAO), Year Book 2015

Making the Farmer Productive

To make the farmer productive therefore three areas must be addressed: the farmer must be trained through the extension system (with available innovative research findings on shelf) in the engagement of appropriate modern technology for agricultural production such as improved seeds, improved soil management and fertilizer use, modern weed control technology including herbicide use or integrated weed management , modern animal husbandry etc; Micro-credit for the farmers when fund is needed to start the new farm year; establishment of agro-industries based on a comparative advantage of crop production within a region. The implementation of these three priority areas must be fairly simultaneous because they are interrelated and interdependent (Fig 18,19,20).

Fig. 18: A weed infested maize farm

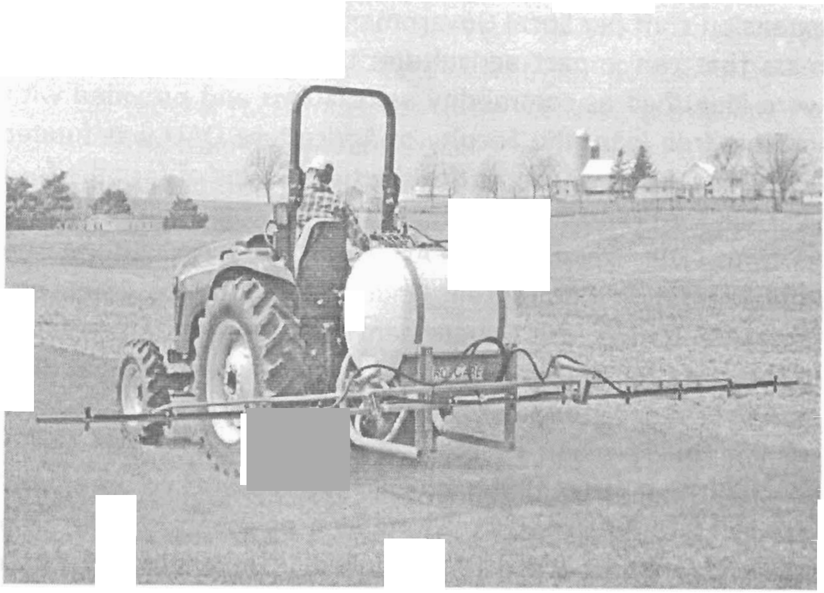


Fig. 19: A boom sprayer applying herbicide for weed control

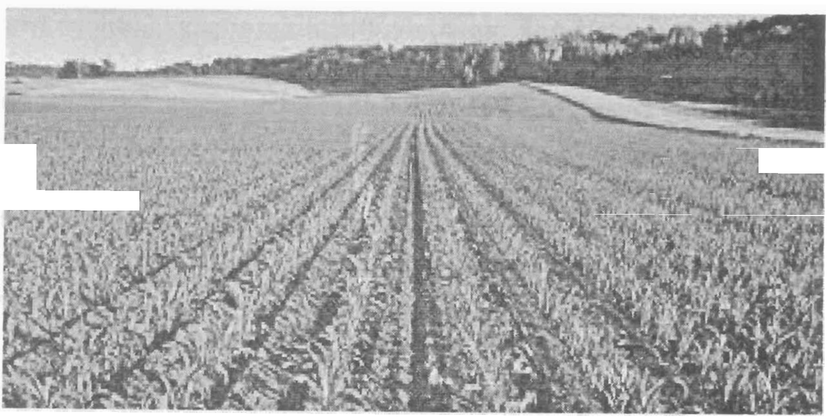


Fig. 20: A clean field free of weed infestation

Connecting the Dots

In September 2003, I was invited to serve as Executive Consultant on Agricultural Development to the Osun State Government in Osogbo, a position I held until June 2007. On my recommendation, the Government improved his extension staff from about 80 in 2003 to about 250 in 2005, for an average of 8 extension staff per Local Government, still a far cry from a critical mass that can impact agriculture; the Cassava and rice farmers were identified as commodity associations and provided with an interest free loan; the Faculty of Agriculture OAU was funded to provide technology support to the two groups of farmers for one year, and a brand new tractor was facilitated for the Faculty to perform the given role. As Chairman, Agricultural Policy Implementation Committee, Ondo State, 2003 to 2009, on my recommendation, the Government increased the extension staff of the state to 10 per Local Government by recruiting about 100 new agriculture graduates to serve as extension staff after a short training; micro-credit facility was available but difficult to assess due to stringent conditionalities in Ondo State; no agro-industry was established. To assist the training of extension staff in both states, 2 publications were produced, Akinyemiju and Torimiro (2006; 2008). Akinyemiju and Torimiro (2008) has been adopted for extension teaching in some Nigerian Universities. To complement this book, an Agricultural Extension Subject Matter text is in press.

It is obvious from above that the peasant farmers, who are about 60% of the Nigerian population and who have continuously been the food producers of this country, have benefitted only very little from the huge sums of money spent on agriculture by the various governments in the last several decades, but much of this fund has invariably gone to support the 100 or so medium-large scale farmers whose agricultural practices are largely unsustainable.

Mr. Vice Chancellor, distinguished audience, permit me to give some recommendations.

THE FUTURE/ RECOMMENDATIONS

1. The Federal Ministry of Agriculture and Rural Development is called upon to resuscitate the National

Advisory Committee on Weed Control (NACWC) by providing funds for its activities;

2. There is an acute shortage of professional Weed Scientists in Nigeria. Government at the state and federal level must therefore increase the funding for the training of Weed Scientists. The Federal Ministry of Agriculture and Rural Development (FMARD) is called upon to re-institute the Short Course in Weed Control sponsored by the Ministry through its Department of Agriculture and organized by the NACWC for graduates of agriculture in the Ministry and elsewhere who had no basic training in Weed Science as an interim programme for the acquisition of Weed Science technology.
3. Government must implement a national programme for the management of water hyacinth to avoid an imminent long term danger of the menace of the weed and to check the current indiscriminate application of herbicides by individuals for the control of the weed.
4. Government at all levels must make the peasant farmer the center of its intervention for agricultural production and indeed if food production will increase in Nigeria in short and medium term. Three approaches are recommended: a) The farmer must be trained on all aspects of modern agricultural practices using on-shelf innovative technology available in all our higher agricultural Institutions, Universities and Colleges nation-wide with the provision of adequate number of extension staff to do the training; b)a Programme of farmer micro-credit assistance must be available and accessible all year round with liberal conditionalities ;c) Agro-industrialization of the country on a comparative advantage of commodity production must begin on a joint public-private-partnership to

form the base and guarantee industrialization of the nation.

5. The Obafemi Awolowo University, as a matter of priority, should establish a Biotechnology Research Institute to organize research and development in biotechnology in the University in order to maintain its national lead in the establishment of centers of excellence.

ACKNOWLEDGEMENT

In the thirty-five years or so that I have been in this citadel of learning, acquiring distinctions and awards nationally and internationally, with privilege to serve in various capacities at different levels of the system, I am immensely grateful to the Obafemi Awolowo University for giving me the space to contribute to humanity in training, research and public service; during the course of my tenure I have come across wonderful colleagues in the Department and in and out of this University, both senior and junior to whom I am most grateful. Several organizations, Governments at various levels, state, national and international have contributed to my research story, I express gratitude. I have trained 10 Masters and 5 Ph.D.s including a First Class Oba in Osun State, many of them have also earned academic distinctions and awards on their own, I thank you all; I thank Professor A. M. A. Imevbore for giving so much of himself to me. I thank members of my family, extended and nuclear, for believing in me. Finally, I thank the Almighty God for giving me good health, and ensuring that there is today.

Mr. Vice- Chancellor, distinguished colleagues, ladies and gentlemen, I thank you for your attention. God bless you all.

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