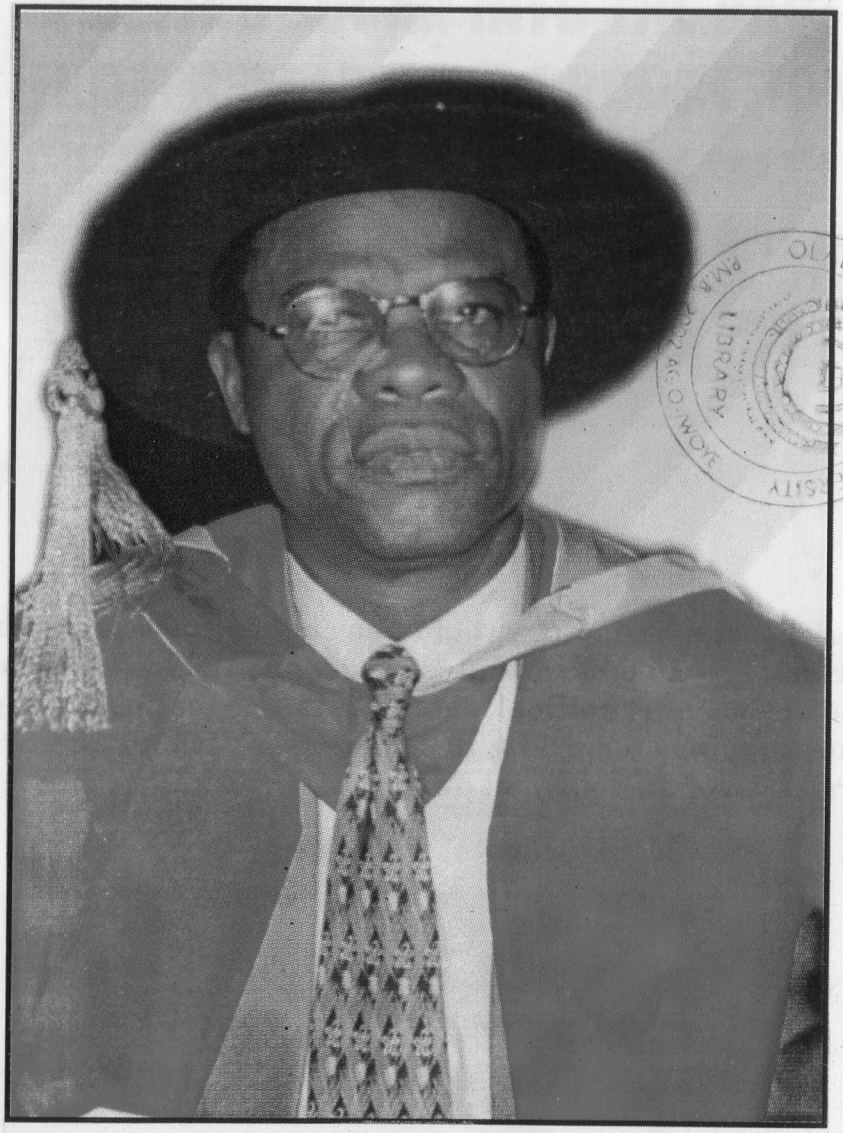

PROFESSOR

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PUTTING SUGAR INTO THE BAG: FROM RESEARCH TO PRODUCTION

An Inaugural Lecture delivered at the
OGUN STATE UNIVERSITY
NOW OLABISI ONABANJO UNIVERSITY
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By

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OGUN STATE UNIVERSITY
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Vice-Chancellor;
Other Principal Officers of the University;
Provosts of Colleges and Deans of Faculties;
Professors from within and other sister Universities;
Directors of the various Directorates;
Distinguished Academics and Professional Colleagues;
Other members of the University Community especially the Students;
Our Numerous Guests at this occasion;
Members of the Press;
Ladies and Gentlemen.

INTRODUCTION

I esteem it a great honour and privilege to present the 15th Inaugural Lecture of Ogun State University. Indeed, this is the first inaugural lecture from the College of Agricultural Sciences and it is coming from the first home Professor of the College since the inception of this citadel of learning.

The interesting journey into sugarcane research started in 1970 when as a young agronomist from Moscow, I was seconded as the counterpart to the FAO/UN sugarcane agronomist, Dr. Guy Castille at the Bacita Sugar Estate from the National Cereals Research Institute, Moor Plantation, Ibadan. This was after a brief stay at the Institute of Agricultural Research, Ahmadu Bello University where I first worked on pasture agronomy with Dr. John Haggar and Dr. Peter DeLeuw.

Dr. Guy Castille and I worked on the agronomy of some exotic sugarcane varieties in the areas of population dynamics, stubble shaving, ratooning and irrigation intervals. Dr. Castille,

a Belgian who spoke French more than English, gave me all the data we collected and suggested that I prepare the report on the projects which he later sent to the Food and Agriculture Organisation of the United Nation (FAO/UN) headquarters in Rome. This sole effort culminated in the award of an FAO/UN post graduate fellowship to study Sugarcane Agronomy at the Imperial College of Tropical Agriculture, University of West Indies, St. Augustine, Trinidad and the West Indies Central Sugarcane Breeding Station, Groves, Barbados in 1972.

Indeed, I was the first Nigerian to write a Ph.D. thesis on this important industrial crop.

Since my arrival from the Caribbean in 1976, I have concentrated on research work aimed at increasing the production of sugar for sustainable self-sufficiency and export.

Mr. Vice-Chancellor, Sir, putting sugar into the bag from a tropical grass such as sugarcane intensively selected for its accumulation of sucrose is multi-dimensional and monumentally complex. The high photosynthetic potential of most graminaceous plants including sugarcane and the apparent need to maintain a flow of photosynthate from leaf to storage are part of the complex features. Competition among individual leaves for conducting elements, integrity of blade union with sheath, and the sheath union with stalk, veinal branching at each node and a great length of conducting tissue are all features of the *Saccharum* complex. It is also known that many plants do not transport sucrose so far as sugarcane does from one end of a leaf to the other. Moreover, although a mature sugarcane plant will commonly extend its green top 1.5 - 2 metres above the ground depending on the species, there is evidence that the lowest internode of the stalk continues to receive some fresh sucrose via the conducting tissue which must traverse some twenty or more joints (node plus internode) having complex node and

internode structure (Oworu 1978).

The amount of photosynthate moved by sugarcane is enormous and granted adequate pathways of sugar transport, the development of sufficient driving forces to move this sucrose, and the control of its movement in the best interest of the overall source-to-sink system, constitutes one of the most fascinating aspects of sugarcane research we tried to resolve.

In the resolution of these problems, my research activities over the years had been tailored to respond to the practical needs of the rural population engaged in sugarcane farming because of my belief that the rural population should be the focus in any research and development projects aimed at liberating our people from poverty and hunger. I have also devoted attention to research projects designed primarily to solve the perennial problems limiting sugar production and consequently putting more sugar into the bag.

Three strategic areas of agronomy were prioritised and formed the basis of achieving our goals in putting more sugar into the bag. They included

(i) Crop Physiology
(ii) Crop Improvement, and
(iii) Crop Production

CROP PHYSIOLOGY

As a physiologist, I wish to amplify on my contributions in this area of agronomy with particular emphasis on sugar storage or accumulation. Sugar storage had been the subject of intense research and this is because the factors which determine the differential sugar stored by different sugarcane varieties are not well understood and yet these factors appear to be of major interest to the physiologists and breeders. Perhaps the main reason for the lack of elucidation is the large number of such

factors. The amount of sugar stored will depend on the size and efficiency of the photosynthetic system, the ability of the cane to translocate and store the sugar and the partitioning of this sugar for growth and storage. These factors may consequently, therefore, be affected by many physiological, morphological and environmental events.

Although much of the early work was restricted to the accumulation of mineral salts (Putman and Hassid 1954; Vickery and Mercer 1963); there is now ample evidence to show that the mechanism of absorption and storage of sugar in sugarcane and other higher plants may be very similar.

The initial work on sugar storage by the sugarcane storage tissue was carried out by Bieleski (1960) in Australia using one variety of sugarcane. He found that sugarcane storage tissue accumulated sugar against a concentration gradient using energy provided by respiration and also suggested that sugar uptake by slices of the sugarcane storage tissue occurs in two stages:

An initial passive uptake which reaches an equilibrium within an hour and it is proportional to the external uptake (active accumulation) which may continue for up to 60 hours at a slow, constant rate and is independent of sugar concentration above 2.0 percent. In kinetic studies on sugar accumulation, Bieleski (1962) showed that at low concentrations of the external solution (below 2%), a hyperbolic relationship exists between external sugar concentration and rate of uptake, suggesting that the rate limiting step is an enzyme-substrate reaction rather than diffusional movement into the tissue.

Bieleski (1962) also showed that through to the rate limiting step, the individual sugar (glucose, fructose and sucrose) behaved as distinct entities with little interconversion taking place. However, subsequent to the rate limiting step, there is a major interconversion of sugar giving sucrose as the predominant

product regardless of the form of sugar originally supplied.

In our studies (Oworu, MacDavid and MacColl 1977a), the storage tissue of eight sugarcane varieties that included high quality commercial clones and low quality F_1 (first filial generation) and backcross hybrids in terms of sugar content were assayed for their potential to absorb sugar from a 2 percent sucrose solution. We found differences in the initial passive uptake and the rate of active uptake between the clones which Bieleski did not demonstrate in his studies.

The uptake of sucrose from the external solution showed a rapid initial uptake (passive uptake) which occurred in all clones followed by a prolonged slow uptake (active accumulation). The amount taken up in the passive stage varied with the clones but was always complete within an hour, while the active accumulation proceeded at a slow rate for the duration of the experiment. Passive uptake was always greater in storage tissue from old internodes than from young internodes and was more than twice as much in some cases, but there was no comparable effect of age on the rate of active uptake.

When the values of passive uptake which occurred during the first hour of the assay were corrected for active uptake, there were highly significant differences between clones. The high quality clones had consistently higher passive uptake values than the low quality clones.

From the passive uptake values, apparent free space (AFS) which we described as that volume of tissue slice which comes into rapid diffusion equilibrium with the external medium and which includes the aqueous phase of the cell walls, cut cells and any intercellular spaces which may have been injected with liquid was calculated for each sugarcane variety. The density of the tissue slice was estimated and found to be 1.00 (Oworu, McDavid and MacColl 1977a). Assuming that the concentration of sucrose

in the apparent free space after the initial uptake was completed was the same as the concentration in the external medium, the AFS was given as:

$$\frac{\text{Initial uptake of diffusible sugars (mg.g.f.wt}^{-1})}{\text{Concentration of external solution at equilibrium (mg/ml}^{-1})} \times 100$$

The apparent free space (AFS) values ranged from 57.0 percent for B62118 to 14.0 percent for B69691 in the old internodes and in the young internodes from 22.7 percent for B63118 to 9.7 percent for B66292 (Table 1, Oworu, McDavid and MacColl 1977a).

TABLE 1. ESTIMATED APPARENT FREE SPACE (%) OF EIGHT SUGARCANE CLONES

CLONE	YOUNG INTERNODES	OLD INTERNODES
B63118	22.7	57.0
B59162	21.0	56.4
Comus	24.1	33.4
BHIO-12	18.5	31.6
SING97	15.4	27.9
B5213	14.9	26.0
B66292	9.7	14.8
B69691	10.2	14.0

It was postulated from the study that the ability of the storage tissue of sugarcane clones to take up sucrose from an external medium, particularly in the passive stage, may be related to

their potential sucrose content in vivo and that the sugarcane breeder should further investigate and incorporate the potential usefulness of this relationship into a breeding programme.

Further elucidation on the differences in the storage of sucrose by the eight sugarcane clones was provided by the study of the anatomy of their storage tissue in relation to sugar uptake (Oworu, McDavid and MacColl 1977b).

This study was initiated to determine if differences in the anatomy of the storage tissue can account for the differences in the uptake of sucrose. The anatomical features examined were the length, width and cell wall thickness of the sugar storing cells of the stalk parenchyma tissue and the number of vascular bundles per unit area of stalk cross section. Also determined was the fibre as a percentage of the fresh weight of whole canes and as a percentage of the storage tissue only i.e. after removal of the nodal tissue and of the outer rind of the internode.

Small cubes of the parenchyma tissue of sugarcane internodes were fixed, embedded and sectioned using the celloidin method of Johansen (1940). Longitudinal sections proved easier to obtain than cross sections and these were therefore taken for the measurement of cell size. The length and width of 50 cells taken at random from several sections were measured for each clone using an eye piece micrometer. Cell volume was estimated by multiplying the length by the width squared. Cell wall thickness was measured under oil immersion on twenty cells at random.

To count the number of vascular bundles per cross section, an internode was taken from the top and middle of each cane. The diameter of each internode was recorded and the internode split into four longitudinally. A thin complete cross section of each quarter was cut using a microtome and the section was stained with phloroglucinol (1:4) in HCl. on a slide. The number

of vasular bundles in each quarter was counted and the four counts were added and expressed as the number per cm^2 of stalk cross section. To estimate the fibre expressed as a percentage of fresh weight of storage tissue only, two 60g samples of storage tissue slices were frozen, macerated to a fine brei and then washed repeatedly with hot water to remove all the sugars. The weight of the dried fibre was expressed as a percentage of the fresh weight of slices.

We found that the length of sugar storage cells ranged from 188 microns for the noble variety 51NG97 to 289 microns for the F_1 variety B69691 and the width from 116 microns for B59162 to 167 microns for 51NG97. 5ING97 thus had the shortest but also the widest cells. The two high quality commercial clones B63118 and B59162 had the lowest values for both length and width and thus had the smallest estimated volumes. B5213 having both long and wide cells had the highest volume. B63118 and B59162 also had the thickest cell walls but the two high quality noble clones, that is, Comus and BH10(12) also had fairly thick cell walls. The thinnest cell walls were those of the F_1 and BC_1 (backcross) clones and of the noble 51NG97. B5213 had cells of intermediate thickness.

There was generally good agreement between the number of vascular bundles in the upper and middle parts of stalks. The high quality commercial and noble clones tended to have more vascular bundles per unit area of cross section than the other clones.

Fibre expressed as a percentage of whole canes to some extent, was in the opposite direction to number of vascular bundles per unit cross-section of stalk, the F_1 and BC_1 clones having the highest values. This apparent discrepancy disappeared when fibre is expressed as a percentage of the storage tissue only. On this basis the high quality commercial and noble clones had the highest values.

Removing the rind of B69691 caused fibre of that clone to fall from 23.0 to 10.9 percent of fresh weight whereas in Comus the fall was 12.5 to 10.8 percent. The fibre in the high quality clones was less concentrated in the outer rind than was that in the F_1 and BC_1 clones. Both cell volume and cell wall thickness were significantly correlated with the estimate of apparent free space (AFS) obtained for the various clones, the respective coefficients were $r = -0.742^{**}$ and $r = 0.888^{**}$ for young internodes. There was therefore a better relationship between cell wall thickness and AFS than between cell volume and AFS. There was also a significant negative correlation $r = -0.693^{**}$ between cell volume and rate of active uptake for young internodes but not for old internodes $r = 0.370$.

The differences shown to exist between clones in the ability of their storage tissue to take up sucrose in vitro can now be seen to be associated with the difference in the anatomy of the storage tissue. High rates of sugar uptake seem to be associated with increased differentiation as opposed to elongation growth of the storage tissue, i.e with small cells, thick cell walls and more vascular bundles.

The frequent occurrence within commercial clones of a positive association between fibre and sucrose as percentages of cane fresh weight had puzzled sugarcane workers, because it could reasonably be argued that since fibre and sucrose compete for the products of photosynthesis, high levels of one should be associated with low level of the other. Undoubtedly such competition may play a part in determining sucrose level when the fibre is largely confined to highly, thickened cells in the outer rind or in the vascular bundles. However, we found that when high fibre expressed as a percentage of fresh weight of storage tissue arises from small cells with thick cell walls, the level of fibre could be positively associated with the level of sucrose.

These findings may also help to explain the positive association among commercial clones between sugar as a percentage of cane fresh weight and the ratio of leaf blade fresh weight to the fresh weight of node plus internode. If cell elongation were to simultaneously increase the weight of internode and reduce the ability of the storage tissue to store sugar, the relationship could be explained. Evidence that this explanation may be partly correct comes from the findings of MacColl (1977) which showed that in one family of commercial seedlings a significant positive association between fibre and sugar as percentages of fresh weight was not independent of a significant positive association between sugar as a percentage of fresh weight and the ratio of leaf blade fresh weight to the fresh weight of node plus internode.

We have shown that the storage tissue from high quality sugarcane clones was able to absorb greater amounts of sucrose in vivo than that from low quality clones, and that the differences in uptake were associated with differences in the anatomy of the storage tissue. It seems reasonable to postulate that the differential sucrose uptake in vitro is a reflection of the ability of the intact storage tissue to store sucrose under field conditions and it might be expected therefore that clones which differ in their ability to store sucrose in vitro would also have different rates of assimilation and translocation in the field. We therefore set out to measure the rates of assimilation and translocation in clones with different efficiencies of sucrose uptake in vitro.

It should be emphasised that in any comparison of assimilation rates of sugarcane clones, leaf weights or leaf ratio must also be considered since there is evidence that assimilation rate is negatively correlated with the weight of leaf per unit weight of cane (Oworu, 1978). Clones with the same weight of leaf per unit weight of cane were therefore selected for this experiment. The clones B63118 and B66292 were found to be

suitable for comparison, having large differences in their rates of sucrose uptake in vitro but the same amount of leaf relative to cane weight. Oworu (1976) found that their leaf blade to joint weight ratios and the longevity of their leaves were not significantly different in either a plant or first ratoon crop.

The apical 35cm of the second fully expanded leaf on intact sugarcane plants in the field was enclosed in a melanex chamber which is 45cm and 6cm in diameter and exposed to 100μ $^{14}C0_2$ for 5 min. The inside of the lower end of the chamber was lined with foam rubber through which the leaf was carefully inserted and the seal was made gas tight by means of strong paper clips. The cover of the upper end of the chamber consisted of a circular piece of thick transparent perspex which was machined to give tapering sides so that a gas-tight fit was obtained. Glued to the inner surface of the cover and projecting downwards into the chamber, was a plastic spectrophotometer cell with a window cut in one side about 1 cm from the base. The $^{14}C0_2$ was released into the chamber from $Na_2{}^{14}C0_3$ placed in the bottom of the cell before the cover was put into position, by injecting excess N HCl into the cell through a small hole in the cover, which was sealed immediately thereafter with cellotape.

The chamber was supported by means of long stakes and retort clamps in such a way that the natural position of the leaf was maintained as far as possible. Five minutes after the release of $^{14}C0_2$, the chamber was removed and translocation allowed for a further 50 minutes. The leaf (including the sheath) was then quickly removed from the stalk, separated into fed and unfed portions, the latter being cut up into 10cm segments, and dried at 80°C. The treatment was carried out at two times, 11.30 and 15.30 hour and at each time three leaves (i.e three canes) of each variety were treated.

The radioactivity in the segments was measured by

macerating each segment in a small quantity of 45% ethanol. To facilitate maceration a few grains of sand were added. The suspension thus obtained was transferred to a 25ml. volumetric flask and the pestle and mortar washed twice with small quantities of ethanol, which were also added to the flask. The volume was then made up to the mark with ethanol and 0.5ml of the suspension placed in a planchet. After drying off the alcohol, the radioactivity in the sample was measured in a lead castle by means of Geiger-Muller tube and an Ekco scaler.

The amount of $^{14}C0_2$ fixed per unit area of the fed part of the leaf showed that fixation was significantly greater in B63118 than in B66292 at both times. The values were 4801 and 5843 ct. $min^{-1}cm^{-2}$ for B63118, and B5213 and 4300ct $min^{-1}cm^{-2}$ for B66292, for morning and afternoon treatments respectively (Fig. 1). The area of the fed part was 174.5cm^2 in B63118 and 165.9cm^2 in B66292. The distribution of radioactivity in the leaves and the percentages of total radioactivity in the fed and unfed part of the leaf 55 minutes after exposure to $^{14}C0_2$ showed that in the morning treatment 49 percent of the total radioactivity moved out of the fed part in B63118 compared to 21 percent in B66292 whilst in the afternoon treatment 56 percent moved out of the fed part in B63118 compared to 37 percent in B66292 (Figs. 2 and 3). The rate of translocation is the amount of assimilate moved per unit time (Hartt, 1963), but a relative measure of this was obtained from the percentage of total radioactivity moving out of the fed part. The rate of translocation in the treated leaves differed considerably between the two clones and was about twice as great in B63118 in the morning, and 1.5 times as great in the afternoon (Fig. 3).

From the distribution of radioactivity (Fig. 2 and 3), the velocity of translocation defined as the distance moved per unit of time was estimated for the two clones. The distance was

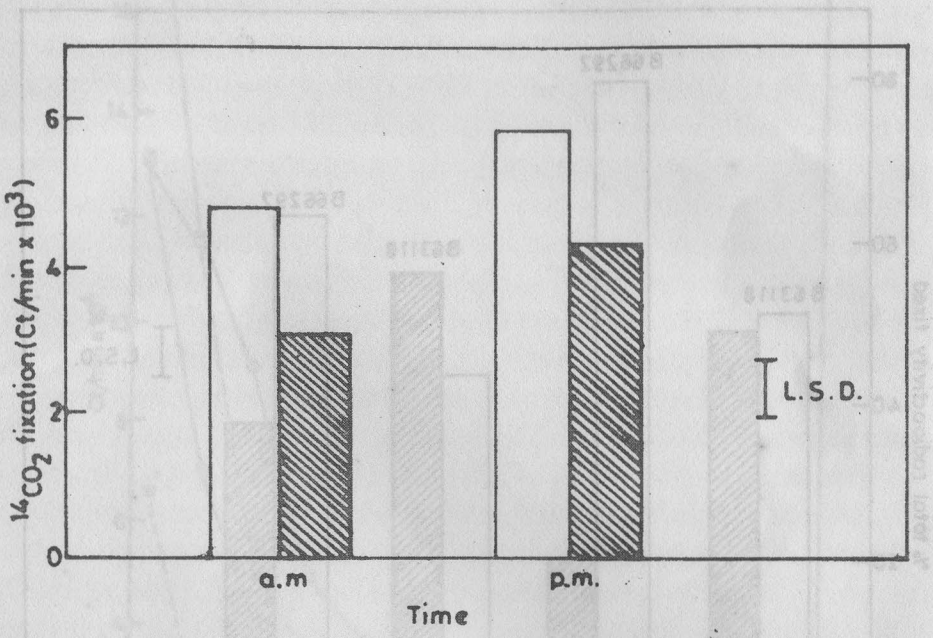

Fig. 1: Radioactivity fixed per unit area of the fed part of the second fully-expanded leaf of two sugar-cane clones, during morning and afternoon exposures to $^{14}C0_2$ □, B63118 ■, B66292.

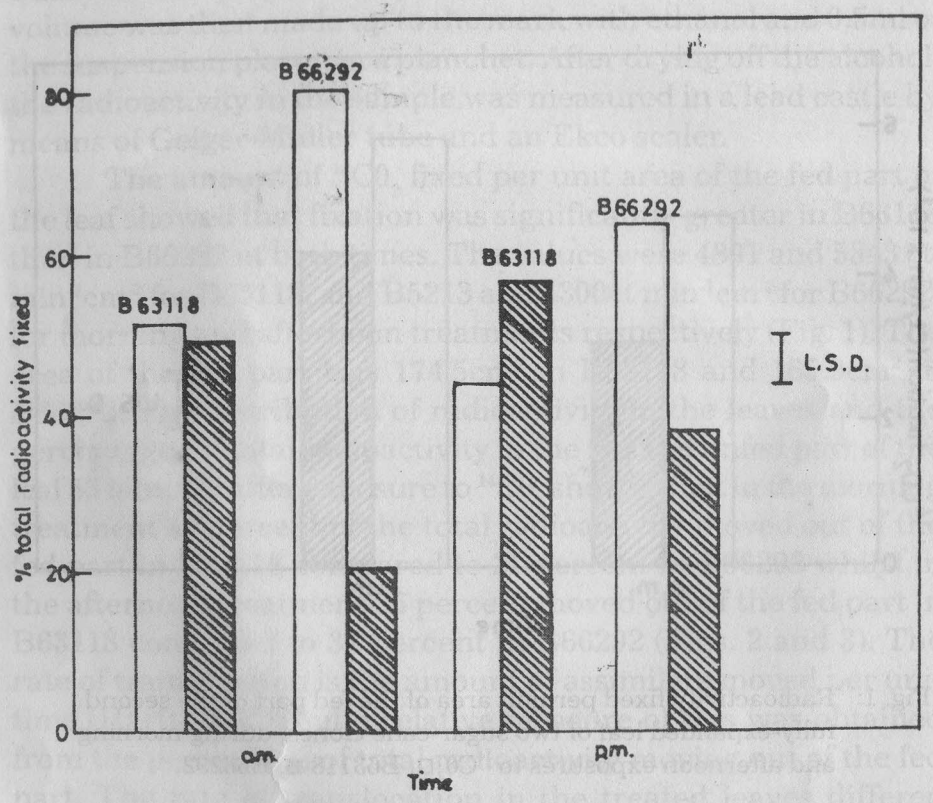

Fig. 2: Percentage of total radioactivity in fed □ and un-fed ■ parts of the second fully-expanded leaf of two sugar-cane clones after morning and afternoon exposure to $^{14}C0_2$

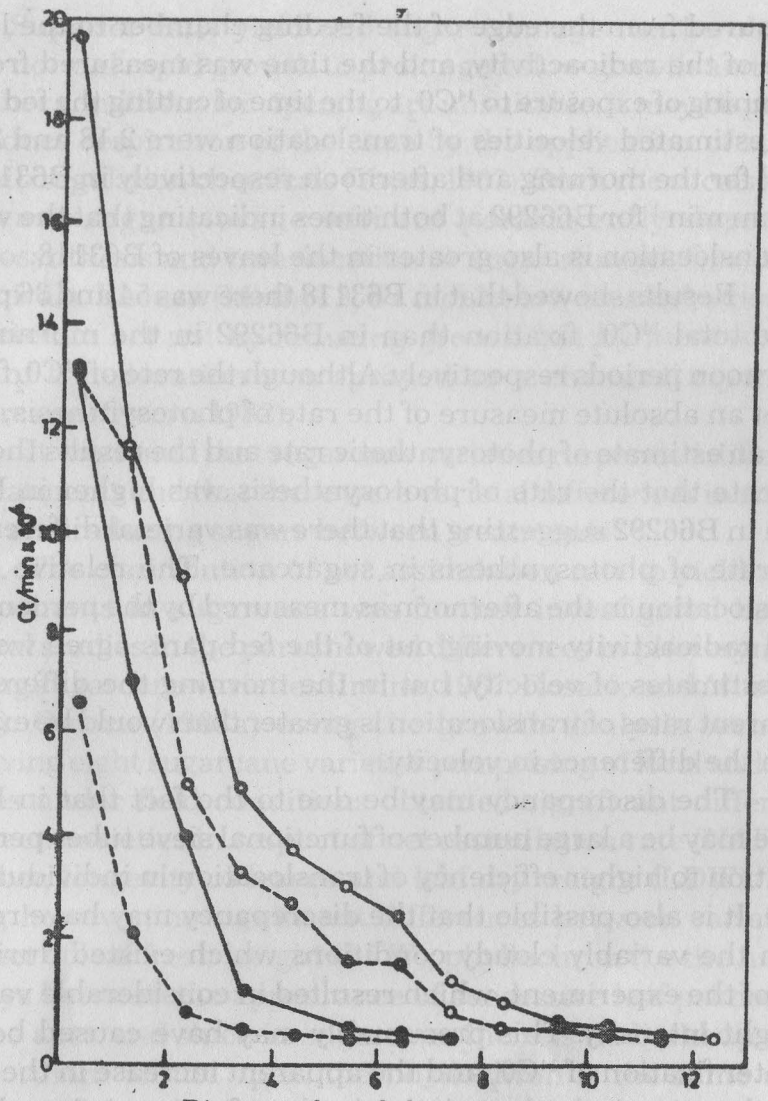

Fig. 3: Distribution of radioactivity in the second full-expanded leaf of two sugar-cane clones 55min after morning and afternoon exposure to $^{14}C0_2$ o, B63118; • B66292. Solid lines, afternoon broken lines, morning.

measured from the edge of the feeding chamber to the leading edge of the radioactivity, and the time was measured from the beginning of exposure to $^{14}C0_2$ to the time of cutting the fed leaves. The estimated velocities of translocation were 2.18 and 2.36cm min^{-1} for the morning and afternoon respectively in B63118 and 1.46cm min^{-1} for B66292 at both times indicating that the velocity of translocation is also greater in the leaves of B63118.

Results showed that in B63118 there was 54 and 36 percent more total $^{14}C0_2$ fixation than in B66292 in the morning and afternoon periods respectively. Although the rate of $^{14}C0_2$ fixation is not an absolute measure of the rate of photosynthesis, it does give an estimate of photosynthetic rate and the results therefore indicate that the rate of photosynthesis was higher in B63118 than in B66292 suggesting that there was varietal differences in the rate of photosynthesis in sugarcane. The relative rate of translocation in the afternoon as measured by the percentage of total radioactivity moving out of the fed parts agree well with the estimates of velocity, but in the morning the difference in apparent rates of translocation is greater than would be expected from the difference in velocity.

The discrepancy may be due to the fact that in B63118 there may be a large number of functional sieve tubes per leaf in addition to higher efficiency of translocation in individual sieve tube. It is also possible that the discrepancy may have resulted from the variably cloudy conditions which existed during the day of the experiment, which resulted in considerable variation in light intensity. This presumably may have caused both the greater fixation of $^{14}C0_2$ and the apparent increase in the rate of translocation in both varieties in the afternoon, since both of these processes may be influenced by the levels of unlabelled sugars at the different times, which in turn may depend on the light intensities immediately prior to the treatment.

Superior cane yield and sugar tonnage can be obtained from normal rapid growth to prolonged slow growth and where weather conditions for ripening are unsuitable, it may be possible to reduce respiration of the cane by the application of suitable growth regulation chemicals (Yates, 1967). Such chemicals should increase sugar storage without permanently depressing photosynthesis and translocation or sugar storage. One of such chemicals, Racuza (Methyl 3, 6 - dichloro-o-anisate) which was reported to act not by reducing growth but by increasing the rate of translocation was sprayed as a chemical ripener on sugarcane (Oworu 1982).

It was found that sugarcane varieties responded differently to treatments and that there were varietal differences in sucrose, fibre and reducing sugars between treatments.

The contribution of net assimilation rate to yield and its components in sugarcane was further investigated because several studies in the part showed differences in photosynthesis among sugarcane varieties (Irvine, 1967, Rosario and Musgrave, 1972). Oworu (1988a) using the growth analysis technique involving eight sugarcane varieties comprising of local and exotic clones under field conditions obtained significant differences between varieties in respect of net assimilation rate (NAR), leaf number, longevity of leaves and leaf dry weight (LDW). There were, however, no significant differences between varieties in respect of leaf fresh weight (LFW), phyllochron (i.e the number of days between the appearance of successive leaf primordium on the apex and since in sugarcane there is no build up of leaf primordium on the apex, the phyllochron is the same as the number of days between the appearance of successive leaves) and is calculated as:

Number of days between painting and sampling date
Number of leaves that appeared during the painting and sampling date, Leaf Area Index (LAI), stalk height and brix (refractometer solids).

The difference in leaf blade/joint weight ratio between the varieties were also not significant. However, when this character was multiplied by longevity (which was calculated by multiplying the number of days between the appearance of successive leaves (phyllochron) by the number of leaves at the end of the period), significant varietal differences were obtained. Net Assimilation Rate was negatively correlated with leaf blade/joint weight ratio multiplied by longetivity suggesting that the higher the leaf weight per unit weight of cane the lower the assimilation rate. It was suggested that some of these characters can be used in the selection of parent materials in the breeding programme for varietal improvement.

CROP IMPROVEMENT

A sugarcane breeding programme for the Nigerian sugar industry which has been in existence for over thirty years and which could be utilised to generate new sugarcane varieties for the Nigerian ecosystems and sugar industry in order to put more sugar into the bag had been proposed (Oworu et al, 1988b) during a post doctoral study at the Hawaiian Sugar Planters' Association Experiment Station and the College of Tropical Agriculture, University of Hawaii in Honolulu.

The sugarcane breeding programme published in the prestigious International Sugar Journal aims at solving the problem of breeding new varieties which is posing a serious threat to the survival of the sugar industry in Nigeria and which to a large extent had relied on the importation of exotic varieties

for commercial cultivation.

However, some of these exotic varieties are becoming susceptible to diseases such as smut (Ustillago scitaminea Sydow). The programme was intended to reduce the vulnerability of our sugar plantations to diseases and pests and declining productivity. Essentially, the programme comprises three major schemes i.e germplasm collection, varietal evaluation and varietal hybridisation and selection. Some of Nigeria's local sugarcane clones collected during expeditions all over Nigeria were evaluated, listing their known agronomical, botamical and genetical descriptions in a national sugarcane catalogue as suggested by Oworu (1978). These local sugarcane clones have also been found to be tolerant to smut and their genetic potential are now being utilised to breed new varieties (Oworu and A woderu, 1985).

A multilocational project in which new varieties are evaluated in various ecosystems of Nigeria including Ago-Iwoye revealed that some of these varieties such as USRI 86/4, BD83/109 and IB85/12 had yield and sugar content comparable and in some instances out-yielding the exotic check variety. These varieties are now being encouraged for spreading in plantations and are used to replace exotic varieties that are declining in tonnage and sugar yield.

CROP PRODUCTION

In crop production, trial was carried out to compare the effects of two planting methods (burying sugarcane seed setts under the soil and placing seed setts slantingly at about 40° in the soil and four types of sugarcane seed setts having cuttings with either 2, 4 or 6 buds and cane tops consisting of two buds on germination and yield.

It was found that germination and tillering were enhanced when seed setts were completely buried under the soil and this contributed about 20% and 33% to the tonnage of cane in both plant and ratoon crops respectively when compared to the farmers practice of planting setts slantingly in the soil. In the plant crop, cane tops buried under the soil had the highest yield of 91.8 tonnes/ha, while the lowest yield of 51.8 tonnes was from the 6 bud setts planted slantingly in the soil. Slanting method allows only one or two buds to be in contact with the soil resulting in poor germination. Similarly, cane tops buried under the soil had the highest yield in the ratoon crop while the 4 bud setts planted slantingly in the soil had the lowest yield. In the plant crop, significant differences were obtained between planting methods in the sucrose and fibre content of the cane (Oworu 1985).

The effects of ratooning (continuous cropping of sugarcane underground stubble) on yield were investigated using two sugarcane varieties. Ratooning was found to be uneconomical in terms of yield because 75 and 79% yield losses were recorded for varieties C01001 and C0957 respectively at the fifth cycle. Sucrose content decreased with the ratoon croppings. It was suggested that farmers and sugar estates should grow sugarcane up to the fourth ratoon cycle before stubbles are ploughed in for fresh plant cane (Oworu, 1988c).

On population dynamics, trials were carried out in a plant and ratoon crops with two commercial varieties and a local clone to study the effect of interrow spacings of 100, 150 and 200cm on stalk population, yield and quality of sugarcane. The results showed that stalk population was higher in closer spacings than in wider spacing. With increase in interrow spacing, there was a progressive reduction in tiller mortality. The highest yield was obtained from the 150cm interrow spacing, while cane planted

in rows 200cm apart gave the lowest yield.

Varietal differences, were demonstrated in cane quality as measured by the amount of the components of dry matter (sucrose, reducing sugars and fibre) (Oworu, 1986).

In an experiment carried out to study the affect of liquid fertiliser (Agromax) on the yield and quality of sugarcane under field conditions, it was found that yield was significantly better for the agromax treatment when compared with either the solid plus liquid fertilisers and the control of no agromax treatment. The agromax treatment gave the highest yield (74.3t/ha) while the control plots gave only 24.1 t/ha. However, no significant differences in sucrose were obtained between treatments (Oworu, 1987).

Heavy weed infestation especially before close-in among other factors is a major cause of low tonnage in sugarcane. Chemical weed control remains one of the primary and probably the only practical approach to removing weed competition in sugarcane. Six herbicides were evaluated for their effectiveness in controlling weeds in plant and ratoon crops. Simazine (2-chloro-4, 6-bi (ethyl amino)-5-triazine) applied to the soil four days after seeding at the rate of 6kg a.i/ha gave the best results and increased tonnage. Asulam, Methyl (4-aminobenzen sulphonyl) carbamate applied post emergence of weeds at 4.5 and 6.0 kg a.i/ha caused slight initial toxicity, but the injury sustained did not significantly affect crop yield (Oworu, 1981).

At the Bacita Sugar Estate, field experiments were carried out to determine the effectiveness of four herbicides, used either alone or in combinations, for weed control in a plant and ratoon crop of sugarcane. The results obtained showed that pendimethalin (N- (l-ethylpropyl) -3-4-dimethyl-2- 6-dinitrobenzeamine) in combination with atrazine (2-chloro-4(ethylamino) -6 (isopropylamino) -1,3,5-triazine) gave the best

weed control and increased tonnage. This combination was effective in controlling perennial grasses such as speargrass (Imperata cylindrica (L) P. Beav.) and corngrass (Rottboelia cochinchinensis L.) which are among the major weed species on the estate (Oworu 1988d).

Mr. Vice Chancellor, sir, I have shown in this discourse that the findings from our research efforts have assisted immensely in the production of sugar through the breeding of improved varieties and other recommended production packages primarily targeted at putting more sugar into the bag. Suffice it to mention that these efforts were further recognised by the Government of the Federal Republic of Nigeria who sponsored me as a consultant to the "Compagnie Sucriere du Senegalaise" (CCS) in Richard -Toll, Senegal in 1982 where our research findings were used to improve production.

The Government also supported my appointment as the Director of Agriculture and subsequently the Director-General of the Save Sugar Company in the Republic of Benin. This company jointly owned by Nigeria, the Republic of Benin and some foreign consortia had been in a state of decay since its inception essentially because basic agronomic inputs were lacking during planting. We utilised our research findings to rehabilitate the entire plantation of 5000 hectares and brought in about 100 varieties of sugarcane from Nigeria to improve the varietal problem in the estate and also initiated a sugarcane breeding programme.

CONCLUDING REMARKS

Mr. Vice-Chancellor, sir, in spite of these agronomic achievements aimed at improving sugar production and also the production of other by products such as molasses and bagasse which are used as raw materials for the production of industrial alcohol, yeast and fibre board, Nigeria produces less than 5% of her sugar requirement estimated to be over 1.5 million tonnes per annum.

Indeed the Bacita Sugar Estate in Bacita, Kwara State; the Savannah Sugar Company in Numan, Adamawa State, the Lafiagi Sugar Company in Lafiagi, Kogi State and the Sunti Sugar Company in Sunti; Niger State produced less than 10,000 tons last year. The reasons for this poor performance include poor technical and managerial skills, lack of working capital sometimes leading to non-availability or late availability of agronomic inputs and industrial unrest in the estates.

Nigeria imports over 95% of her annual sugar requirement which gulps staggering millions of naira in foreign exchange. This importation bill on sugar alone may be contributing to the worsening of the country's economic problems.

In 1993, the Government of Nigeria established the National Sugar Development Council (NSDC) located in Abuja to promote among other things the development of the sugar sub-sector through the provision of guidance on the development of sugar estates and the organisation of the sugarcane out-growers' schemes to enhance the local production of sugar with a view to ensuring that Nigeria achieves at least 70% self-sufficiency in sugar requirement as soon as possible. The Council has identified thirty-five potential sugar growing sites in many states of Nigeria including Papalanto in Ogun State where the Gayvita Sugar Company - (a joint venture between the Ogun State Government and some Nigerians mostly from the

academia) has established a sugar plantation. The Company when fully operational is expected to produce about 50,000 tons of sugar annually grinding about 2,500 tons of cane per day during a 200 day harvest and production schedule and thus save Nigeria an estimated 15 million US dollars in import bill annually.

In the light of the foregoing, I wish to call on Nigerians particularly scientists including agronomists, biochemists, engineers, medical scientists, extensionists, sociologists, economists, educationists, information technologists, lawyers and others to harness their formidable knowledge in a multi-disciplinary approach and invest in the fertile sugar sub-sector to improve their lots.

The estimated total sugar production capacity of the identified estates is less than 1million tons, a far cry from the estimated annual consumption of over 1.5 million tons. I therefore suggest the encouragement of a viable out growers scheme around identified estates to increase sugar production.

The management of existing sugar estates should be restructured to ensure efficiency and huge profit. Indeed, I wish to advise that more estates should be identified nation-wide and privatisation of the existing facilities should be encouraged. Emphasis should be placed on private investors in the development of the identified sugar estates to produce at least 70,000 tons of sugar per estate per annum for sustainable self-sufficiency. This effort should be backed-up with the establishment of a viable Sugarcane Extension Programme (SEP) by the NSDC.

If all our research efforts are adopted and management problems are restructured, Nigeria can conveniently produce enough sugar for home consumption and export saving about I billion US dollars on import bill annually and provide jobs for many Nigerians.

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