Cassava - Based Cropping Systems Research 1

International Institute of Tropical Agriculture

CASSAVA-BASED CROPPING SYSTEMS RESEARCH

I

Contributions from the First Annual Meeting of the Collaborative Group in Cassava-based Cropping Systems Research

Theme: "Linking similar environments"

Ibadan, 16-19 November 1987

ORGANIZED BY THE
RESOURCE AND CROP MANAGEMENT PROGRAM

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Session I

Introduction

EXTRACTS FROM INTRODUCTORY REMARKS: a summary

L.D. Stifel
Director General, IITA

Participants should address themselves to (a) the paradox of abundance and starvation existing at the same time in most of sub-saharan Africa; (b) the establishment of sustainable systems of agriculture; (c) the problem of food availability and (d) the development of a sound resource-based system of crop production. The participants should therefore regard themselves as partners in the development of viable systems. The International Institute of Tropical Agriculture (IITA), on its part, is committed to the development of crop varieties that are easily adaptable to the range of ecological zones in West and Central Africa.

Efforts have been made to devise methods of integrating resource and crop management research with commodity improvement research. Scientists in the Resource and Crop Management Program liaise in their research with a corresponding commodity program, eg, cassava-based systems with the root and tuber improvement program. IITA hopes that through such working arrangements, which will be reviewed from time to time, research will be better focused to address the relevant, urgent problems of alleviating starvation from insufficient production of its essential mandate crops.

The Resource and Crop Management Program of IITA
D.S.C. Spencer, Director, RCMP

The goals of the Resource and Crop Management Program (RCMP) of IITA are to develop economically and ecologically stable farming systems through efficient management of such resources as soil, water, energy, crop planting materials and vegetation; and to increase resource productivity to meet future demand.

Program strategies center on:

1. Analyzing and understanding physical, biological and other factors affecting degradation.

2. Devising resource management tactics that reduce degradation.

3. Identifying useful innovations that can be adapted to farmers' conditions. Major program achievements include the Alley Cropping system, Macuna and other live-mulches, and fertilizer use management.

Future strategies of the resource management research include:

4. Using principles identified in the past; eg, live-mulch, prevention of erosion and refining them for on-farm use by extension personnel.

5. Developing and strengthening programs in acid soils in humid forest ecology for which there are few activities.

6. Conducting base-line data studies in the inland valleys for lowland rice production.

The second major area of RCMP is the setting up of crop-systems-based working groups. Three of them have already been established: for cassava-based cropping systems, maize-based cropping systems and rice-based cropping systems.

The cassava-based systems collaborative research group was previously called root-crop-based collaborative group. Following the IITA strategic study, the Group is emphasizing cassava-based cropping systems; hence the need to adjust its name. Collaboration will continue with national programs where yams and other tuber crops are very important, because research thrusts on cassava are systems-oriented. the geographical area of major focus remains West and Central Africa.

In all the activities of the RCMP, attention is given to post-harvest problems such as processing.

The Root and Tuber Improvement Program of IITA,
S.K. Hahn, Director, TRIP

The Root and Tuber Improvement Program (TRIP) now places major emphasis on cassava. Research on cocoyams and other tubers is for the national program. TRIP will concentrate on cassava improvement, plantain research and post-harvest technology, which is aimed at designing and testing of post-harvest equipment.

Most of the major cassava-producing countries have received improved materials from TRIP either in tissue culture or seed form. Among improved cassava varieties gaining popularity are TMS 30572, whose cuttings are sold by the roadside, and TMS 4(2)1425, a sweet type. Those materials are high yielding and produce much dry matter. TMNS 4(2)14-5 is pounded like yam. Improved cassava and trained personnel are therefore widely available ion many African countries for collaborative research in cassava-based systems across diverse environments.

CASSAVA-BASED CROPPING SYSTEMS RESEARCH COLLABORATION

H.C. Ezumah

Cassava is the most important root crop grown in Africa. Others are yam (*Dioscorea* spp.), sweet potato (*Ipomoea batatas*) and cocoyams (*Xanthosoma sagittifolium* and *Colocasia esculenta*). These crops had, until recently, received little attention research and related policy, yet they are important because:

(a) They provide on the average 16 percent of the calorie needs of the entire African population.

(b) They supply almost all the energy needs of an estimated 165 million Africans who live in the humid regions.

(c) In specific zones of some countries in West, Equatorial and Central Africa, root and tuber crops account for over 60 percent of peoples' caloric intake.

They are also sources of animal feed and industrial raw materials and can be enriched and processed into convenient foods. The potentials of root crops at present under-exploited, can be better utilized by more rapid research to develop component technologies and evolving methods to accelerate flow of contributes over 80 percent by weight of root crops produced in Africa in 1984 (FAO 1984).

Background. Interaction among scientists, through organized research collaboration, can facilitate sharing of information, reduce duplications and save scarce resources. As operational methods for a farming systems approach to research become clearer, the need to provide improved component technologies applicable to specific problems identified during on-farm research activities is accentuated. Confidence in the suitability of improved component technologies for specific environments of application. Given the diversity of environments for agricultural research and the location specificity of farming systems research, it is not practicable to develop technologies in all environments of application, but a step towards making technologies suitable to wide range of environments is achievable through collaboration with researchers working at several strategic locations.

Purpose of research collaboration

The purpose is to generate technologies which will enable development of improved economic and ecologically sustainable cassava cropping systems for humid Africa with emphasis on West and Central Africa.

Specific objectives of research collaboration

1. To bring together scientists interested in cassava research systems in order to: (a) develop technologies suitable or potentially adaptable for cassava-based cropping systems (b) facilitate interactions between IITA and national research institutions in problem identification and planning of experimentation for developing improved technologies appropriate for cassava-based systems.

2. To facilitate rapid dissemination of improved technologies to various research centres,

3. To identify which data are required in linking similar production environments and develop methods for their collection, analysis and interpretation.

The above objectives and the operating procedures were discussed and endorsed during an inaugural meeting held at IITA in February 1986. Participants comprised seven scientists from:

Ahmadu Bello University, Zaria

National Root Crop Research Institute, Umudike;

Institute for Agricultural Research and Training, Ibadan

University of Nigeria, Nsukka;

Imo State Agricultural Development Project, Owerri;

Shell Company, Warri

-in addition to IITA, the convenor. The location of these institutions across the major ecological zones of humid tropics (perhumid, humid, humid/subhumid, transitional and subhumid) permits research to be conducted at sites having major soils of interest (Alfisols, Ultisols and Oxisols) ranging in annual rainfall from about 800mm to over 2,200mm per year.

During the meeting, diagnostic survey results emanating from primary and secondary data available for each experimental site were discussed, constraints were identified, researchable topics were discussed and rational experimental plans were made for each of seven locations. Research covered topics on development of component technologies and subsystems and methods of disseminating these technologies to other research stations. At a follow-up meeting held in July 1987, detailed discussion took place on research methods, and on the need for clear understanding of research environments as a base for linking results to similar environments. Ghana, Zaire, Nigeria, Cameroon and Republic of Benin were represented at the July meeting.

Some available component technologies

Improved cassava varieties capable of yielding over 30 tons per hectare in 12 months, such as Tms 30572, are available at IITA. This and other cultivars have shown high levels of resistance to mosaic disease and bacterial blight and tolerance to mealybug. High-yielding virus and weevil resistant varieties of sweet potato (25 to 35 t/ha in 4 months) are also available. The mini- and micro-sett seed yam production technology, originally developed by the National Root Crops Research Institute and improved and popularized in conjunction with IITA, provides an excellent example of inter-institutional collaboration in technology development and transfer. That technology is capable of reducing the once-prohibitive expenses in yam planting material inn which 30 percent of tuber produced is saved for planting to less than 5 percent.

With increasing environmental hazards, eg, drought, African countries have faced food shortages in recent years. Some of the root and tuber crops, particularly cassava, are tolerant of drought and are, in fact, extensively grown whenever risks are anticipated. The root-crop-based system is normally associated in multiple cropping systems with cereals (maize and rice) and grain legumes (cowpeas and soybeans). Improved, high-yielding, rice and cowpea varieties, resistant to different environmental stresses, are available in Nigeriaat IITA, at the Institute of Agricultural Research and Training, at the National Cereal Research and at the Institute of Agricultural Research, Ahmadu Bello University. Other research centres in Africa have also developed improved component technologies.

In addition to improved crop varieties, technologies developed by farming systems researchers aim at continuous and sustained productivity of soils with little degradation. Multiple cropping systems, weed management, alley cropping, reduced tillage, mulch farming and land clearing methods are among areas in which technologies are available for further location-specific research. Mechanisms are required to accelerate accessibility to these technologies and their components to research centres in Africa, which will also develop them further as subsystems to suit their specific needs in root crops research. This constitutes the thrust of the collaborative research management.

Operation of the research group

The Convenor of the cassava-based cropping systems collaboration is IITA st Ibadan. During inaugural meetings held in February and July 1986, the specific operating procedures were discussedas follows:

Disciplinary composition. Since the research group involves interactions of scientists in base data analysis, research station studies and on-farm research, it requires multi-disciplinary teams comprising a core of agronomists, economists and soil scientists. Other disciplines will be co-opted as the need arises.

Ecology. Most of the tropical root and tuber crops in Africa are grown in the humid and subhumid zones. Those are the ecologies of major mandate for IITA. Countries with these ecological zones in which cassava is important will be encouraged to join the research grouos, which will expand by gradual degrees.

Research activities. Drawing from the existing body of knowledge in cassava-based research, emphasis will be on: (a) development of relevant component technologies at research stations or other environments similarly controlled; (b) dissemination of these technologies to research centres. Achievement of the objectives will require clear understanding of the research environments.

The biophysical and socio-economic environments and resources will be determined from secondary data, records of on-farm research team or rapid survey by the research teams. Monitoring of the biophysical environment, particularly radiation, soil and rainfall will be routinely carried out. Data will also be collected on crops responses to treatments and management inputs.

Experiments. Cassava-based experiments will be designed, discussed during the annual workshops and approved for execution. Varietal trials and cropping patterns of various designs, especially the dominant multiple cropping systems, will feature prominently.

Annual meeting. The yearly meeting, prior to cropping season, will provide an opportunity for presentation of research results of the preceding year and plans for the following season. The venue of the annual meeting will be rotated among member countries and/or institutions represented in the collaborative group. The representative in the group or country hosting the next meeting becomes the chairperson for the year.

Resource persons. Funds will be set aside or solicited to invite highly experienced resource persons to the meeting. Who is to be invited will depend upon the specific problem area wewant to emphasize, eg, soil classification, Instrumental in weather monitoring, economic parameters in interpretation of cropping pattern experiments, among others.

Visiting the trials. Visits by all members may not be feasible because of limited funds. The Convenor should organize one monitoring visit during the growing season.

Opportunities for Training. On-the-job training will be given to technical-level staff to facilitate data collection and care of instruments. Professional-level training on various data processing techniques is offered at IITA. The group members will be encouraged to participate in appropriate programs.

Session II

"Linking similar environments"

Papers in this section are followed by a selection of comments by participants

CHARACTERIZING THE CROP ENVIRONMENT: AN AGROCLIMATIC PERSPECTIVE

T.L. Lawson

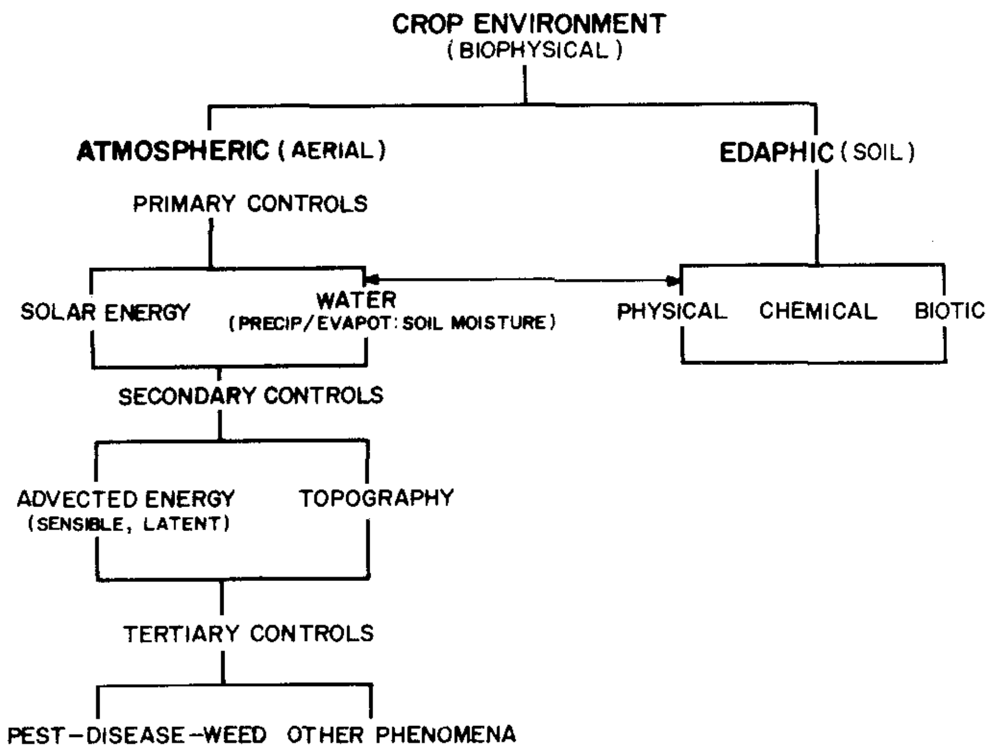
Weather and climate are the most pervasive factors of the crop environment. They restrict the occurrence and choice of species that can grow or be grown in given areas or localities and thus constitute a major determinant of crop distribution over the earth (Bunting et al. 1982). They also determine the species' productivity in those localities over given seasons. Crop yield has, in fact, been defined as the physiological expression of the genetic potential of the crop (Landsberg 1972). The strong dependence of crop physiological processes on the characteristics of the biophysical environment makes a thorough analysis and characterization of the environment not only a logical starting point but also a continuing necessity in the rational exploitation of given crops and/or cropping systems.

A cropping system may be thought of as an ensemble of activities designed to modify or improve the crop environment to achieve a better, or the best possible, yield using a given natural resource base under given socioeconomic conditions. The role of weather and climate in determining the status of the resource base and the level and timing of human intervention in the production of the crop provides a second level of influence of weather and climate in determining crop productivity. This again creates the need for the assessment and characterization of the agroclimate as a component of the biophysical environment in the exploitation of the crop, or the elaboration or application of the relevant cropping system(s). This paper will, however, focus on the direct rather than the indirect role of the aerial environment.

The agroclimatic environment and its characterization

Figure 1, derived in part from Hogg (1971), gives a summary representation of the main factors involved in the interaction between the crop and its biophysical environment. Considering crop production in its essence as "the conversion of solar energy, water and soil nutrients into economic end-products" (Hogg 1971), it is evident why solar energy and its derivatives, air and soil temperature, should constitute key factors in our characterization of the biophysical environment, and in particular the agroclimate. It is, however, rainfall or moisture that is most limiting in crop production and therefore has been and will continue to be used as the primary factor in the stratification of crop environments.

Figure 1. Crop biophysical environment



The moisture balance parameter

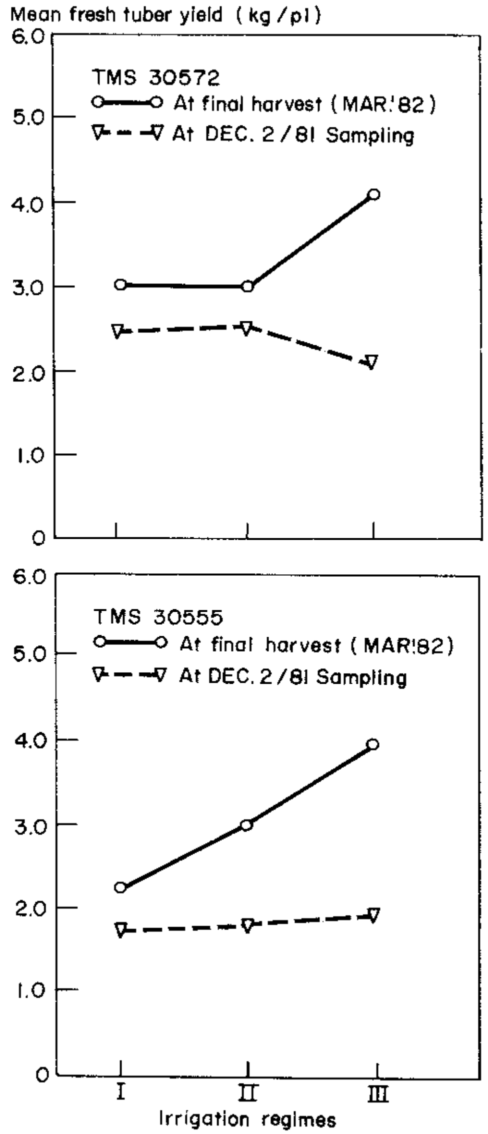
While rainfall/precipitation constitutes the source of moisture input to the soil or surface storage system, the climate of any given locality imposes a certain amount of evaporative demand which translates into a continuous outflow of water from the system as long as water remains available. Thus, although it is easier to use the primary variable, rainfall/precipitation, in the first order classification of the agroclimate of different localities, it is the water balance (the difference between rainfall and evaporation/evapotranspiration) or, better still, the moisture balance, where feasible, that has proven more viable for the purpose.

The first indication of this was provided in 1948 when Thornthwaite, defying the tradition of defining or equating climatic zones and their limits by empirical matching of temperature and/or precipitation values to apparent boundaries of vegetation types, published his article "An approach toward a rational classification of climate," based primarily on the concept of moisture balance. Contemporaneous or subsequent works by Penman (1948), Turc (1961), Cocheme and Franquin (1967), and Franquin (1969), among others, have demonstrated useful applications of the concept not only in defining and delineating agroclimatic zones but also in establishing crop calendars.

The viability of water/moisture balance as a basis for these latter purposes in general and for the objectives of the cassava-based cropping systems group in particular has been more than amply demonstrated by a recent study on cropping patterns in West Africa (Dennett et al. 1981) reported by Bunting et al. (1982). This showed that the proportion of arable land in a country devoted to particular crops was related to the average length of the period of the year during which rainfall exceeded potential evaporation (M. in days)—an approximation "of the period when growth is not likely to be restricted by water shortage" (Bunting et al. 1982).

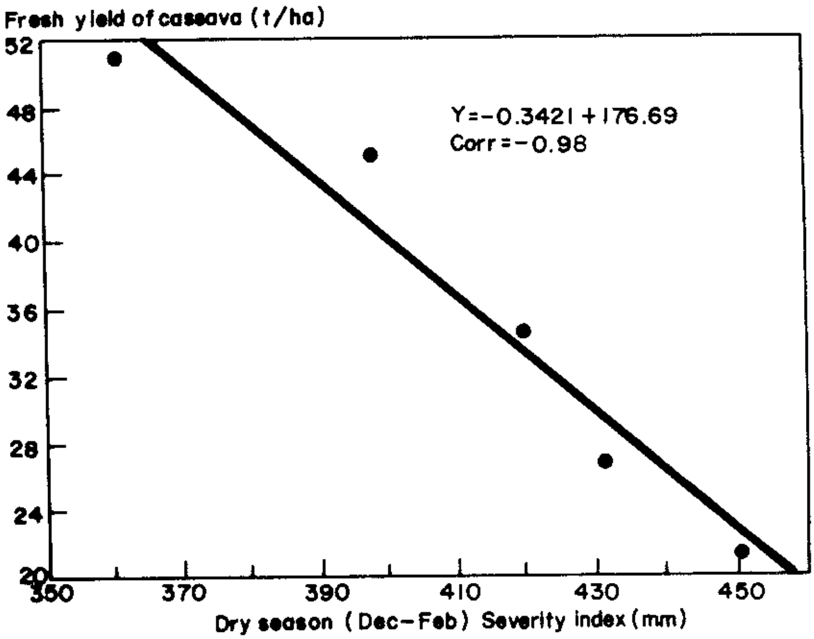
Clearly, the length of the period of positive moisture balance, defined as the period when rainfall is equal to or greater than potential evapotranspiration (Lawson and Juo 1979), will adequately serve our purpose in the broad delineation of a representative domain for research aimed at determining productive root-crop-based cropping systems and analogue areas of application. In the case of cassava, it could even serve as a good indication of the relative performance of the crop in the various zones, as may be inferred from figures 2 and 3, which show the results of two different studies by this writer.

Figure 2. Mean yield of cassava (kg/pl as affected by the duration of favorable moisture cycle



Note on irrigation regimes: In addition to blanket irrigation on 20November and 1 December: Regime I—no supplementary irrigation; Regime II—supplementary weekly irrigation through 31 December; Regime III—supplementary weekly irrigation through 5 March

Figure 3. Relationship between the fresh yield of cassava and the dry season severity index at IITA over a five-year period



Shorter-term variability in moisture balance

Beyond establishing the broad zones of moisture balance defining the mean duration of the cropping cycle in space, time variations in this parameter on a decreasing scale which reflect the year-to-year and inter- and intra-seasonal situations, and which more directly affect the corresponding yields, are crucial and require collation/observation and analysis as both historical and concurrent data in the cropping season. The results provide a basis for modifying the environment to suit the crop or cropping system where possible, but more generally for fine tuning the crop/cropping system to the environment. It is also indispensable for sound interpretation and comparison of experimental yield data (Lawson and Juo 1979; Lawson et al. 1979; Lawson 1982a).

Potential evaporation/evapotranspiration as a component of the moisture balance is, as observed elsewhere (Lawson et al. 1979), a relatively conservative property of the environment, and much less variable than rainfall. In most practical applications, therefore, the variability in moisture balance is primarily assessed in terms of the variability in rainfall.

It is also to be noted that root crops, particularly cassava, yams and sweet potato, to name those of interest in the region, are much more resilient than other crops under conditions of short-term moisture deficits or limited moisture supply (Jones 1961). Except for the demands of associated crops in mixed cropping a rougher time determination of rainfall variability than the weekly period found to be appropriate in this region for other crops, especially cereals, should prove adequate.

Finally, as plants gain access to moisture through the soil, any substantial moisture storage capacity found in the soil should be taken into account when the crop moisture regime is assessed. In all cases, observations of both soil moisture and water balance components are desirable.

Other aspects of rainfall/precipitation are relevant in the context of the envisaged activities and should be monitored where feasible. These include the rainfall intensity, which largely determines the redistribution of the incoming rain at the surface and the amount entering the soil, its erosive capacity, and its indirect effect through its influence on pest and disease manifestation.

Solar energy: light

The cardinal role of solar energy, or light, cannot be overstated. It is generally agreed that in the humid and, to a lesser extent, the subhumid tropics, where a large part of the root crops in West and Central Africa are grown, global radiation levels are less than optimal and must therefore be regarded as limiting to growth and productivity in seasonal crops (Lawson et al. 1979, Lawson 1982a). Thus, under non-limiting moisture (and nutrient) conditions, comparatively higher insolation, and/or more efficient interception of the incident light, dry-matter production and yield should increase. With the predominance of crop mixtures as the basic cropping pattern in the region of interest, the efficient use of light through the temporal and spatial manipulation of crops and choice of crop varieties in the above circumstances must be regarded as a premium. This has been confirmed by experimental studies (Lawson 1982b; Lawson and Jackai 1983).

It is therefore evident that the assessment of the actual light climate at given locations, as well as the quantitative monitoring of the variable on component mixtures in specific experimental conditions is indispensable for the design of efficient cropping systems and for comparative analysis of experimental results (IITA 1981; Lawson 1982b). Qualitative assessment of the incident light in this situation may also be needed.

Accurate measurement of solar radiation however requires fairly expensive instrumentation. Where this is not available, proxy measurements with mechanical pyranometers or sunshine recorders can provide limited but useful information. Even in the absence of these, accurate estimates of cloud cover may still serve a purpose.

Temperature regimes

Air and soil temperatures are generally not limiting for root crops in much of the lowland humid tropics. Supra-optimal temperatures can however occur, particularly at the onset of the growing seasons (Lal 1974; Monteith 1978; Lawson 1982a), affecting sprouting in yams, for example, and accelerating water loss by cassava cuttings and sweet potato vines. These temperatures need to be monitored, and methods of modification should be incorporated into the relevant cropping systems.

As in the case of solar radiation, the temperature regimes on the microscale in crop mixtures may reveal substantial modification of the prevailing mesoscale temperatures monitored in standard screen (IITA 1981; Lawson and Jackai 1986). Systematic monitoring of these temperature regimes should also prove useful, in specific cases, in assessing crop performance and incidence of disease and pests (Lawson and Jackai 1986).

Humidity

In addition to its influence on evapotranspiration rates and the consequent effects on yield potentials (Lawson 1982a), the relative humidity regime in the crop canopy may, like temperature, influence disease and pest incidence in the crop or crop mixture. Parallel observation of these related variables can only be useful (Lawson and Jackai 1986; Jackai and Lawson 1986).

Wind

As an important factor in atmospheric turbulence transport and evapotranspiration losses, the monitoring and assessment of wind speed can assist in estimating potential moisture demand and establishing the moisture balance (Lawson 1982a). Its role in the advection of pests and disease organisms also justifies its measurement where possible. Where wind speeds are such as to induce lodging, there is added reason for monitoring them.

Topography

The role of topography in the aerial environment is indirect, deriving essentially from modification of the main climatic variables as a result of changes in elevation and the aspects and slope of the land.

Conclusion

The profound influence of the environment on distribution of crop species and on the growth and yield of individual crops makes it both pertinent and necessary for the production of these crops or the evolution of cropping systems to occur in the context of a sound assessment and understanding of the agroclimatic background of the localities of production or experimentation. The need for adequate monitoring of the important variables for the duration of the relevant studies is self-evident. In any given case, the range of data to be collected will depend on the objectives of the study or the facilities and resources available.

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PHYSIOLOGICAL CONSIDERATIONS FOR TUBER YIELD IMPROVEMENT IN CASSAVA (*MANIHOT ESCULENTA* CRANTZ)

O.A. Akinyemiju and A.S. Adegoroye

Abstract

Cassava is an important tropical root crop largely because it is a cheap source of carbohydrate. It is amenable to agronomic as well as genetic improvement, and it is a crop that is native to the tropics. Much agronomic work has been done on cassava, and even more on improvement studies. However, very few studies have been conducted on the influence of environmental components on the growth and development of cassava; nor has much been done on the physiological processes of cassava and their interaction with environmental factors in the different ecosystems where cassava is cultivated. In order to achieve a systematic approach to yield asymptote of cassava, it is recommended that studies be carried out on important physiological determinants of yield in cassava. To aid breeding work, a cassava ideotype is proposed. The proposed cassava ideotype should have a 10-month growth cycle in which crops are planted at the onset of rains and harvested towards the end of the following dry season; a single short erect stem; rapid early leaf area development, a maximum leaf area index of 3-4, slow decline of leaf area during senescence and early initiation and cellular development of the tuber.

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Cassava is a major tropical root crop, important in supplying the daily carbohydrate needs of the vast populations of the tropical countries of Africa, America and Asia. Its botany is well covered by Cobley (1965) and Purseglove (1968) while its agronomy was comprehensively reviewed by Onwueme (1978). However very little is reported on its physiology.

This paper reviews some of the physiological constraints on yield improvement in cassava. It is divided into three sections: the first examines the environmental and developmental components that are considered important for the growth and development of cassava; the second considers the physiological and metabolic processes that lead to tuber initiation and bulking in cassava; and the third proposes a cassava ideotype.

Environmental components important for growth and development of root crops

There is little information on the effects of environment on growth and development of any root crops, particularly cassava. Consideration of these environmental effects will therefore be general.

1. *Light intensity*

High light intensity (3,000-16,000 lx) increases initiation and early growth of the tuber, early attainment of maximum stem length, and senescence. Total dry matter and distribution of dry matter to tubers should increase at high light intensities, but final tuber weight will be limited because of earlier leaf senescence (Wilson 1977). In the humid tropics, cassava will be expected to be higher-yielding during the late season than in the wet season because of partial cloud cover and reduced light intensity in the wet season (Onwueme 1978).

2. *Day length*

The effect of day length on growth and development is particularly important in tropical tuber crops such as cassava. Tuberization in cassava is promoted under short-day conditions and reduced by day lengths greater than 10-12 hours. The crop is therefore most successfully cultivated between latitudes 15°N and 15°S (Njoku 1963, Onwueme 1978). However, varieties have been identified at IITA (1982) that are classified as short-day or long-day plants.

3. *Temperature*

Seasonal variations in temperature are small in the tropics, so the effects of temperature on growth and development in tropical root crops like cassava are less relevant. However, little work has been done on the effects of temperature on other tropical root crops. Kim (1961) established that low night-time temperatures increased tuber weight in sweet potato. Tuber development in sweet potato was more rapid at 25°C than at 30°C and no tubers were formed at 10°C and 15°C (Spence and Humphries 1972).

4. *Evapotranspiration*

Few studies if any have been done on the relationship between tuber yield and potential evapotranspiration in tropical root crops (Wilson 1977). However, yields increase from less than 5 to more than 10 tons/ha as potential transpiration increases from 2 to 6cm. A linear relationship between tuber yield and evapotranspiration has been reported for *Solanum* potato (Wilson 1977).

5. *Water*

Water supply is probably the most critical environmental factor affecting the growth and development of tropical root crops since precipitation is subject to seasonal and diurnal fluctuations. It is particularly important for the establishment of cassava and other tropical root crops because of the methods of vegetative propagation used in their cultivation. For further growth of the crops, water requirements are different. Except at planting, cassava can withstand prolonged periods of drought and is a valuable crop in regions of low or uncertain rainfall (300-500mm) (Onwueme 1978). Optimal water requirement is, however, in the region of 1000-1500mm of well-distributed precipitation (Kay 1973). Inadequate and/or irregular water supply leads not only to poor yields but also to malformed tubers. A better understanding is still needed of the relationship between tuber yield and water supply in cassava.

6. *Oxygen*

The deleterious effects of waterlogged soils on tuberization in tropical root crops are due to restriction of the oxygen supply shown to be critical for tuberization in sweet potato (Wilson 1977). On poorly drained soils, cassava root growth is poor, and the tuber-to-shoot ratio is considerably reduced. The poor soil aeration under such conditions causes the few tubers formed to rot readily (Onwueme 1978).

7. *Soil Physical Conditions and Nutrient Supply*

The best soil for cassava cultivation is a light, sandy loam of medium fertility; but tropical root crops can be cultivated in heavy clays with proper management. In crops in which the yield organ (ie, the tuber) must grow against the resistance of compacted soil, soil physical conditions become important for high yield. However, very little work has been done on the interrelationship between physical properties of soils and tuberization of tropical root crops.

Under conditions of very high fertility, cassava tends to produce excess vegetation at the expense of tuber formation (Onwueme 1978). Yields on many soils are apparently limited by lack of adequate potassium: when the potassium level in the soil is low the response of cassava to N fertilization is poor (IITA 1982, Onwueme 1978). However, little information exists on the best times to apply fertilizer to cassava, although it is more appropriately applied at planting (Onwueme 1978).

Physiological processes leading to tuber yield in cassava

Shoot and tuber ontogeny, photosynthesis and protein synthesis are among the most important physiological and metabolic processes that contribute to growth and development, and are therefore important in the productivity of tropical root crops.

1. *Shoot ontogeny*

Shoot ontogeny in root crops can be separated into the following stages according to Wilson (1977):

(a) germination (sprouting) to produce a seedling
(b) period of juvenile growth
(c) period of growth of the mature plant to maximum leaf area
(d) leaf senescence.

Besides the report that juvenile leaves of cassava are high in anthocyanin content, the effects of the environment on shoot ontogeny and indeed on ontogeny per se have not been critically examined in most tropical root crops (Wilson 1977).

2. *Tuber ontogeny*

The morphogenetic processes of tuber initiation and tuber growth are different and distinguishable from one another. Some external factors affecting tuberization in tropical root crops have been reported (Wilson 1977). The only environmental factor categorically shown to have an effect on tuber initiation is photoperiod in root crops sensitive to day length. The cellular events leading to tuberization in root crops other than *Solanum* potato and sweet potato have not been thoroughly studied. However, the anatomy of tuberization in cassava has been described (Doku 1970). Light intensity, temperature, water supply and mineral nutrients apparently operate through their influence on tuber growth rather than on tuber initiation.

The effects of the various environmental factors on tuber initiation and the cellular component of tuber growth are mediated through hormonal responses. Several plant growth substances have been shown to be involved in tuber growth. These hormones include auxin, gibberellin, cytokinins, ethylene and abscisic acid (Wilson 1977).

However, the exact nature of the plant growth substance involved in tuber formation has not been identified. What is known is that the inhibiting effects of light and low oxygen supply on sweet potato tuber growth and development are mediated through inhibition of meristematic activity in tubers (Milthorpe 1967). Similar studies on cassava tuberization have not been reported.

3. *Photosynthesis*

There is a close interrelationship between the parameters of dry matter accumulation in cassava. For example Enyi (1972) established a direct relationship between LAI (Leaf Area Index) and tuber bulking in cassava. Since accumulation of dry matter depends on photosynthesis, it is important to examine quantitative interactions between the environment and photosynthesis.

It is generally believed that only a very small percentage of incident radiation is used for dry-matter production. For example in maize it is estimated that only about 3 percent of incident radiation is used during the active growing period of a crop that has a vertical display of its leaves and C4 photosynthetic efficiency. A major problem in crop production, therefore, is increasing the efficiency of the conversion of radiant energy into dry matter. The optimal light interception has been estimated to occur in most root crops at LAI = 3 (Wilson 1977). Rapid increase in leaf area during early growth would therefore increase the efficiency of light interception. Very little work has been done to elucidate the interaction of LAI and photosynthesis in cassava. However, in sweet potato it has been established that the quantitative yield limiting process is tuberization rather than photosynthesis and hence the external factors which influence tuberization, eg, water supply and oxygen, are likely to have considerable effect on yield (Wilson 1974).

4. *Protein Synthesis*

Protein synthesis involved in cell division and expansion is important in tropical root crops. It is known that abundant N promotes excess foliage at the expense of tuberization. Besides this fact, little is known of the role of nitrate reductase in root crop metabolism.

Clearly, an enormous amount of information is lacking both on the environmental factors affecting growth and tuber yield in cassava and on the physiology of the growth and development of cassava in particular and other tropical root crops in general. These are virgin areas for root crop physiologists. In the next section, evidence will be adduced to show that very little permanent improvement in tuber yield of tropical root crops can be achieved without first understanding the physiology of the growth and development of crops.

Cassava Ideotype

Classical plant breeding methods rely on two approaches: (i) defect elimination in breeding programs for disease resistance and (ii) selection of individual plants for high yield (Donald 1968). The gross shortcoming here is that no reference is made to designated physiological or morphological characters which determine such high yield. For example, in cassava improvement at IITA the mosaic virus resistant variety is expected to out-yield the non-resistant varieties. Leaf area seems to be a factor in this. However, as has previously been highlighted, the relationship between leaf area production and tuber yield in cassava is not known. In cowpea (*Vigna unguiculata* [L.] Walp), for instance, it is known that a 25 percent defoliation will not lead to any significant yield reduction (Ezedinma 1973; Akingbohungbe 1980). The obvious drawback therefore in the use of the two classical breeding approaches is that the methodology does not generate any information on the plant characters associated with improved crop performance. Therefore improvement in crop performance to the asymptotic limit of the species by systematically optimizing the determinants of yield (or disease resistance) in new cultivars cannot be obtained (Donald 1968).

Donald (1968) proposed an approach to systematic improvement in crop productivity to the species asymptote through breeding for model plants or ideotypes. A crop ideotype was defined as a biological model which is expected to perform or behave in a predictable manner within a defined environment and to yield a greater quantity or quality of useful produce than existing varieties when developed as a cultivar. Wilson (1977) then concluded that an ideotype therefore presupposes detailed and accurate knowledge of the range of anatomical, morphological, physiological and biochemical characters existing in varieties and/or cultivars within a species. Data on the performance of the cultivars in the ecosystem for which they are intended needs to be compared with data obtained on a variety of ecosystems. Such a model was characterized for cereals (Donald 1968). However, no such model has been developed for cassava or any other tropical root crop. The absence of such a model may be due in part to the lack of basic physiological information as well as to the diversity of the habitats in the species. The implication is that a model will have to be developed for each tropical root crop. The ideotype of cassava will be considered.

1. *Crop Growth Cycle*

The wet season of the humid tropics is characterized in general by high precipitation but low incident radiation; this may lead to reduced rates of photosynthesis, reduced leaf density, increased stem length, reduced individual leaf area and consequently reduced availability of assimilates for storage. The dry season, on the other hand, apart from the lack of moisture, provides conditions of soil oxygen and nutrient supply, light intensity, day length, and night temperature which are more favorable for growth (Wilson 1977). Therefore one basic worry in a long-season crop like cassava is the development of leaf area (LAI) in relation to the optimal conditions of growth. The choice of crop growth cycle should be such as to maximize cassava tuber productivity. A 10-month growth cycle in which the crop is planted at the onset of the wet season and harvested towards the end of the following dry season will be ideal for cassava.

2. *Stem habit*

In cassava, as in most root crops, the stem has the following functions: (i) support, exposure and display of leaves; (ii) transport of assimilate from leaves to tubers; (iii) storage in the underground stem or root; and (iv) genesis and attachment of tubers (Wilson 1977). The important considerations here, in contrast to cereal crops where the stem is involved in aerial support for the yield organ, are the leaf display and transport of assimilate, which require opposite characteristics. In cassava, a single short erect stem rather than many long stems would seem to be an advantage for efficient utilization of environmental resources (Enyi 1972).

Another consideration in the stem habit is the potential for mechanization in cassava, when shallow compact rooting may be advantageous over deep diffuse rooting.

3. *Production and Distribution of Assimilate*

Some characteristics worthy of consideration in assimilate production and distribution in cassava and other tropical root crops are:

(a) rapid early leaf area development to LAI = 1 for effective light interception during early growth,
(b) development of leaf area to a maximum LAI = 3-4, and slow turnover of leaves after maximum LAI has been attained,
(c) slow decline of leaf area during leaf senescence, since this period often coincides with maximum rates of tuber bulking,

(d) early initiation and cellular development of tubers to create an active tuber sink for assimilate (Wilson 1977).

These characteristics are considered important physiological determinants of yield in cassava and any improvement based on them is likely to lead to a systematic approach to the yield asymptote of cassava. However these characters have not been seriously investigated in cassava. In order to establish the potential of each character, it must be closely studied, taking into account the environment for which the ideotype is being designed.

In Nigeria, for example, IITA has several reports showing that improved cassava clones out-yielded local standard varieties by 2 to 18 tons, primarily because they are resistant to diseases and have benefited from improved cultural practice (IITA Annual Reports, 1975, 1976, 1977, 1980, 1982). But in a recent study conducted at Obafemi Awolowo University, Ile-Ife, Alimi and Akinyemiju (1987) observed that the "gari" processed out of a local cassava variety, Odongbo, was as good as or better than that from the improved varieties of IITA (TMS 30572) and IAR&T, though the tuber yield in Odongbo was significantly lower than that from the improved varieties. In this example, Odongbo, a native unimproved cultivar, is susceptible to various foliar diseases (mosaic disease and bacterial blight), the leaf area production is much less than the improved varieties and also it usually has few stem branches which are considerably taller than the improved varieties. The contradiction in cassava improvement program revealed in this study underscores the significance of detailed studies of the physiological determinants of growth in order to systematically improve the quality and yield potential of cassava to the asymptote level within our environment.

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LINKING SIMILAR CROP ENVIRONMENTS: RELEVANT AGRONOMIC DATA

H.C. Ezumah and M.P. Gichuru

Abstract

Network experiments at carefully selected sites where important features of both environment and crop performance are measured are useful in the interpretation of and extrapolation from the climatic, edaphic and socioeconomic factors that determine crop adaptability, distribution and productivity. Important edaphic factors are: (i) chemical and physical properties of soil, including inherent soil fertility; (ii) erosion hazard; (iii) topography; and (iv) water deficiency or excess and other crop-related factors. These are among the most important causes of site-specific crop responses to given agronomic management practices. They may to some extent determine agronomic practices, including planting dates, growth cycles and planting patterns, and consequently yield and yield components. The importance of careful data collection to quantify the edaphic factors and effects of related agronomic practices is emphasized.

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Although crops may grow over wide areas, geographic segregation over a range of environments is common (Martin and Leonard 1964). The degree of adaptation to environments of growth is determined by normal growth and high level of biological yields. Factors influencing localization include climate, topography, soil characteristics, insect pests, plant diseases and economic conditions (de Vries 1963).

A further illustration of the overriding importance of climatic factors in crop adaptation and distribution is provided by Good (1953), who states that "Plant distribution is 1) primarily controlled by the distribution of climate, 2) secondarily controlled by edaphic factors, and 3) great movement of flora have taken place in the past and are continuing."

Climate comprises temperature, moisture, light and wind. The edaphic factors are parent materials, soil and physiography. Since the manifestation of these edaphic factors is influenced by climate, they are secondary. However, soil factors determine whether a plant or crop is actually found in an area, and in what abundance. Thus every plant species exists and reproduces successfully only within a definite range of climatic and edaphic conditions, a clear understanding of which will facilitate extrapolation of cropping systems results across similar environments.

A network of experiments located at carefully-selected representative sites at which important features of the environment are measured will be useful in interpreting and extrapolating results. This is especially the case in farming systems research which aims to develop location-specific packages of farming practices. Results from a given site should be applicable to areas with similar environments. The key tasks are, therefore, (a) to collect environmental data in specific experimental areas, and (b) to determine the minimum set of data essential to interpret site-specific results and extrapolate from them to other environments.

Relevant data

Climatic and economic conditions and their influence on crop plants are discussed in the papers of Lawson, Akinyemiju, Nweke, and Hahn. Salient data generally required to describe crop edaphic environments include:

1. Physical features:
—location: longitude, latitude, elevation;
—physiography: land form and land type; sloping, flat, or rolling; slope direction; angle of slope; position of land type on land form.

2. Soil classification information: the underlying assumption in soil fertility evaluation is that fertilizer recommendations and agronomic management practices are site-specific. Differences in soil properties are a main reason for this site-specificity. A logical conclusion is that soil fertility characterization must be closely related to soil survey and classification, but soil survey groups gather only a fraction of the information needed by soil fertility specialists. Although soil survey reports can be of value in determining the general nutrient deficiencies and average fertilizer requirements of a region, they cannot serve as a basis for fertilizer management recommendations for a specific field. Therefore, both pedon description and on-site characterization of the soil are essential. In order to correlate crop response to these factors, a pre-plant topsoil sample (0-15cm) should be analyzed for organic C, total N, pH, extractable P, exchangeable bases, and acidity. These are indicators of soil reaction and fertility for any given site. Any soil amendments applied, including source and amount, should be recorded clearly (see table 1).

3 Land clearing: type of vegetation, method of land clearing (mechanized or manual), and residue management (whether burned or left on soil surface).

4. Cropping history: cropping history and fallow management sequences as far back as obtainable but at least for five years.

5. Experimental design and treatments: The experimental design used and rationale for choice of design should be stated clearly. Other information required includes:

—treatment factors
—factor levels
—number of replications
—land area and plot size
—other resources (labor, chemicals, etc.).

6. Land preparation and soil amendment: tillage information indicates type of tillage (if any)—hoe tilled, no-till, tractor tilled with harrowing and disking—and depth of tillage; how residues and fertilizers are handled, whether incorporated or surface-applied; and to what extent native vegetation is destroyed.

7. Plot Size: plot size should be in meters; treatments should be labeled. Border and interplot areas should be sketched and labeled.

8. Planting: rainfall is the most important determinant of planting time in the tropics. The objective is to enable a crop to develop when rains are available. Therefore, timing of planting should be matched with the length of the growing season and the duration of effective rainfall. Plant density and spacing (inter- and intra-row spacing), should be recorded; optimum density gives the highest crop yield.

9. Crop variety: the crop and variety use should be indicated. A brief history of the source is helpful.

10. Pest and disease control: insect and disease problems sometimes determine the success or failure of a crop. Any disease or pest attack should be recorded along with control measures taken. Weeds should be included, even though they are not always seen as problems.

11. Crop growth data: at specific growth stages it may be necessary to obtain information on such growth parameters as:

a) date to 50 percent emergence (seedlings)
b) date to 50 percent tillers (leaf stage)

c) date to 50 percent anthesis

d) number of apical branches at certain periods

e) other information related to harvest samples, such as biomass at given growth stages.

12. Harvest information: the final yield data, an integrated value of all the factors that have influenced the crop during the season up to harvest (thus Yield = f [climate, soil, crop variety management, insects, diseases, etc.]). This final product (output) will determine the crop production enterprise. Extreme care should be taken in recording the data as follows.

Area harvested:	m^2
Plant population in area harvested:	plants per m^2
Biomass (top):	g/m^2 or kg/plot.
Pod weight (soybean, cowpeas):	g/m^2 or kg/plot
Grain weight or root (tuberons/wt):	g/m^2 or kg/plot
Seed or root number:	seed/m^2 or roots/plot
Panicle number (sorghum, rice):	panicles/m^2
Ear number (maize):	ears/m^2
Pod number (soybeans, cowpea):	pods/m^2

Table 1. Common commercial fertilizers

Element	Source	Remark
Nitrogen	Sodium Nitrate	Soil tends to be alkaline
	Ammonium sulfate	Soil tends to be acidic
	Urea	May volatilize
Phosphorus	Single superphosphate	Fixation
	Treble superphosphate	Fixation
	Ammonium phosphate	Soil tends to be acidic; fixation
Potassium	Potassium chloride	
	Potassium sulfate	
Mixed (contain two or more of the above elements)	15-15-15	most common in Nigeria

Table 2. Environmental requirements of crops

Edaphic (soil) factors	Physical properties
Soil reaction chemical properties (soil pH)	Soil particle size distribution—soil texture
Nutrient reserve Exchangeable bases—Na, K, Ca, Mg Cation exchange capacity Exchangeable acidity Base saturations	Bulk density Water-holding capacity/ infiltration capacity
Available P	Soil temperature Soil N
Micronutrient elements - Mn, Fe, S may also affect crop performance.	Soil organic matter

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COLLECTING AND INTERPRETING RELEVANT DATA REQUIRED TO LINK RESEARCH RESULTS FROM VARYING ENVIRONMENTS: AN ECONOMIST'S PERSPECTIVE

F. I. Nweke

One way to link research results from varying environments is comparison of conclusions reached on the basis of data collected and interpreted. From the economist's perspective, environmental factors that could vary from place to place and from time to time include farm, household, infrastructure, market, and public policy.

Farm Factors

Among farm-level information important to economists in our type of investigations are farm and non-farm enterprises adopted, farm size, yield attained, availability and use of farm labor, level of commercialization of production, and inputs employed.

Virtually all the smallholders in IITA mandate regions engage in multiple farm enterprise. They keep livestock and grow crops, and also grow tree crops and different arable crops both for home consumption and for sale. Most would also engage in non-farm activities. This diversification is due to the high risk in tropical agriculture, to family food security needs, and to the low cash income from farming.

Farm size, even crop farm size alone, is a difficult concept to define because it depends on enterprise, level of capitalization, and other factors. For the present purpose, farm size should be defined as area cropped in one farming year. Where fields are fragmented, it includes all the different fields cultivated.

Definition of cassava farm size is particularly problematic because cassava has no planting or harvesting season. Care should therefore be taken to ensure that cassava farm size is not overestimated by double counting. Only fields planted within a 12-calendar-month period should be counted, whether they are immature, mature, or even harvested.

Farm size should not be determined by questioning the farmers, since their estimates may be subject to wide margins of error even in locations where there are local measures. Field measurements with compass, chain tape, and ranging poles are not expensive, and computer programes can compute the areas from such measurements.

Knowledge of field size is important for farm budgeting. In one case, a team of investigators using USAID funding collected large amounts of farm input data over a period of 12 months from a large sample of fields. The data included fertilizers, seeds and labor by cost route approach, but the information was useless because field size was not obtained. One ton of fertilizer, or 10kg of millet seed, or 100 mandays of labor per year in field X is meaningless information in itself. To be useful, the information must be given in units per unit area such as one ton of fertilizer per ha, 10kg of millet seed per ha, and 100 mandays per ha.

The need for field size measurement may not be critical if the objective is just yield determination and if such yield determination is done by standard methods of yield sampling.

In taking cassava yield samples, care should be taken to ensure that fields of different ages and cassava varieties are not mixed up. It is necessary that the age at which a yield sample is taken be that at which most of the cassava is harvested by the farmers. Sometimes, however, this may not be possible because of sample size limitations.

Most economists would agree that farmers should not be paid for scientific information because such pay would introduce various types of bias and can make scientific investigations expensive. However, some consider that it is unfair to the smallholder, who may not have more than one hectare of cassava for an entire year, to take two or three yield samples of 40 square meters each from his farm without compensation, especially when the farmer is not ready to harvest. I am personally concerned that the investigator should pay for such harvest at the market rate. Whether he should take the harvest after the payment will depend on the cost of redisposing of it.

Both assistance from family and hired hands are labor forces on the farm. In predominantly farming areas, household size tends to be large, especially among polygamous people, such as the Tiv people of Nigeria, who may be able to increase farm labor by increasing the number of wives per household. Hired labor is more often used by relatively large smallholders who may produce more for sale than for home consumption.

Although farm labor is the most critical item of cost for the smallholder, it is also the most expensive farm information to secure accurately. Farm labor collected by the cost route method for one year for a reasonably large sample would take several years to analyze even with modern computers.

Farmers know peak labor demand periods, and the most labor-intensive farm operations; for such purposes, labor information collection by the cost-route method is not necessary. More precise labor information is, however, necessary for farm budgeting or for production function analysis. As a short cut, instead of following selected farmers and fields over the entire crop season in a cost-route approach, one could take labor measurements wherever, whenever, and by whomever a required operation is observed. Cassava is particularly amenable to this methodology since it has virtually no limited planting or harvesting season. It should be remembered, of course, that harvesting is more labor-intensive in the dry than in the wet season.

Knowledge of the degree of commercialization helps predict potentials for adoption of new technologies, especially those technologies that require purchased inputs. There is published evidence that farmers in general are more willing to adopt new technologies for production of crops for sale than for family food security.

Household factors

Household information of value to economists on the type of studies that we conduct includes size, composition, religion, income, and tribal origin of the household as well as age, education, sex, social standing, and secondary occupation of household head and spouse or spouses.

Household size and composition with respect to age and gender of members provide indications of the labor available to the household as well as its consumption and expenditure needs.

Religion and tribal origin could also influence labor availability and use. Among certain Muslim sects, women can leave the residence only at night. The contribution to farm labor of women thus restricted would be, in most cases, limited to crop processing at home. There is abundant evidence that among some tribes, farm operations and even farm crops are divided along gender lines.

Household income, age, education and social status of the household head determine access to material inputs from public sources and to extension advice. These could also determine consumption and expenditure habits. Age of household head could, to some degree, be negatively related to access to material inputs and extension advice and hence to adoption of new technologies.

Household income information is virtually impossible to obtain *directly with a reasonable degree of accuracy because most people are not* able to estimate their income accurately; and even if they can, they may be reluctant to disclose it. A proxy often used is household expenditure. To obtain a reasonably accurate estimate of household expenditure, information must be sought on individual items as disaggregated as possible, even when the period of recall is short.

Age is difficult to ascertain in the absence of birth records. Where an age grade institution exists, however, age can be approximated by ascertaining the respondent's cohort and the range of the age of his cohort.

Precise information about level of education is obtained by determining the number of years the respondent spent in formal school irrespective of whether the years were spent repeating the same classes.

Social status is often constructed as an index based on possession of items of social value or prestige in the area such as modern housing, furniture, or vehicles. A simple index could be the sum of the market values of such items.

Infrastructure Factors

The presence or absence of certain rural infrastructures, such as transportation, health, water, industries, credit, and extension, is often used by economists to explain farm situations in study areas.

Rural transportation facilities include rural road network and its linkage with urban centres, and transportation vehicles. Their availability would determine the extent of the available market for the farm products as well as access to some farm inputs.

The presence of rural health, water and certain industrial facilities would influence farm labor availability in a farming area. When a woman or her baby is sick, she is not available for farm labor. The presence of pipe-borne water or of grain or cassava grinding machinery would reduce the amount of time women and children spend on fetching water or milling food crops. Time thus saved would probably be diverted to farm work.

The presence or absence of modern health facilities could also affect the amount of cash available for farm investment. Where there are no modern health facilities, rural people often spend more money on native medicine and fortune-telling than others spend on modern medicine where there is such a facility. Rural credit also influences farm investment. Most of the time, traditional credit is all that is available to the smallholders. This system of credit is much more expensive than modern credit systems.

The distance of the extension office or farm service centre, the farmer-to-extension-worker ratio, mobility, knowledgeability, and general working incentive of the extension workers influence adoption of new technologies and availability of publicly provided farm inputs.

Market Factors

If asked why they engage in farming, most smallholders in Africa would say it is to feed their households and to earn cash income. Cash-income earning depends on certain market factors, especially the size of the market for the farm produce in question as well as the cost of purchased inputs.

Farm produce may have a limited market if it is consumed mainly by low-income groups or if it cannot be moved at a reasonable cost from the producing to consuming centers as a consequence of inadequate transportation, processing, or packaging facilities.

Symptoms of low market availability for produce are relatively low market prices, and seasonal or cyclical fluctuations in the price. Cassava, especially in certain forms, is an example of a commodity which has a limited market because it is consumed by low-income groups. For example, in 1986, in Bendel State, Nigeria, the price on a dry-matter basis was ₦0.76 per kilogram for cassava as against ₦2.29 per kilogram for cowpea.

The price of gari, the major commercial form of cassava, exhibited substantial year-to-year fluctuations between 1968 and 1985 in Bendel State, as shown in figure 1. Expansion in production results in steep price declines because the available market is not able to absorb the additional production.

Plantain is another commodity that has a limited market because it cannot be moved at a reasonable transportation cost from producing to consuming centers. It exhibits steep seasonal price fluctuations in producing areas, as shown in figure 2, and wide spatial price differences between producing and consuming centres.

Figure 1. Real price of gari (at 1960 level) in Ovia LGA, Bendel State, 1968-85

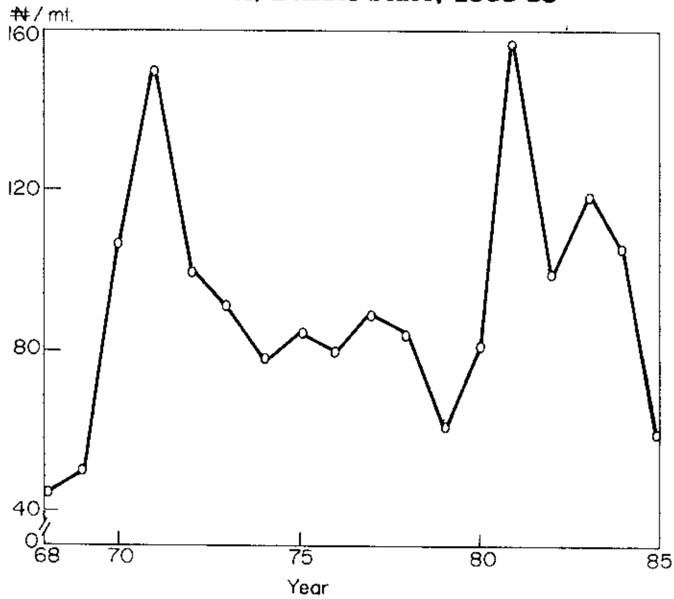
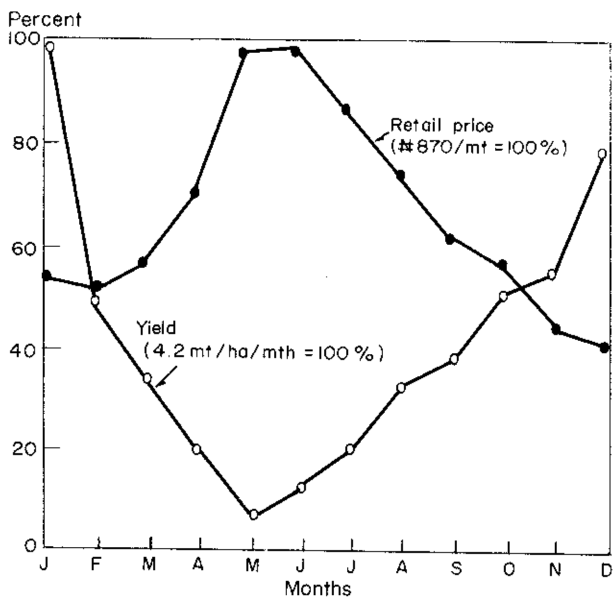


Figure 2. Indices of retail market prices /mt at Umuagwo village market and plantain bunch yield in Umuagwo, January-December 1985



Price information needs for our type of study would therefore include time series, if possible monthly, and cross-sectional prices not only for cassava but for its major substitutes and complements. In most countries, a notable exception being Cameroon, price information is routinely collected over time and space. In this case, an investigator usually need not collect price data just as he need not collect most agroclimatic information directly.

The wage rate is another important item of market information. It may vary significantly with location, gender, farm enterprise and operation, and sometimes with season, but rarely with farmer in one location.

Policy factor

Public policy with respect to exchange rate can affect aggregate market availability and hence product prices. It can affect availability and prices of such imported inputs as fertilizers, herbicides, other pesticides, farm machinery and appliances, and fuel. Government policy on urban minimum wage rate could result in artificially high farm wage rates leading to high production costs and reduced produce markets. The consequence of negative public farm policies in these areas would be a reduction in incentive to adopt improved technologies.

Direct governmental production in agriculture affects the availability and efficiency of use of important farm resources. It would be interesting to see how much of available prime farm land, labor, and other farm resources are employed by the CDC and how much is left for private farmers in Cameroon. The iterature is loaded with evidence of inefficient use of resources including land, labor, and extension resources in direct governmental production in agriculture. The case of Ghana in the 1960s is a classic example.

Grouping for efficiency in data collection

To collect the required data efficiently, the information needed should be listed for each objective and then grouped according to source, as follows:

1. Primary information which the investigator should obtain by direct observation or measurement without asking the respondent. This includes crops grown, crop mixtures adopted, farm size, yield attained, and certain items required to construct index of social standing of the household such as the type of house, household furniture, transportation vehicle owned, as well as some rural infrastructural facilities. A young

PhD holder once interviewed a farmer who was staking yam in his yam+cassava+maize+vegetable mixed-crop field. When this professional asked the farmer what crops he grew, the farmer retorted with "You've got eyes; can't you see with them?"

2. Primary information which the investigator cannot obtain by direct observations or measurement but is common to all respondents in a location. Examples are certain infrastructural facilities, farm wage rates, sources of hired labor, and frequency of market meetings. Inexperienced colleagues often make such mistakes as asking every sample farmer in a village what the wage rate was or when the rainy season set in the previous year.

3. Primary information that the investigator cannot obtain by direct observation or measurement and that varies with respondent in a location. This includes most data at the farm and household levels.

4. Information obtainable from secondary sources. This includes all time series data such as price, weather, and import and export information, that are routinely collected by public agencies. In Nigeria, such agencies are the Federal Office of Statistics, the state ministries of Finance and Economic Development, the Central Bank, the Meteorology Department, the Department of Customs and Excise, research institutes and universities. This type of information can also be obtained internationally: FAO, USDA, WHO, UNICEF, for example, also publish secondary data of interest for investigations in agricultural economics.

The first three groups of data suggest that, for collection of primary information, three different types of data collection schedule may be prepared: one for direct observations and measurements, one for group or village interviews, and the third for individual respondent interview. All the schedules should be labeled with field, farmer, and village numbers.

Sampling

The unit of investigation could be the field, as in the case of yield sample, the household, or even the village, depending on the objective of the investigation. Sample size should not be too large, or analysis will become unwieldy and final result will be delayed.

The spread or concentration of the sample would depend on the importance of different types of information in the investigation. For example, if the main focus is on the farm or household factors, then the sample could involve many farmers in a few locations. If, on the other hand, the main focus is on the variables which are common to farmers in a location but vary from location to location, then the sample should involve many locations with few farmers in one location.

Analysis and Conclusion

A wide range of economic analyses, including adoption, supply or demand function, sensitivity or risk, farm or household budgeting, market integration, and marketing margins, are possible with the type of data discussed above in combination with some agroclimatic and agronomic data discussed in other papers. Therefore, it will be possible to compare different environments with respect to adoption of any given technology, efficiency of use of resources in production of a given crop, its market potentials, the relative riskiness of production of a crop or use of a new farm technology, the efficiency of the marketing system for a crop, with respect to potential income distribution effect of wide adoption of a new technology which could result in significant increase in the output of the commodity of interest. In other words, with the type of data discussed above, it is possible to predict and compare potentials of new farm technologies in different environments.

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PROCESSING, UTILIZATION AND NUTRITIONAL LINKAGES FOR CASSAVA-BASED SYSTEMS IN VARIOUS ENVIRONMENTS

N.D. Hahn

During the 1980s, cassava has been receiving increasing attention from international groups. UNICEF has cited it as a crop for "household food security" as indicated in a policy shift from primarily health and immunization programs to improved cropping systems and the use of "social mobilization" in introducing improved cassava varieties and food products. A US$40 million program on cassava multiplication, with support from the International Fund for Agricultural Development (IFAD) and the World Bank, was started this past year in Nigeria. In August 1987, the International Food Policy Research Institute (IFPRI) organized a workshop in Washington, D.C., on "Trends and Prospects of Cassava in the Third World" to round off this interest in cassava by international donors.

Some skepticism has been voiced concerning this reported attention to cassava research. Many observers wonder whether it is because the crop does not compete with U.S. and European produce and is thus safe for further development. More positive opinions stress that cassava has been grossly underresearched and underdeveloped, and that appropriate processing, improved storage, and inter-country marketing have vast potential for the urban African population. The research concentration has so far been on the production aspects.

The purpose of this paper is to highlight the linkages among utilization, processing, and nutrition, and the reasons why these factors must be reincorporated as an integral part of cassava research in varying environments. Recognizing and reducing the enormous crop losses that occur between harvesting and final use can significantly contribute to improving the supply of agricultural products above and far beyond what may be achieved by increased primary production (Booth 1974).

Cassava possesses many merits as an insurance crop, but it also presents constraints, particularly as an energy food. Losses during storage are high and the crop is highly perishable. In addition, the arduous processing necessary requires much labor, particularly female.

Roots and tubers: food consumption in Africa

For countries such as Central African Republic, Congo, Mozambique and

Zaire, cassava provides 70 percent of the caloric intake, and an average total of 407.4kg is consumed annually per inhabitant (Dorosh 1987; Gebremeskel and Oyewole 1987). Cassava ranks far above any other roots and tubers or cereals in consumption both in these four countries, which constitute Group I in table 1, and in the countries of Group II.

Table 1. Staple food consumption (kg per inhabitant) in sub-Saharan Africa, 1981-83, by group

	Group I	Group II	Group III	Total
		kg per inhabitant		
Roots: total	**427.2**	**234.9**	**43.1**	**182.4**
Cassava	407.4	123.0	21.3	117.8
Yam	6.6	72.4	3.5	36.8
Sweet potato	6.6	20.3	5.0	12.5
Others	6.6	19.2	13.3	15.3
Plantain	26.2	39.1	2.0	22.7
Cereals	39.7	83.8	134.1	98.3
		% equivalent calories		
Roots: total	**74**	**43**	**8**	**35**
Cassava	70	22	4	24
Yam	1	14	4	7
Sweet potato	2	3	1	2
Others	1	4	3	2
Plantain	4	6	—	4
Cereals	22	51	91	61

Source: FAO.

Note: These countries are grouped as follows:
Group I: Central African Republic, Congo, Mozambique, Zaire.
Group II: Angola, Benin, Burundi, Cameroon, Comores, Guinea, Gabon, Ghana, Côte d'Ivoire, Nigeria, Rwanda, Tanzania, Togo, Uganda.
Group III: Botswana, Burkina Faso, Cape Verde, Chad, Ethiopia, Gambia, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Namibia, Niger, Réunion, São Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, Swaziland, Zambia, Zimbabwe.

Cassava accounts for about 1,200 calories per capita per day (about half of total calories) in Zaire and the Congo and more than 900 calories per capita per day in the Central African Republic. On the basis of FAO Food Balance Sheets, it is estimated that "there are 40 million people living in Central Africa and Mozambique whose average daily cassava consumption exceeds 600 calories per day, and another 120 million people (throughout Africa) whose average daily cassava consumption exceeds 200 calories per day" (Dorosh 1987).

Cassava as a staple

Cassava has some distinct disadvantages. The protein content is only 1 percent of fresh weight and 3 percent on a dry matter basis. This protein content compares unfavorably with other roots and tubers: white potato has 9 percent, sweet potato 4.3 percent and yam 8.7 percent protein. Compare this with the 40 percent protein content of soybeans. Cassava has a moisture content of between 60 and 70 percent, which increases transport costs, and a very short post-harvest storage life. The losses have been estimated at 14 to 75 percent (Janssen and Wheatley 1985). A more conservative estimate suggests that around 25 percent of all perishable food crops harvested are lost before they are consumed. Nevertheless, the potential long-term ground storability of cassava is a distinct advantage. Deterioration, manifest in loss of quality and quantity, results from pathological, physiological, or mechanical damage (Booth 1973). Because cassava can be stored for only two or three days after harvest, it is left in the ground until needed and then is consumed or processed immediately. According to calculations given by Ingram and Humphries (1972), if only half the global cassava crop is left in the ground for as little as two months longer than necessary, more than 8 percent of the total area planted to the crop is unnecessarily occupied, assuming a 12-month growing season. Thus, on a global basis of just over 9 million hectares cropped with cassava, about three quarters of a million hectares of agricultural land are withheld from alternative production. Cassava is usually available all year round thanks to this practice of "storage avoidance" (Intermediate Technology Development Group 1987).

Cassava nutritional drawbacks are its low protein content, low energy density, and potential toxic effects from the natural content of cyanide-yielding compounds (Jaynes 1987). The first of these can be effectively counteracted with protein-rich supplementary food and the second with energy-dense supplementary food (Rosling 1987).

As reported by Dr. Jesse Jaynes, the cassava root contains 30-40 percent dry matter, composed mainly of starch and sugar, which is found in a higher proportion than in most other roots and tubers. Thus cassava is an admirable source of calories, but its low protein content and the extremely poor quality of the protein it does contain make it an incomplete food (see table 2).

Table 2. Dry matter, carbohydrates, and protein content of root and tuber crops

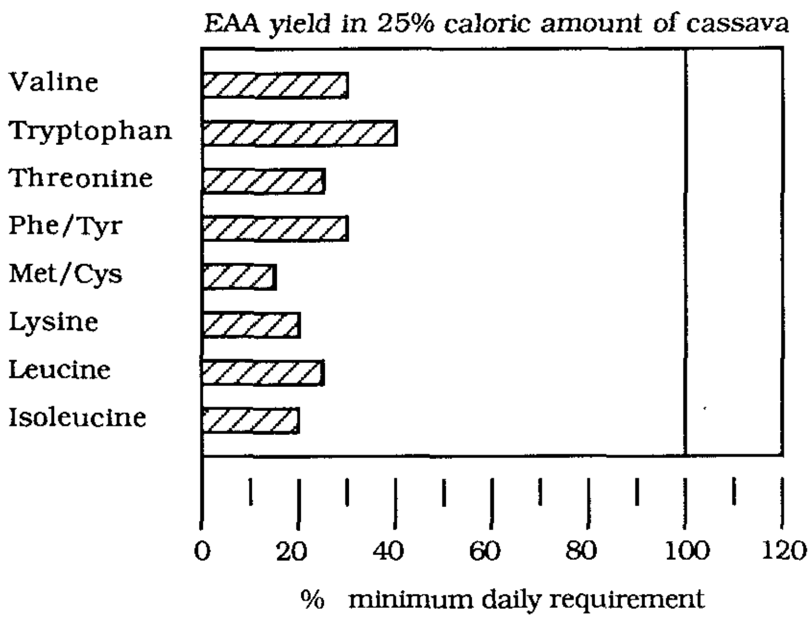
Crop	Dry matter (%)	Carbohydrate (% dry matter)	Protein (% dry matter)
Cassava	37.5	92.5	3.2
White potato	22.0	85.9	9.1
Sweet potato	30.0	91.0	4.3
Yam	27.6	87.3	8.7
Taro	27.5	84.4	6.9

Source: Jaynes 1987

Figure 1 shows that cassava is extremely deficient in certain essential amino acids. It has been difficult to produce significant increases in the essential amino acid content of cassava by means of classic plant-breeding approaches (Jaynes 1987).

Rosling (1987) showed that toxicity in cassava is caused by the poison cyanide (prussic acid), which has the simple chemical structure HCN. Toxic effects occur when cyanide is liberated from a more complex chemical compound called linamarin. Dietary cyanide exposure from cassava will result from consumption of insufficiently-processed roots, probably from liberation of cyanide in the gut from ingested linamarin. The human body has a fairly effective thiocyanate (SCN). The substrate for this reaction is sulfur (S) originating from proteins in the diet; so if the protein intake is adequate, the human body can withstand moderate cyanide exposure without any symptoms of accumulated effects. But cassava has a low protein content, and, especially during droughts, poor families will also have a low intake of protein-rich supplementary food. The toxic effects of ingested cyanide may thus be aggravated by a low sulfur intake.

Figure 1. Essential amino acid yield in the amount of cassava necessary to yield 25 percent of the caloric requirement of a 20-kg child (about 325 g)



Rosling explains the incidences of goiter and cretinism (a form of mental retardation) as caused by iodine deficiency. These disorders can be considerably aggravated by continuous dietary cyanide exposure from insufficiently-processed cassava. This effect is caused by the detoxication product thiocyanate which interferes negatively with iodine uptake in the thyroid gland. Paralysis of both legs, caused by permanent damage to the spinal cord, has been associated with a combination of a high cyanide and a low sulfur intake from diets dominated by insufficiently-processed cassava and lacking protein-rich supplementary food. The disease, named Epidemic Spastic Paraparesis, has in the last decade crippled 5,000-10,000 women and children during periods of food shortages in cassava-dominated areas in Zaire, Tanzania, and Mozambique. For lack of other foods, the affected families had to consume newly-harvested cassava roots without processing normally; more than one week is required to remove cyanide effectively (Rosling 1987).

The historical association of cassava consumption with kwashiorkor in weaned infants in tropical Africa and Brazil rests on the very low protein content and the frequently simultaneous absence from the diet of satisfactory sources of supplementary protein.

It is essential to understand the cyanogenic effects of poorly processed cassava to ensure proper processing for the crop's development. Nevertheless, as a household food security crop, the advantages of cassava production and use certainly outweigh the disadvantages. The following factors are put forward for consideration as national collaborators initiate a program on cassava post-harvest technologies and utilization.

Factors to consider when collecting and interpreting relevant data related to cassava utilization, processing and nutrition

1. Socioeconomic-nutritional base-line surveys that determine the importance and trends in cassava production and use within production system. Particular attention should here be focused on the methods of cassava preparation for household use; market sales for feed, food, or industrial use; prices of cassava products vis-à-vis other competing crop products; measured nutritional value of various cassava-based foods and potential for introducing new cassava-based foods, both for household and commercial use.

2. On-farm research to include a nutritional and health assessment component for cassava-based regions. The most common sets of indicators are mortality statistics and anthropometric measurements. Keep in mind that children from birth to three years suffering from third-degree malnutrition have been found to have mortality rates 6 to 20 times as high as children of normal weight. For anthropometric indices, measurements of weight and height (or supine length for children under two years) are the most sensitive indicators of the nutritional status of infants and young children. In addition, arm circumference can be used for assessment of nutritional status independent of age between six months and four to five years (Austin 1981). Other assessments which non-nutritionists can make include aclinical assessments of hair, eyes, and indications of edema. The most certain assessment is laboratory biochemical analysis of bodily fluids.

3. In terms of the quality of the improved cassava varieties, it will be necessary to determine whether they speed up or slow down processing time and marketing. Data will need to be collected on time allocation and labor use at various stages of cassava development. Careful consideration needs to be given to women's labor and women's response to the improved varieties. Some women's groups in Oyo and Ondo States,

Nigeria, have complained that the larger tubers are more difficult to peel and to market and that they require longer frying because of the high water content.

4. Medical and health-related research needs to be developed on the dangers, particularly to pregnant women and children who inhale fumes during the frying of gari.

5. What are the richer energy foods that can be introduced into a cassava-based system? The potential agronomic and nutritional advantages of introducing soybeans should be considered.

6. Collection and analysis of samples of processed cassava from processing centers to determine the overall quality of product, storage capabilities and mechanical damage on the improved tubers. Research should be done in local traditional settings rather than in sophisticated laboratories.

7. Extent of bitter and sweet varieties in a production system and the incorporation of both varieties into any new system with complementary research on the acceptability of new food products. Oben and Menz have concluded that "the potential benefits from the breeding of improved low cyanide cassava varieties in Nigeria are extremely high relative to the cost" (1980). Their survey indicates the relative importance of sweet cassava in various regions of Nigeria.

One of the primary objectives of the IITA-UNICEF Program on Household Food Security and Nutrition is the development of cassava-based foods from sweet varieties. Primarily indigenous sweet varieties are used and 44 new food products have been developed.

8. A South-South Exchange on the introduction and testing at rural household level of new food products based on Asian preparation techniques and use.

9. Improved efficiency in machinery, particularly for the processing of cassava into gari to cut down on the time women spend in processing. A 1986 IITA survey by Oyewole indicates that a power grater can reduce the time needed to grate 140kg of tubers from 6 hours to 20 minutes.

The development of machinery to cut down on labor requirements is essential. Given the hours spent, particularly by women, cassava is not a low-input crop. A study comparing the percentage of labor input contributions in cassava processing and utilization in five Nigerian states

Table 3. Relative importance of sweet cassava in various regions of Nigeria

State	Sweet cassava as a percentage[a] of total cassava grown (by area)	Percentage[a] of farmers growing only sweet cassava	Percentage[a] of farmers growing both sweet and bitter cassava
Anambra	0	0	0
Bendel	6	0	47
Ogun	21	3	45
Kaduna	97	97	3

Source: Oben and Menz 1980

Note: *a* i n a given year

found that women contributed 82 percent of the total requirement (Ikpi et al. 1987). A 1986 IITA-UNICEF Study in Oyo State, Nigeria, indicates that with the introduction and use of new cassava-processing equipment, women can save considerable time. For instance, one processing hour on a machine saves women 21 hours' work each week. Given the average amount of cassava processed by a household in a year in the Oyo State areas surveyed, with appropriate cassava processing equipment, each family could save an average of 441 hours of work (Ikpi et al. 1986).

10. National research on genetic engineering should be initiated to modify the essential amino acid composition of cassava and thus increase its nutritive value. Priority research attention should be given to supplementing the existing proteins of cassava with new synthetic proteins with a high content of essential amino acids.

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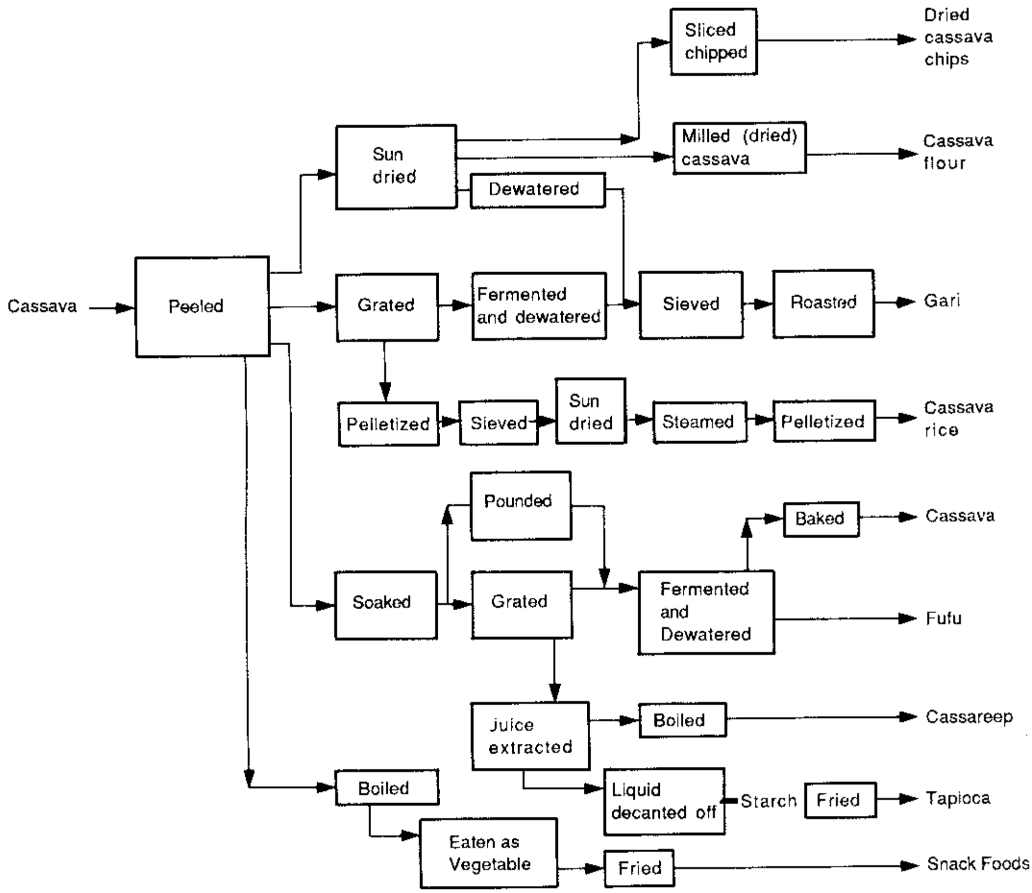
Appendix I. Stages of cassava processing



Source: UNIFEM/WAFT October 1987

Appendix II. Source of calories (%) by commodity group (1977)

Source of calories	All developing countries	Developing market economies			
		Africa	Latin America	Near East	Far East
Vegetable products	90.9	93.4	82.6	90.5	94.3
Animal products	9.2	6.6	17.4	9.5	5.5
Cereals	60.6	47.4	39.4	61.5	67.2
Wheat	16.2	10.4	14.8	40.1	14.5
Rice	28.6	5.8	9.5	7.2	40.2
Maize	7.7	13.6	14.4	6.3	4.4
Millet and sorghum	6.1	13.8	0.3	5.8	6.9
Roots and tubers	7.2	20.0	6.2	1.7	3.2
Sugars and honey	6.9	4.5	17.2	9.5	8.3
Pulses	4.2	4.2	4.4	2.7	4.4
Nuts and oilseeds	2.2	3.4	0.7	1.8	2.1
Vegetables	1.5	1.0	0.9	2.2	1.4
Fruit	2.1	4.3	4.8	4.0	1.7
Meat, eggs, fish, milk	7.8	5.7	15.0	7.4	4.3
Oils and fats	5.9	7.2	8.2	8.5	6.2
Miscellaneous	1.7	2.4	3.1	0.6	1.0
Total Kcal/day	2 260	2 205	2 557	2 620	2 028

Source: FAO Food Balance Sheets

Richard Longhurst and Michael Lipton, Secondary food crops and the reduction of seasonal food insecurity: the role of agricultural research. IFPRI/FAO/AID workshop on "Seasonal Causes of Household Food Insecurity: Policy Implications and Research Needs," 10-13 December 1985, Annapolis, Maryland.

Appendix III. Source of calories (%) by season in three Zaria villages in northern Nigeria, 1970-71

Food Group	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov	Dec-Jan	Feb-Mar
Cereals	77.4	67.8	67.4	75.5	65.2	63.4
Cereal products	6.0	12.7	8.5	5.5	10.4	16.2
Starchy roots	0.6	2.2	5.1	2.2	1.6	1.8
Milk	1.0	1.3	1.2	1.0	0.8	0.9
Meat	0.4	1.0	0.4	1.1	1.0	1.5
Poultry, fish, eggs	0.0	0.0	0.0	0.5	0.0	0.1
Seeds, nuts, legumes	2.9	4.7	6.0	2.7	5.0	3.5
Fats and oils	9.1	7.5	7.6	8.1	12.6	9.9
Vegetables, fresh	0.2	0.5	1.6	0.8	0.4	0.3
Vegetables, dry	1.2	1.1	1.0	1.1	1.2	1.1
Fruits	0.4	0.0	0.0	0.1	0.0	0.0
Sugar, sweets	0.2	0.4	0.2	0.4	0.7	0.5
Salt, spices	0.0	0.0	0.1	0.1	0.0	0.0
Snacks, Misc.	0.6	0.9	1.3	1.0	1.1	0.7
Total calories intake Kcal	2 457	2 311	2 456	2 274	1 951	2 137

Source: Calculated from E.B. Simmons, Calorie and Protein Intakes in Three Villages of Zaria Province, May 1970-June 1971. Samaru Miscellaneous Paper 55. Ahmadu Bello University, Zaria, (1976), 11 and 129.

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Appendix IV. Percentage labor input contribution of females and males in cassava production and processing activities

Activity	(1) Anambra		(2) Bendel		(3) Benue		(1) Cross River		(1) Oyo		Approx. average for Nigeria	
	F	M	F	M	F	M	F	M	F	M	F	M
Field preparation	20	80	60	40	25	75	30	70	35	65	34	66
Planting	90	10	80	20	75	25	70	30	70	30	77	33
Weeding	90	10	100	—	75	25	90	10	75	25	86	14
Harvesting	80	20	90	10	75	25	80	20	60	40	77	23
Processing	100	—	100	—	100	—	100	—	100	—	100	—
Storage	100	—	100	—	100	—	100	—	100	—	100	—
Marketing	100	—	100	—	100	—	100	—	100	—	100	—
Overall Average	83	17	90	10	79	21	81	19	77	23	82	18

Source: J. A. Ekpere, A. E. Ikpi, G. Gleason, T. Gebremeskel, IITA-UNICEF Consultation on Promotion of Household Food Production and Nutrition, 2-8 March 1986, IITA, Ibadan, the place of cassava in Nigeria's food security, rural nutrition and farm income generation: A situation analysis for Oyo State, Nigeria.

Calculated and compiled by Dr A. Ikpi, Senior Lecturer, Agricultural Economics Department, University of Ibadan from (1) Ongoing field surveys in Anambra, Cross River and Oyo State, 1985-86; (2) Grace O. Udele "Rural women in agricultural marketing—case study of cassava in Isoke Local Government Area, Bendel State," MSc thesis University of Ibadan, for the Bendel State figures and (3) Mary E. Burfisher and Nadine R. Horenstein "Sex roles in the Nigerian Tiv farm households" for the Benue State figures (1981).

COMMENTS ON THE THEME TOPIC :
"LINKING SIMILAR ENVIRONMENTS"

1. *H.J.W. Mutsaers*

The emphasis in this section was "similar environment". The first objective should be to ascertain how similar, how different and what key factors are responsible and how the information can be gathered. The papers provided too much data. there should be a minimum set of data perhaps at different levels of the environments, eg, broad zones within which selected regions are identified for research with which specific research sites are identified.

2. *J. Smith*

The first question should be an identification of purpose of data collected. It could be for production-function analysis, adoption studies etc. The research objectives determine which data to emphasize. The paper did not address comparison across countries, given different currencies. What exchange rate should be used to compare data meeting terms? One may examine possibilities with shadow exchange rates, ratios of wage rate to price of commodity. If the wage rate is low compared with price of cassava, there will be more incentive to produce cassava.

3. *O. Olorunda*

Cassava is increasingly becoming an industrial, not just a food, crop. There is a need to emphasize end use. Flexibility of harvest time affects end product quality and quantity, eg, water content and garification rate. Most products derived from cassava are affected by pre-harvest factors.

4. *D.S.C. Spencer*

While noting the danger in oversimplification in data collection, especially when research/survey objectives are not fully observed, the set of data suggested in the papers is too broad. Groups may define a minimum data set for activity groups, for example, in the following areas:

(a) Constraints analysis
(b) Experimental station studies
(c) Research managed studies
(d) On-farm studies

The objective should be to ascertain how similar or different various research sites are, and what minimum sets of data are needed to characterize the environments. It is perhaps more practical to consider only agroclimatic data in a broad sense and link socioeconomic data with specific use intended for data collected.

Diagnostic survey results presented showed two trends: those based purely on qualitative data and those based on quantitative data as well. For the collaborative research objectives, quantitative data should be routinely collected by the survey group themselves, eg, field area and yield.

Session III

Diagnostic survey reports

CASSAVA IN THE FARMING SYSTEMS OF CAMEROON'S HIGH-RAINFALL COAST

S.W. Almy and M.T. Besong

Abstract

The Fako Division in the Southwest province of Cameroon extends from sandy loam soils with a mere 1,800mm annual rainfall to the recent volcanic soils of the highest rainfall area in Africa (9,800mm). In both areas food-crop farmers grow cassava, but not as the only staple. Prolonged rainfall permits two cropping seasons and the sequential cultivation of several major and minor crops, thereby increasing food quantity, quality and security. This report is based on a 1986 agro-socioeconomic survey with accompanying agronomic resarch. Implications of the ongoing release of new high-yielding varieties of cassava into the area are discussed in this context.

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The Fako Division of the Southwest Province stretches from the coast of Cameroon to the eastern, western, and southern slopes of Mount Cameroon, the tallest peak in West Africa (4,072m) and an active volcano. The larger part of the Division is recent volcanic soil, rich but very rocky. The major cassava-producing area is on the older, sedimentary, sandy loam soils of the Tiko Plain (TP), which receives 1,800-2,800mm of rain annually. The second major area is the volcanic coast (Lower Volcanic, or LV), from the old port of Limbe (Victoria) up to an altitude of 600m, with from 4,800mm of rainfall on the coast to 2,200mm inland. Both regions enjoy seven to eight months a year with more than 100mm rainfall. Rainfall is unimodal. A third volcanic area along the western coast of the mountain (West Coast, WC), with few food-crop farmers, receives 5,400-9,800mm of rain a year, with 0-2 months under 100mm. The fourth zone, the Upper Volcanic (over 600m high) grows no cassava.

Almost half the agricultural land is in large plantations of rubber, oil-palm, and banana, most belonging to the parastatal Cameroon Development Corporation. The rest is in the hands of small farmers, primarily food-crop growers. There are five principal staples: plantains (*Musa* L. [AAB]), cocoyams (*Xanthosoma sagittifolium*), maize (*Zea mays*), cassava (*Manihot esculenta*) and taro (*Colocasia esculenta*), in order of land area occupied. Cassava is the predominant crop on the Tiko plain and West Coast.

Fako farmers come from all over southern Cameroon and eastern Nigeria, and confront such a wide variety of soils and topographical and climatic conditions that it is not surprising that farming methods have not standardized around a single system, even within a village. Previous agronomic and breeding research was based on patterns found in other parts of the country or observed at roadsides and among farms near the experimental fields. In order to comprehend the diversity of Fako farming and to locate some modal patterns from which agronomic trials could start to test improvements, a survey was launched in October-November 1986. A partial report, focusing on the place of cassava within the farming systems, is made here. The full report, *Farming systems survey of Fako Division*, can be obtained from the Testing and Liaison Unit (TLU), IRA-Ekona.

Methods

A nine-page questionnaire requiring one and a half hours for execution was administered to 124 randomly selected full-time farmers in 18 towns and villages chosen to represent nine tentatively defined agroecological zones of Fako. The questions covered all aspects of the farming system—household composition and labor, land access and use, cash flow and credit, cropping patterns and calendar, crop provenance, field problems, harvesting, storage, marketing, the place of animals, and extension. More emphasis was put on maize since the TLU receives its outside funding from the National Cereals Research and Extension Project (USAID). Enumerators were school-leavers with O-levels who received three days' training and close supervision. Farms were not directly evaluated except as described below.

In order to obtain a picture of the relative importance of the different crops in Fako and its zones, a series of approximations had to be made, both for crop area and production. Fako farmers do not have any measure for land area, so for the first we substituted clearing time. This was checked by measuring one field per village and comparing the averages. This showed that previous status of the field (forest, bush fallow, immediate replanting) affected these times drastically, so any results have to be used with extreme care. Estimates of area within a field occupied by a specific crop were made using a formula based on the farmer's identification of the crop as major or minor to the field, and the number of other major and minor crops in it. From these figures, a very rough calculation was obtained of the percentage of total food-crop area planted in one year (1985-86) occupied by each crop.

For production figures, farmers were asked to remember how many hand-trucks, basins or baskets they had taken from any of their farms in the previous two seasons. In the case of crops harvested over several months, they were asked to recall how often they went and what they removed in one trip. These approximations were converted to standard units[1] of volume, weight, and then price. Neither area nor production figures are very satisfactory, but the latter has only one principal source of unreliability—the farmers' memories. Such results should only be used for purposes of general comparisons of crop importance. For yield estimates and farm budgeting, intensive measurements must be carried out on a subsample of farmers, as we are now doing for cassava in Fako.

Results and Discussion

Fako farmers adopt one of two general strategies for their fields. Either they plant many crops in a few fields, or a few crops in many. They range from the 25 percent of farmers who plant only one field, with an average of 5.7 crops, to the 6 percent that plant five fields, each with 1.5 crops (including minor crops with only a few plants per field). Twenty-four percent of the fields in the survey contained only one crop, while another 41 percent contained only one major crop, plus one or more minor ones spotted through the field. But monocropped (and what we call "effectively" monocropped) fields are smaller: 18 percent of the land is estimated to be in monocropped fields, 40 percent in effective monocrop, and 43 percent in major intercrops. Twenty-seven percent of LV fields were monocropped but only 8 percent of TP and 4 percent of WC fields.

In terms of relative crop area, plantains lead with 23 percent followed by cocoyams (20 percent), maize (18 percent), cassava (15 percent) and taro (8 percent). The largest number of farmers (93 percent) grow maize, but only 55 percent as a major crop, whereas 76 percent grow plantains as a major crop, 60 percent cocoyams, 55 percent cassava, and 26 percent taro. Eighteen percent of cassava, 29 percent of plantains and about a third of other major crops are found in fields with two to three other major crops. Maize is most often intercropped with cassava (at twice its frequency with any other crop) especially in the Tiko plain, but cassava is equally often intercropped with cocoyams or plantains. Cocoyams and plantains are almost always found together, and often with taro (major or minor) as well.

Production estimates, which are probably more reliable, give more weight to plantains and less to maize (see tables in Appendix). In terms of energy provided, plantains provide 35 percent of the total kilo-

[1] Help with weight price and volume equivalencies came from J. Wutoh of the Ekona ROTREP project, P. Kofi of Ekona Plantains, and M. Besong's1986 Food price survey of Fako Division (TLU-Ekona).

calories, cocoyams 10 percent, cassava 41 percent, maize 8 percent, and taro 4 percent. But in market values, plantains give a full 49 percent of food-farm income, cocoyams 18 percent, cassava 17 percent, taro 7 percent and maize only 6 percent. Plantain prices have been going up for some years, both from internal pressures (increasing borer and nematode infestation, according to farmers' reports) and external ones (destruction of Gabon's plantain production by black Sigatoka disease, and entry into the Cameroonian market). Cocoyam prices have been rocketing (tripling in ten years) because of the root rot (*Pythium*) disease now spread throughout Cameroon. As these are the preferred staples, there has not been simple displacement of demand to other crops (although taro seems to be progressively invading cocoyam fields).

Local cassava is basically of two types: (i) white cassava, which is too high in hydrocyanic acid ("bitter") to eat raw or boiled, but has to be processed into water "fufu" (by peeling, soaking for three days, grating, drying one day, sifting and mixing with water) or sometimes "gari" (peeling, grating, squeezing one to two days in a bag, sifting and roasting); and (ii) a lower yielding reddish tuber which can be eaten boiled (either as tuber or pounded fufu). In the Fako survey, 73 percent eat pounded fufu, and only 54 percent water fufu and 36 percent gari. But only water fufu and gari can be kept long enough to market at a distance. Cassava leaves are not a major dietary item.

Except on the west coast, planting usually occurs in late March to April and late August to September, later and earlier respectively in the lower-rainfall areas. The July-August rains are too heavy to allow crop establishment. Three-quarters of all cassava fields are planted first season. Uusally all crops are planted together, or within a week of each other. The maize, often with a minor crop of "egusi" melon as well, is harvested and the cassava left to take over the field and provide shade to a cocoyam intercrop. Second season plantings usually include a minor crop of groundnuts. From field observations, plantains intercropped with cassava as major crops are usually scattered in clumps or segregated in one part of the field. Weeding ceases at four months after planting for 57 percent of farmers, and by six months for 84 percent. Local varieties have sparse canopies and are planted at low densities (about 6-8.00pph) because of the intercropping strategy. The fields thus begin to relapse into heavy weed fallows even before harvest starts.

Cassava is usually harvested at 12-18 months. Although the average harvesting duration is six months, because of variations in planting and harvest commencement, at least 28 percent of Fako cassava farmers are harvesting every month in the year. The scarcity months (18-36 percent of farmers harvesting) are in July or November, with 45 percent or more harvesting most of the rest of the year. The July to September harvests are impeded in the major processing zone (TP) by swollen rivers cutting people off from their farms. Processing also suffers in this season from competition with cocoa and coffee harvest labor needs.

The cassava yield study still in progress shows that cassava in 12 months has yields ranging from 4.6 to 23.8 tons/ha, with a mean of 11.6 tons. Eighteen-month yields range from 6.0 to 22.9 tons/ha, with a mean of 14.8 tons.

Within this framework, the IRA/IITA/Gatsby Foundation cassava project, based in IRA-Njombe (Littoral Province), is now introducing several new high-yielding cassava varieties (at present denominated 8017, 8034 and 8061). All three are moderately bitter and have a white tuber. They were selected on the worst (loamy sand) soils to be found in the coastal lowlands, to ensure high performance under poor conditions. Controlled on-farm testing under intercrop and low-management conditions began in early 1987 in Fako and Mem Divisions, under the TLU. Sample harvests of 8061 distributed to farmers for in 1986 give yields at 12 months ranging from 14.6 to 39 tons/ha, with a mean of 28 tons.

Apart from yield differences, the new varieties differ from local ones by closing canopy completely (at 10,000 pph) by four months. Apparently they do not degenerate faster than the local varieties stored in the soil past their peak (15 months). The demand for these varieties, which started to be distributed to farmers in small quantities in 1985, is growing rapidly, and coming from far beyond the environs of Ekona and Njombe. It is highly probable that within another five to ten years they will be found in the fields of most farmers in the majority of the villages of the coastal lowlands.

Let us speculate on what this means for Fako farming systems. First, if farmers were simply to replace their present cassava with the new varieties, they would harvest a lot more cassava. This would increase processing time which might be acceptable in the first season but most farmers already have major processing tasks with cocoa or coffee in August to November. Thus they would probably reduce the area planted to cassava that season. Alternatively, an increase in cassava production might provide a boost to the introduction of processing technology, if demand increases correspondingly.

Second, important secondary crops might be eliminated by the new cassava. The 1987 TLU on-farm trials have indicated that the maize yields of the new CMS8501 C_1 ES are not affected by type of cassava, whether local or any of the three new varieties (at 10,000 pph cassava and 30,000 pph maize), but this maize variety is somewhat earlier than most local ones. Egusi melon grows until the fourth month after planting, and may be shaded out, as may the groundnuts usually planted with second-season cassava. North of Fako Division, in Meme, some farmers plant cassava several weeks after the establishment of the companion crops, but it is heavily shaded until their harvest, and yields must be affected. Melon and groundnut are minor but are high-value and nutritive crops important to farmers, and will have to be put into separate fields. If the new lowlands maize initiative does well, there may be more monocropped cassava fields (or cassava intercropped with cocoyam) and separate plantain-maize-egusi/groundnut fields in the Tiko Plain. This in turn would indicate a reduction in the cassava area and, probably, reduced fallows for the maize fields. (Fallows near TP villages are already low. In the LV, field separation already exist, but the soil is more fertile).

Third, there will undoubtedly be more cassava produced in Fako Division. Where will it go? Douala is often mentioned, but no one has studied the market potential for cassava flour or other storable products in Douala and other major urban centers of Cameroon. Already, 81 percent of cassava farmers sell an average of half their crop—65 percent as raw tubers and 30 percent as gari—at local markets. Douala truckers come to buy up plantains, cocoyams and green maize in season, but not cassava as yet. The Cameroon Development Corporation feeds its huge body of workers on rice, maize and beans, because these crops store better in their warehouses. Is there a market?

Conclusion

Cassava is secondary in importance in Fako Division to plantains and cocoyams, but both the latter face serious production constraints that are increasing their scarcity. IRA is now widely introducing varieties that could multiply local cassava production two to three times. Farmers are likely to respond by reducing the area planted to cassava (especially if processing technology is not improved), separating cassava from seasonal intercrop fields, and increasing overall cassava production. A market will have to be created outside the farming villages, either among the wage-workers of the Division, in Douala, or abroad.

Appendix: Tables on average household production by crop in Fako

Assumptions for Tables:

Plantains:	15 kg/bunch, 100 CFAF/kg, 73% edible matter
Cocoyams:	27 kg/bag, 185 CFAF/kg
Cassava:	54 kg/bag, 50 CFAF/kg (as tuber)
Taro:	25 kg/bag, 140 CFAF/kg
Maize:	21 kg (dried shelled) per bag of cobs, 195 CFAF per kg (dried shelled) if sold green
Yams:	54 kg/bag, 200 CFAF/kg
Groundnuts:	15 kg/bag (unshelled), 340 CFAF/kg; 73% edible matter.

The bag used is the 50-kg N-P-K 20-10-10 fertilizer bag.

Table 1. Production (in kg) of seven crops per Fako farming household in1985-86

Crop	Zone				
	Fako	LV	TP	UV	WC
Plantains	7 835	9 130	5 835	5 515	845
Cocoyams	1 585	1 725	270	5 690	265
Cassava	5 585	4 345	12 615	0	2 265
Taro	815	1 110	60	480	200
Maize	485	650	795	135	60
Yams	165	90	85	1 550	115
Groundnuts	30	35	15	0	10

Table 2. Production (in '000 CFAF) of seven crops per Fako farming household in1985-86

Crop	Zone				
	Fako	LV	TP	UV	WC
Plantains	784	913	584	552	85
Cocoyams	293	319	50	1053	49
Cassava	279	217	631	0	133
Taro	114	155	5	67	28
Maize	95	127	155	26	12
Yams	33	18	17	310	23
Groundnuts	10	12	5	0	3

Table 3. Production (in '000 Kcal) of seven crops per Fako farming household in1985-86[1]

Crop	Zone				
	Fako	LV	TP	UV	WC
Plantains	7 320	8 530	5 450	5 155	790
Cocoyams	2 110	2 295	360	7 570	350
Cassava	8 545	6 650	19 300	0	4 080
Taro	920	1 255	70	540	225
Maize	1 760	2 360	2 885	490	220
Yams	170	95	90	1 600	120
Groundnuts	125	150	65	0	40

Note: 1 Assuming insignificance of minor crops

Table 4. Relative contribution of seven crops to total loss income in Fako in 1985-86[1]

Crop	Zone				
	Fako (%)	LV (%)	TP (%)	UV (%)	WC (%)
Plantains	49	52	40	27	26
Cocoyams	18	18	3	52	15
Cassava	17	12	44	0	40
Taro	7	9	1	3	8
Maize	6	7	11	1	4
Yams	2	1	1	15	7
Groundnuts	1	1	—	0	1

Note: 1 Assuming insignificance of minor crops

Table 5. Relative contribution of seven crops to total loss energy in Fako in 1985-86[1]

Crop	Zone				
	Fako (%)	LV (%)	TP (%)	UV (%)	WC (%)
Plantains	35	40	19	34	14
Cocoyams	10	11	1	49	6
Cassava	41	31	68	0	70
Taro	4	6	—	4	4
Maize	8	11	10	3	4
Yams	1	1	—	10	2
Groundnuts	1	1	—	0	1

Note: 1 Conversion data from Westphal et al. 1985. Cultures vivrières tropicales avec référence spéciale au Cameroun, pp. 96, 170, 302, 422. Wageningen, the Netherlands, Pudoc.

DIAGNOSTIC SURVEY OF CASSAVA-BASED CROPPING SYSTEMS IN TWO ECOLOGICAL ZONES OF BAS-ZAIRE

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Abstract

Cassava-based cropping systems were studied in separate exploratory surveys of two ecological zones, the forest over deep sand (forest arenoferrals) of Kasangulu zone and the savanna over clayey ferrisols around M'Vuazi, in Bas-Zaire.

In both regions the cropping system consists of one year of intercropped cassava followed by a fallow. The main association crops are maize, melons and cowpeas in the forest zone, and groundnuts and pigeonpeas in the savanna zone. In both regions the optimum planting dates of association crops are observed with greater respect than are those of cassava, which is planted as long as there is enough soil moisture for sprouting.

The principal agronomic constraints in both regions are low soil fertility, unimproved variety, and disease. The intervention most desired by farmers is a high-yielding, erect, drought- and disease-tolerant cassava variety with tubers that retain their marketability for 18-24 months.

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Cassava is Zaire's most important food crop. Its tubers furnish about 60 percent of the calorie needs of over 70 percent of the Zairean population. The leaves of cassava, which are consumed as "pondu," are the most popular leafy vegetable and a good source of protein in the diet. The regions of Bandundu and Bas-Zaire are the main suppliers of cassava products—"cossette," "pondu" and "chikwanque" to the urban population of Kinshasa. Although the average tuber yield per hectare is slightly higher in Bandundu (7.0 tons) than in Bas-Zaire (5.0 tons), market preference is for Bas-Zaire products, which are whiter. The brownish tint to Bandundu cossettes has been traced to the color of water in the streams in which the tubers are soaked. The proximity of Bas-Zaire to Kinshasa also gives the region a greater share of the pondu market in the capital city.

Description of Survey Areas

Two sample areas—Kasangulu forest zone and M'vuazi wooded savanna zone—were selected for this exercise.

Kasangulu forest zone

The area surveyed fell between 4°35' and 5°7'S latitude and 15°3' and 15°15' E longitude. The altitude is between 450 and 650m. The terrain is very hilly with V-shaped valleys and slopes sometimes attaining a 40-percent gradient. The villages are located on hill crests; the slopes are cultivated. The valleys are generally too narrow for extensive cultivation.

The vegetation is essentially secondary forests of varying ages, depending on the periods they have remained in fallow. About 30 percent of the species in these forests were, however, observed to be leguminous. Important leguminous species are *Sapium cornutum*, *Pentaclethra cetveloleama* and *Milletia lanrenthi*.

The soils in the area have been described as forest arenoferrals on Kalahari sand (Sys 1972). Depending on the age of the forest fallow, the soils consist of 3-8cm of humified gray-brown loose sand at the surface, and very loose grayish sand subsoil reaching a depth of 150cm in places. This layer is underlain by another very deep fine yellowish-brown sand, equally structureless. The soils are extensively uniform. The soil pH is around 4.0, organic carbon 0.90 percent, and exchangeable Ca, K, and Mg are 1.0, 0.2 and 0.8 meq/100g respectively. They are excessively drained with poor capacity for both nutrient and moisture retention. The sole means of fertility regeneration are the long (10-20 years) forest fallows.

The climate is typical "Aw" of Bas-Zaire. The dry season, which has an approximate duration of 130 days, begins generally between 20 and 25 May and lasts untill around September 30. The rainy season is bimodal, with maxima in April and November. There may be a short gap in the rains between January and February. The average annual precipitation is about 1500mm.

The average daily air temperature is 25.5°C in the rainy season, with a maximum of 37°C. In the dry season, the average air temperature is 23.5°C with a maximum of 27°C. The mean monthly insolation is between 25 and 60 percent.

M'Vuazi wooded savanna zone

An area of approximately 25km radius was surveyed, with M'Vuazi as center. The area lies between 5°27' and 5°45'S latitude and 14°45' and 15°10'E longitude. The altitude ranges from 470m to 750m. The area is part of the formation on Calcitic Schist System. The relief is strongly influenced by the nature of the prevailing rock in the substratum. In the more calcareous formations the valleys are V-shaped and dry. In the regions dominated by schists, the relief is very steep with abrupt slopes of concave shapes, signifying the greater resistance of the schists to weathering. The plateaus and valleys are more extensive and highly cultivated than the Kasangulu forest region. The nonconcave and less steep slopes are equally cultivated.The vegetation in this area consists of herbaceous fallows composed mainly of *Imperata cylindrica*, *Panicum maximum* and *Pennisetum purpureum* on the plateaus and slopes. These grasses are often associated with *Phaseolus lunatus* and *Mucuna pruriens*. *Hyperrhenia confinis*, occupies regions that are sandy to sandy clay in texture. The alluviums in the valleys that are only periodically inundated are occupied mostly by *Andropogon gabonensis*, *Pennisetum purpureum* and *Hyperrhenia confinis*. These grasses often attain heights of up to 3-4 meters.

Sys (1972) classed the soils in the area into two groups:

1. The ferrisols (Paleudults), derived from residues from the alteration of calcareous and schist rocks on the plateaus and slopes. These materials are heavy clays, but are porous. The structure is subangular with excellent water retention capacity.

2. The Alluviums, derived from altered materials transported and deposited by rivers. These alluvial materials are of variable depths, clayey to sandy clay in texture, with good structure, permeability, and aeration. (See also Denisoff and Davred 1954.)

Both groups of soils are often humic to about 30cm in the profile, and show acid conditions; the pH varies from 4.6 at the surface to about 5.1 in the lower horizons. Exchangeable bases are very low; Ca, 1.0 meq/100 g K, 0.17 meq/100g and Mg 0.8 meq/100g. Exchangeable Al is generally about 2.0 meq/100 g.

Land Preparation

Land preparation for cassava and associated crops begins in July. In the forest zone, the secondary forest earmarked for the year's cropping is slashed and allowed to dry through late September before being set on fire. Most of the month of October is spent stacking the wood either for charcoal or for direct sale as fuel in Kinshasa, and for construction of heaps. As most of the terrain cultivated is very hilly, the farmers start work from the lower part of the farm and work uphill. During heap construction, the fine and medium roots around the heaps are removed. According to the farmers, these roots can damage cassava tubers if they are left within the heaps.

In the savanna zone, land preparation may start with burning of the grassland, followed by the construction of ridges which on plateaus and slopes are generally constructed along the slope irrespective of the gradient. Sometimes unburnt grasses are lined up and buried under the ridges. The ridges are commonly about 1.5 to 2m apart and may be as wide as 60-70cm at the top.

A more ingenious method of land preparation is the "Mafuku". Dried grass, cut at the base with some root mat left with soil adhering, is arranged in heaps 1 to 1.5m apart, about 0.75 to 1.0m high, and 70 to 90cm in diameter. The soil between the grass heaps is then loosened by hand hoe and piled over the grass heaps until the vegetation is partially buried but with sufficient air space left to permit slow burning. The mixture of ashes, soil, and partially-burned debris is left until the start of the rains. In some villages, after two or three showers, ridges are constructed in the adjoining space between the Mafuku heaps forming continuous ridges with the heaps. For further description of Mafuku land preparation system, see Ezumah and Okigbo (1980).

Cassava Planting System

The cassava planting system is remarkably similar in the six communities surveyed in the forest zone. This similarity is mainly a reflection of the generally uniform soil/vegetation types in the area and method of land preparation. The planting system in the savanna zone, however, offers slight diversity depending on the land preparation method, whether Mafuku or ridges.

The main elements in the cassava production systems in the two zones are planting time, stake size, varieties, stake planting (depth, arrangement, population), crop association, weeding, and maintenance of soil fertility.

Planting time

Cassava planting in Bas-Zaire generally begins in mid-October and continues until the end of the rains in May. If the rains extend beyond May, some farmers in the forest zone will continue planting. All farmers interviewed were aware that October/November plantings gave the best yields, and plantings tend to be concentrated within these two months. One main reason for stretching planting throughout the rainy season seems to be the need for a regular supply of tubers and pondu throughout the year.

In the M'Vuazi savanna zone, farmers seem to observe a break in planting in January and February, the short dry period. Whereas in the forest region farmers clear more land than they can plant at one time, leaving space for continuous planting, farmers in the savanna have to go through the process of land preparation again for the second season. Planting begins again in March and continues through the end of the rains in May.

Varieties

Popular varieties being grown in each region appear to be those that have survived the harsh processes of natural selection. In the forest region the common varieties observed in the fields were Mpelo-Longi, Kidombi, Nsubakani and "six mois". Visual observations on the farms show that these varieties are fairly tolerant to drought, a problem that can be severe in the deep arenoferrals.

In the savanna region the common varieties are Mpelo–Longi, Leni, Dinkondo, Mapuata and Mboaki. Considering the soil conditions in the area, these varieties are most likely to be tolerant to high Al concentration in soil solution, and also perform well under low soil fertility conditions.

As many as two to five different cassava varieties were observed per field. The greater number of varieties are more likely to be planted per field in the forest zone, where the unit farm size is larger and planting is spread over a longer period than in the savanna zone.

Farmers' reasons for planting more than one variety include:

1. The desire to maintain a mixture of early and late maturing varieties to assure a steady supply of tubers for family consumption and as a source of cash.

2. The need for a small quantity of sweet cassava for home consumption. It was noted that farmers refrain from planting large areas of sweet cassava varieties because they are more often stolen.

Although there was no preference for any particular variety for early (season A) or late (season B) planting, the farmers in both regions agree on what qualities constitute a good cassava variety: high yields, erect stem, early maturation (but with tubers that retain their quality when the harvest period is prolonged), late flowering, and good pondu and fufu quality.

Stake size and stake planting

In the forest zone stakes are generally between 15 and 20cm long. In the savanna zone, they are a little longer, ranging from 20 to 40cm. The shorter stake length in the forest zone may be related to the shortage of planting materials common at the onset of the rains, which is the result of loss of planting materials from dry season harvests. In the savanna there is a relationship between stake length and method of plantation.

Stake planting offers some interesting points of comparison between forest and savanna. In the forest zone, three or four stakes are planted on the same side of the heap. The stakes are buried completely in horizontal positions 5-10cm into the soil. In the savanna zone stake planting varies with methods of land preparation. Where Mafuku is practiced, as many as six stakes may be inserted on the periphery of the Mafuku mound. The center of the Mafuku itself is reserved for the associated crops. Where the Mafuku mounds are joined by ridging, the stakes are planted on the ridges between the mounds.

On the ridges, the stakes are planted about 50cm apart in double rows 60-70cm apart. The stakes, which vary in length between 25 and 40cm, are planted in slanting positions leaving at least 2-3 nodes exposed above ground.

Given the variations in number of stakes per hill and spacings used, it was observed that the stake populations in farmers' fields are generally between 15,000 and 20,000 per hectare. After taking into account poor stake sprouting, the actual plant population is nearer 15,000/ha.

Crop association

The main crops grown in association with cassava in the forest zone are, in order of importance, maize, cowpea, and melon. Occasional stands of water yams, sweet potatoes, or tomatoes may be inserted. Maize is planted in October and late February. When wood clearing and heap construction are completed on time, maize is planted immediately at the base of the heaps. Cassava follows after some days or weeks. Where wood clearing is delayed, maize is planted in late October 1-1.5m apart, 2-4 seeds/pocket, among the partly burned wood. When clearing is completed, the heaps are constructed between the maize stands and stakes introduced. Maize population barely exceeds 10,000/ha. Melons and cowpeas are more frequently associated with the cassava planted in February/March.

Crop associations with cassava are more intensive in the savanna zone than in the forest zone. On the plateaus and slopes, the main food crops in association with cassava are groundnuts, beans, sweet potatoes, and pigeonpea. Where Mafuku is practiced, beans, tomatoes and amaranthus may be planted on the Mafuku mound. Groundnuts are planted about 30cm apart on the ridges between the two rows of cassava stakes. There are usually about three rows of groundnuts on each ridge. The spacing for beans associated with cassava is similar to that of groundnuts. There is no specific or planting pattern for pigeonpeas, although south of M'Vuazi the population may be about the same as cassava. Groundnuts and pigeonpeas are usually planted at about the same time as cassava. Although some farmers intercrop groundnuts with March-planted cassava, most season-B cassava fields are monocropped.

Weeding

Weeds pose a greater problem to cassava in the savanna than in the forest zone. The grass weeds, mostly *Imperata* and *Hyperrhenia*, grow rapidly after land preparation, and the first weeding for cassava/groundnut association is needed three to four weeks after planting. A second weeding is done about eight weeks after planting, and a third after the harvest of the groundnuts. If need be, another weeding may be done at the beginning of the dry season. In the forest zone, because the long forest fallow generally suppresses all fast-growing grasses, no weeding is needed until after the maize harvest in April/May. A second weeding may be done during the dry season.

Maintenance of soil fertility

The main crop rotation in both zones is one crop of cassava followed by a forest or grass fallow. The forest fallow may last 15-20 years. One variation in the forest fallow systems was observed in some villages: the crop planted after the 15-20 year fallow is followed by a short (3-5 years) secondary forest fallow, then a second crop, and finally the long fallow again.

In the savanna zone, the grass fallow following the cassava crop, lasts 3-5 years. If Mafuku is to be repeated the old burned spots are avoided. Where ridges are used the new ones are constructed in the furrows of the old, sometimes burying the grass stubble.

Agronomic constraints of production

The agronomic constraints listed by the farmers and the changes desired are very similar in the two zones surveyed and are relevant to all the crops grown in both zones. The nature of these constraints, however, varies. The major agronomic constraints are poor soil status, crop varieties, crop management, crop disorders, and weeds (table 1).

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Table 1. Agronomic constraints of cassava-based crop production in Bas-Zaire

Nature of constraint: Forest zone	Nature of constraint: Savanna zone	Change desired by farmers
Soil		
Low fertility, very sandy, acid, poor moisture retention. Supports only one crop of cassava/ maize before reverting to fallow.	Low fertility, high exch. Al, low exch. Ca, K & Mg. Problem of empty kernels in groundnuts. Can support only one crop of cassava/ groundnuts before reverting to fallow	A means of sustaining soil fertility so that more than one crop of cassava can be grown after each land clearing.
Crop varieties		
Low-yielding and susceptible to diseases and pests	Low-yielding and susceptible to diseases and pests	High yielding, disease resistant varieties of cassava, maize and groundnuts
Crop management		
Lack of respect for optimum planting dates for crops. Improper plant density in crop association	Same as in the forest zone	Information on both compatibility and optimum crop densities in cassava associations
Crop disorders		
Premature death of plants caused by CBB and anthracnose cause low tuber and pondu yields	Same as in the forest zone	Varieties resistant or tolerant to pests and diseases
Weeds		
Invasion of *Chromolina odorata* slows down forest regeneration	Imperata and other grass weeds required frequent weedings for crops. Mimosa, originally introduced as a fallow crop, now poses a serious land-clearing problem	Improved cultural methods for weed control other than the use of a hand-hoe.

PERFORMANCE OF IMPROVED IITA CASSAVA, *MANIHOT ESCULENTA* CRANTZ, AT FARM LEVEL

F.I. Nweke, H.C. Ezumah and D.S.C. Spencer

To assess the performance of IITA's improved cassava varieties, TMS 30572, TMS 30211, and TMS 30555, a survey was conducted in February 1987 in a predominantly cassava-producing area in Nigeria where such improved varieties were observed to be widely grown. The area, Ohosu in Bendel State, lies 6° 25'N latitude and 5°30'E longitude and within the tropical rainforest vegetation zone. Mean annual rainfall is about 2,000mm and soil type is "Acid Sands".

Multiple cropping and land fallow are the main features of the cropping pattern. The major intercropping associations with cassava are intercropping with maize and vegetables; intercropping with plantains, maize, and vegetables; and intercropping with trees, plantains, maize and vegetables. The introduction of the improved cassava varieties has not induced change in the cropping pattern.

Yield Attributes of the Improved Cassava Varieties

The improved varieties harvested at 12 months yielded 75 percent higher root weight than local varieties. This difference is statistically significant at 1 percent level using the two-tailed 't' test. Since number of plants, shoot fresh weight, and number of roots per hectare are not significantly different between the improved and the local varieties (table 1), the difference in root yield is attributed to higher bulking capacity by the improved varieties (Hahn 1979). This is reflected in higher root size (by 38 percent), higher harvest index (by 29 percent), higher total biomass (by 32 percent), and higher average root weight per plant (by 101 percent) obtained from the improved than from the local varieties (table 1).

Root yield from the improved and from the local varieties were regressed with average yield of the two (the environmental index, **e**) using the model of Eberhart and Russell (1966) and Hildebrand (1984). This analysis, as well as the observed yield distribution frequencies (figure 1), confirm that the improved varieties have higher potential for tuber yield and may consistently outyield the local varieties at the farmers' level of management. The percentage difference in yield of improved over local varieties however declined by 77, 75, 56 and 32 percent at 9, 12, 16 and 18 months respectively.

The performance of the improved varieties in terms of root yield is, however, below their potential, based on breeders' expectations (Hahn 1979). The reasons would include suboptimal plant population and production without chemical fertilizers.

Nutritional effects of cassava consumption

Infant mortality, observed at the rate of 22 percent of the total sample, occurred in 65 percent of the households. Kwashiorkor symptoms were observed in 85 percent of the children under five years of age. In April, the kwashiorkor symptoms had virtually disappeared. February is the peak of the dry season; vegetables are scarce, and women are very busy harvesting and processing cassava. By April the rains have set in, vegetables have appeared in the fields, and harvesting and processing of cassava has eased off.

Economics of use of the improved varieties

The total cost of gari production is about 45 percent higher per hectare and 20 percent lower per ton under production with improved than with local varieties. Higher cost per hectare is a result of higher harvesting and processing costs associated with higher yields, while lower cost per ton is because of the higher yields under production with improved compared with local varieties. Net revenue is about 85 percent higher per hectare and about 75 percent higher per ton of gari under production with improved varieties than with local varieties. Production expansion is constrained by shortage of labor and perhaps by aggregate demand limitations.

The probability distributions of net revenues and gross margins per ton for production with both the improved and the local varieties (figure 2) are positively skewed, suggesting that under production with either the improved or the local varieties the probabilities of generating positive net revenues are higher than of generating negative. However, the probability of generating positive net revenues is higher under production with improved (75 percent) than with local (54 percent) varieties. In addition, production with improved varieties has lower probabilities of generating high negative net revenues than do local varieties. This is because of lower yield under production with local than with improved varieties and because of the additional negative effects of possible incidence of pests, especially cassava mealybug (CMB), under production with local varieties. The probability of generating a negative gross margin is zero under production with improved varieties and very low under production with local varieties.

Areas for further research

Further research in the following areas would be likely to lead to fuller realization of the potentials of the improved varieties. IITA's nitrogen management technology needs to be tested in researcher-managed adaptive research to assess its potentials in replenishing the soil nutrients in the cassava-based cropping system. Estimates of marketing margins from cassava products at the processor, transporter, wholesaler and retailer levels are essential to complement this study, which has provided estimates of cassava income at production level. Knowledge of cassava income at these other levels, in case of expanded production based on wide adoption of improved technologies, will help predict the potential effects in terms of income redistribution of the new technologies and incentives to farmers to adopt them. A nutrition study would be necessary to determine the cause, extent, and seasonal nature of the nutrition problem in the area. On-farm adaptive study would be necessary to determine the feasibility of introduction into the farming system of grain legumes, which would be available in the dry season when vegetables are not, and to evaluate the potentials of various IITA cowpea and soybean varieties in the area. Research in mechanization of more of the gari processing operations would, if successful, allow women of the area more time to attend to the nutritional needs of their children.

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Table 1. Yield of improved and local varieties of cassava from 18 fields surveyed in the Ohosu area, Bendel State of Nigeria, 1987.

Yield parameter	Improved		Local		't ' value for comparison between variety means
	Mean	SE	Mean	SE	
Fresh cassava tons/ha	19.6	+3.95	11.2	+3.19	
No. of plants ('000)/ha	7.0	+1.70	7.8	+1.25	NS
Shoot fresh wt. (tons/ha)	21.9	+8.72	19.3	+7.41	NS
No. of roots ('000)/ha	26.0	+9.30	27.8	+7.91	NS
Average root size (kg)	0.77	+0.14	0.56	+0.21	
Harvest index	0.49	+0.079	0.38	+0.009	
Total biomass (tons/ha)	41.0	+12.26	31.2	+10.36	
Average root wt. (kg)/plant	2.94	+0.83	1.46	+0.36	
Potential yield[a] (tons/ha)	29.4	—	14.6	—	

Source: Field survey.

Note: *a* Potential yield = yield at recommended population of 10,000/ha, ie, observed kg/plant x 10,000 - 1000 tons/ha.

Figure 1. Root yield response at 12 months of improved and local cassava varieties obtained by farmers in Ohosu area, Bendel State, Nigeria, 1987

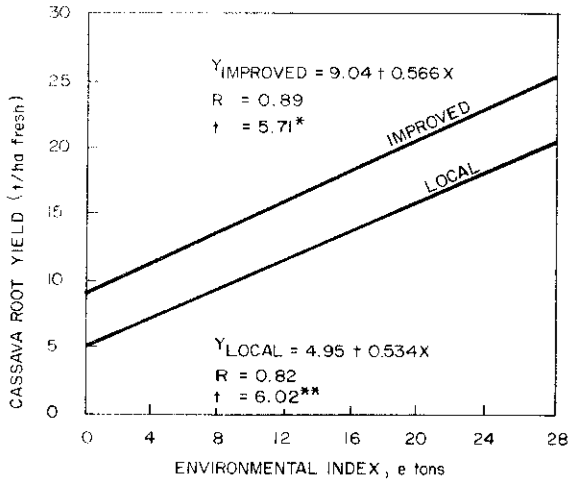


Figure 2. Frequency distribution of root yield (t/ha) obtained by sampled farmers in Ohosu area, Bendel State, Nigeria, 1987

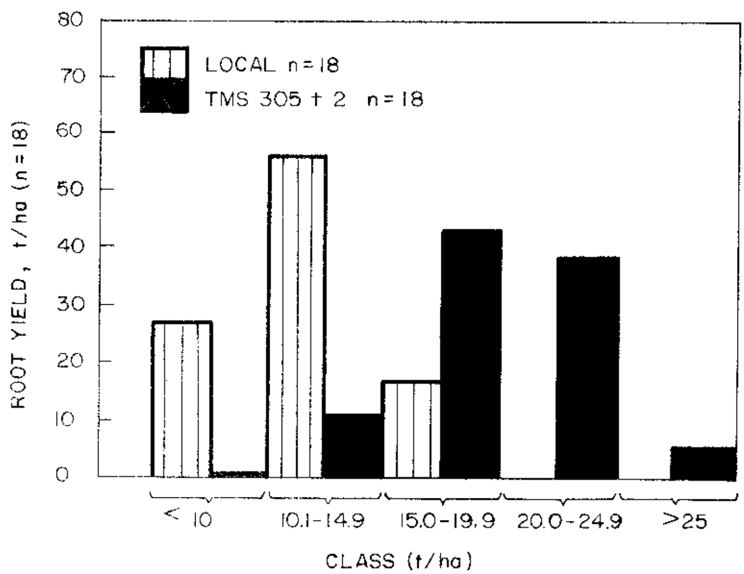


Figure 3. Root yields of improved and local cassava varieties at different ages obtained from sample fields in Ohosu area, Bendel State, Nigeria, 1987

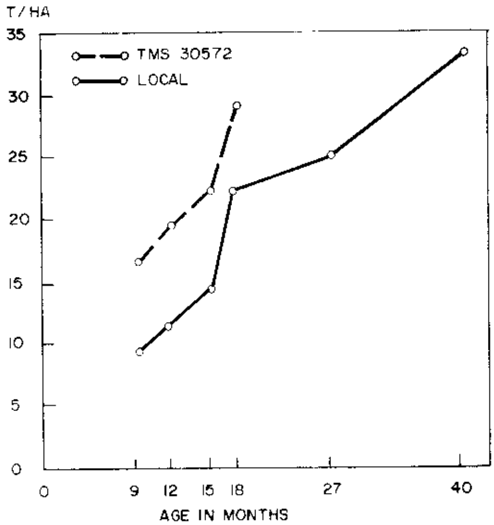
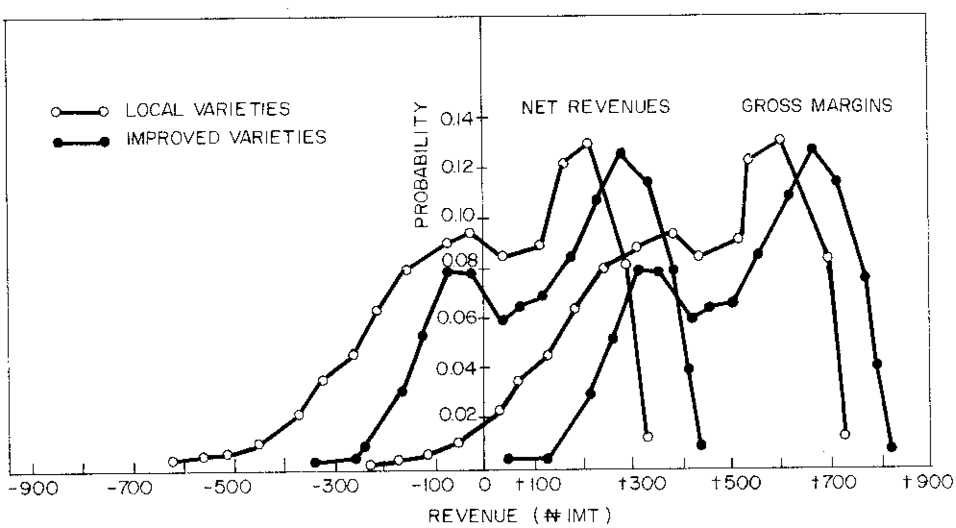


Figure 4. Probability distributions of net revenue and gross margin under production with improved and with local cassava varieties in Ohosu area'



Session IV

Papers in this section are followed by a summary of comments by participants

THE PERFORMANCE OF CASSAVA WITH OTHER STAPLES IN INTERCROPS IN CAMEROON

T.J. Ambe, S.N. Lyonga, A.A. Agboola and S.K. Hahn

Abstract

Studies of land productivity in a cassava-based cropping system showed that cassava fresh storage root yield was depressed in association with cocoyams (*Xanthosoma sagittifolium*), sweet potatoes (*Ipomoea batatas*) and maize (*Zea mays*) with spatial arrangements of crop stands in the field indicating inter- and intra-specific competition for growth resources. However, the yields of the other crops were also depressed.

Ten thousand cassava stands intercropped with 20,000 maize stands and with 9,000 cocoyam stands per hectare respectively gave higher returns per unit area of land than when planted as sole crops. This shows profit realization in intercropping but the correct choice of crop component combinations and optimum populations in association are imperative. A cassava/sweet potato intercrop did not seem profitable with an income equivalent ratio (IER) of less than one.

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The major tropical root crops—cassava, yams, cocoyams and sweet potatoes—are widely grown and used mainly as subsistence staples in many parts of the African tropics and subtropics. They are a major source of energy for well over 200 million people in the continent (FAO 1979). Their leaves (except for those of yams) are often used as vegetables, providing proteins, vitamins and minerals. These root crops are also grown for industrial raw materials and as livestock feed.

In Africa, cassava grows from sea level to an altitude of 1,800m (Hahn 1984). If a major food is defined as one providing 50 percent of calorie requirements, it is estimated that cassava could be a major staple food for 420 million people.

In most traditional cropping systems, cassava is intercropped with other staples. The other crop components in the intercrop are short-season and early-maturing. They include maize, sweet potatoes, cowpeas and cocoyams. When these are harvested, the cassava is left in the field to mature and harvested later when needed.

In Cameroon, peasant farmers grow their cassava in a complex mixed intercropping system. Given the role cassava plays in the nutrition of the people, and, the fact that intercropping is a mainstay in the cropping systems of the peasant farmers, it was necessary to study and quantify the performances of the component crops in the intercrops, to investigate the influence of intercropping cassava with other staples on yields and land productivity and to make recommendations on the appropriate method of crop production for sustained land productivity and increased production.

Materials and methods

A local white cassava cultivar was intercropped with the Ekona Mixed Color maize variety (EMC), a sweet-potato clone (see table 1). and a local cocoyam cultivar (*Xanthosoma sagittifolium*). The land was plowed and harrowed, and the crops were planted on flats. Seven treatments were used: sole cassava, at 10,000 plants per hectare (pph); sole maize at 40,000 pph; sole cocoyams at 10,000 pph; sole sweet potatoes at 30,000 pph; cassava at 10,000 pph plus cocoyams at 9,000 pph; cassava at 10,000 pph plus sweet potatoes at 20,000 pph; and cassava at 10,000 pph plus maize at 20,000 pph (see figure 1). Sole plots of maize and sweet potatoes were cropped for two seasons, ie, March and August each year. Each treatment was planted to four 12-m rows 1m apart. A randomized complete block experimental design was used with four replications and a plot size of 48 m^2. The two middle rows were sampled for data collection. Observations were made on plant stand counts at harvest, dry grain, fresh root and tuber yields at harvest. IERs were also extrapolated using local market prices in Cameroon. The experiment was run for three years consecutively.

Results

The stand counts of crops were not seriously affected because of intercropping at harvest. Cocoyams, sweet potatoes and maize depressed the fresh storage root yield of cassava in association by 15.4 percent, 18.6 percent and 29.5 percent respectively. The total cash return per unit area of land was highest for cassava plus cocoyams followed by cassava plus maize intercrop. These same treatments exhibited the highest IERs of 1.58 and 1.38 respectively. Cassava plus sweet potato gave the lowest cash returns per unit area of land and had the lowest IER of 0.98 (see table 1).

Cocoyams were seriously attacked by a fungal disease (*Pythium myriotylum*), particularly in the sole cocoyam plots.

Figure 1. Geometric arrangement of cassava-cocoyams, cassava-sweet potato and cassava-maize intercrops

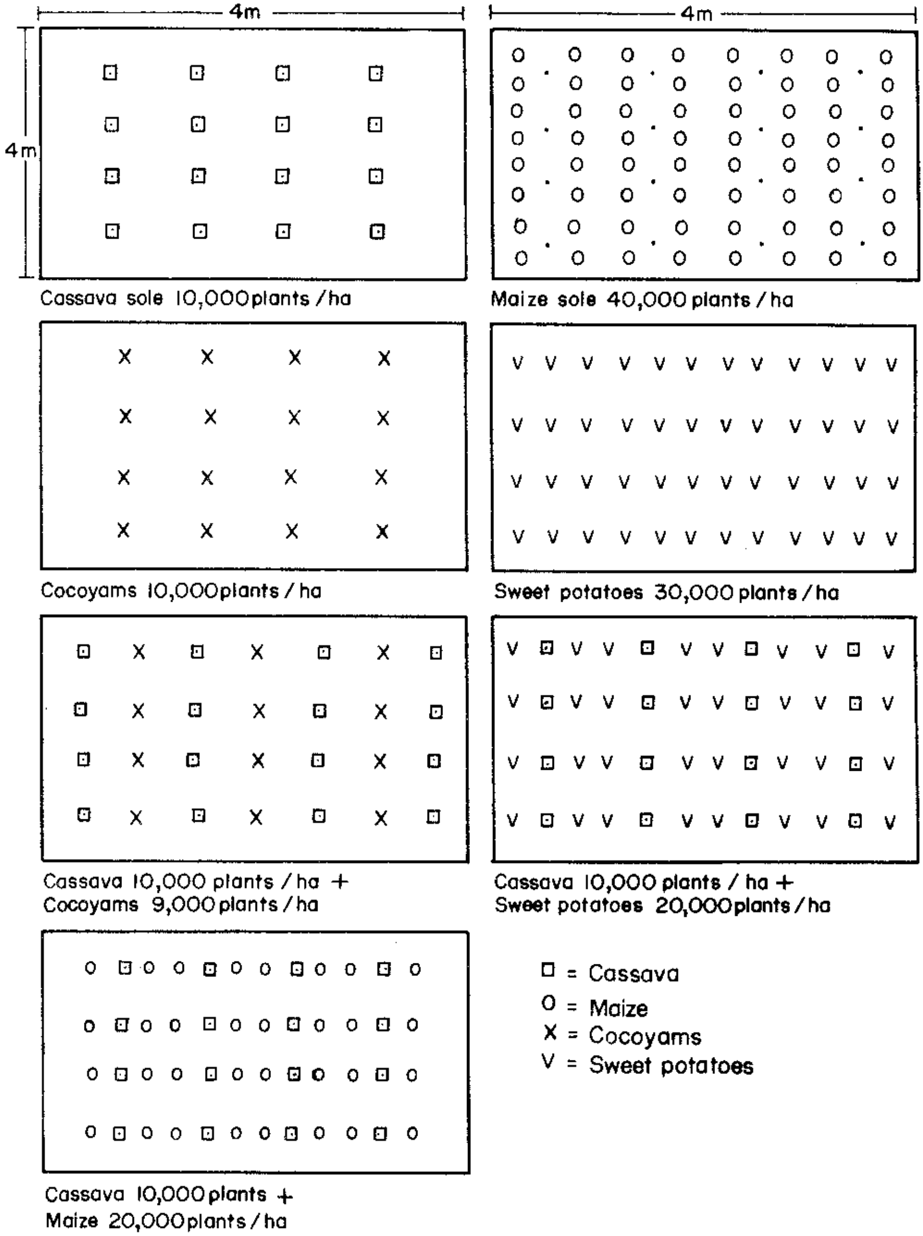

Table 1. The effect of intercropping cassava with other staples on their mean yields[a] per 10 m^2 plot

Treatment	Plant stand count at harvest	Fresh storage root, tuber and dry grain weight at harvest (kg)	Cash returns CFAF		IER[b]
			per plot	per ha '000	
Cassava 10,000 plants/ha	9.9	15.6	390.0	390.0	1.0
Cocoyam 10,000 plants/ha	8.8	4.5	337.5	337.5	1.0
Sweet potato 30,000 plants/ha	22.2	21.8	545.0	545.0	1.0
Maize 40,000 plants/ha	36.7	5.7	285.0	285.0	1.0
Cassava 10,000 plants/ha	9.9	13.2	330.0		
+				577.5	1.58
Cocoyam 9,000 plants/ha	6.9	3.3	247.5		
Cassava 10,00 plants/ plants/ha	10.0	12.7	317.5		
+				410.0	0.98
Sweet potato 20,000 plants/ha	16.6	3.7	92.5		
Cassava 10,000 plants/ha	10.0	11.0	275.0		
+				465.0	1.38
Maize 20,000 plants/ha	19.2	3.8	190.0		

Note: *a* Mean yield data for three years.
b IER = income equivalent ratio

Discussion and conclusion

Competition of crops in association does not tend to affect the stand count of crops at harvest. Yields of cassava in association with other crops were depressed indicating that competition exists among the crops for the same available resources. This is seen when the yields of the sole plots of cassava are compared with the yields of cassava in association with other crops. This depression may not necessarily mean unprofitability. The yields of the other component crops in association may more than compensate for the yield depression of cassava. The profitability of this can be determined by the use of land equivalent ratio LER calculations. The LER can only be used if the sole plots and the intercropped plots received the same management level inputs and had the same crop densities per unit area of land. In this case, crop densities varied and the only way to determine profitability was to convert the total yield per plot to one unitary factor. Local market prices were used to convert the yields into monetary values and IERs were calculated. On this basis, cassava-maize and cassava-cocoyam intercropping gave higher income returns per unit area of land than sole cropping. It would appear that when these crops are in a mixture, they exploit the available resources differently, thereby reducing the pressure of competition. There is no doubt that there is some competition among the crops in association but so long as the IER is greater than one, profits can be realized from the combination.

Andrews (1972) showed intercropping to be most rewarding when crops make their maximum demands on the environment—soil nutrients, moisture, temperature and light—at different times. This can be seen from the cassava-maize and cassava-cocoyam intercropping in this experiment. The low IER (0.98) for cassava-sweet potato shows that no profit will be realized from such intercropping. On the contrary, more income will be realized by the farmer if the component crops are cultivated as sole crops. Since some farmers still intercrop cassava with sweet potatoes, it may not mean that they cannot be compatible but that the correct crop varieties or even population densities or planting sequences have not been used. More investigations are required in these areas.

The low yields recorded for the cocoyam emanated from an attack of cocoyam root rot fungal disease (*Pythium myriotylum*). This disease has been responsible for the drop in production of cocoyam in Cameroon, particularly the *Xanthosoma* species. The sole plots of the cocoyam treatments were more severely attacked than the intercropped plots. Intercropping is advantageous with respect to disease control (Mukiibi 1976). Since the root rot disease of cocoyam is soilborne, cassava intercropped with cocoyam creates barriers between the diseased roots of one plant of cocoyam and another. Although the yields were low, the IER of cassava-cocoyam was greater than one. Karikari (1980) in Ghana showed that a cassava-cocoyam intercrop reduced yields but the LER greater than one (1.2) and was hence profitable.

There is no doubt that intercropping is a mainstay in the peasant farming communities. There is an obvious compatibility and complementarity of crops in association.

Little information exists on the effects of intra- and inter-specific competition of crops in association. Similarly, there is little information about the effects of soil fertility on the performance of intercrops. More research needs to be done on what happens in the soil when crops are grown in association. Knowledge of this will give guidelines on the choice of crops to be planted in mixtures and to other cultural practices that may go along with it to increase productivity and production. While breeders are breeding species for intercropping, soil and crop agronomists should work together to determine crop species that are compatible and complementary in association for optimum yields.

Production inputs such as fertilizers can be tested if the growth resources that are competed for by the two crops are understood.

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EFFECTS OF FERTILIZER AND TIME OF INTRODUCING CASSAVA ON THE PERFORMANCE OF YAM-MAIZE-CASSAVA INTERCROP: 1. EVALUATION OF THE BIOLOGICAL YIELDS OF THE COMPONENT CROPS

R.P.A. Unamma, T.O. Ezulike and A. Udealor

Abstract

The trial was conducted in the 1986/87 cropping season on a tropical rainforest acid sandy loam soil. The effects of the time of introducing cassava through yam (*Dioscorea rotundata* cv. Nwopoko or Abii) intercropped with maize (*Zea Mays* cv. TZSR-W), and the application of 15-15-15 NPK fertilizer 400 kg/ha, 56 days after planting (dap) yam/maize, were evaluated. Sole Nwopoko yields of 15 t/ha and 15.4 t/ha with and without fertilizer respectively were significantly better than corresponding yields from all the crop mixtures under comparison. Sole Abii that received fertilizer gave the third best yield (11 t/ha). Without fertilizer, the sole Abii yield (5.3 t/ha) was comparable to those of intercropped Nwopoko (3.1 t/ha) in which cassava was introduced at 0 dap, without fertilizer or intercropped Nwopoko (4.7 t/ha) with fertilizer in which cassava was interplanted at 56 dap, respectively. The latter yields were comparable to that of intercropped Abii where cassava was introduced at 28 dap (6.1 t/ha) and fertilizer applied. Without fertilizer, the maize component yield (2 t/ha) was unaffected by the time of introducing cassava, the yam cultivar used and intercropping. Fertilizer application raised the maize yield to more 3 t/ha in both the mixtures and when grown alone.

Sole cassava with fertilizer gave a yield (32 t/ha) that was significantly greater than any of the other treatments under comparison. Without fertilizer, the sole cassava gave a yield (27 t/ha) that was comparable to the Nwopoko carrying mixture in which fertilizer was not applied, or the Abii mixture with fertilizer but with the cassava introduced at the same time as the other two components. Introducing the cassava component at the same time as the other two components favored cassava productivity whether fertilizer was applied or not.

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Over 80 percent of the farmers in the southeastern agroecological zone of Nigeria invariably grow their crops in mixtures (Okigbo 1978; Unamma et al. 1985). In some parts of this area, for male farmers whose crop mixtures are yam based, yams are the major crop. Women are allowed to put in maize in very light populations (often below 3,000 stands/ha) and to introduce cassava at 56 or more dap. This reasonably well-defined practice is based on farmers' experience over the years of working in a system that focused on the interdependencies of the components of this cropping pattern within the farmers' control, and how these factors interacted with the physical, biological and socioeconomic environment beyond their control.

The farmers' practice has stabilized. Any alternative interventions must be technically feasible, economically viable, socioculturally acceptable and superior to their current practice. Farmers' cropping arrangement and spacing used to be haphazard and suboptimal, resulting in yields more than 50 percent below the potential productivities of the mixture (Unamma et al. 1985). Intercropping is a farming practice that has in recent times attracted the attention of agronomists as a means of improving land usage. Intercropping involves studying the farmers' mixed cropping patterns and practices and evolving more scientifically arranged planting patterns that aim at increasing output per unit area as well as giving more money to farmers at the time they need it most.

There are plenty of commodities-research results on yams, but they are not used by farmers since invariably they are irrelevant to their conditions and outside their capabilities (Eze 1981; Unamma et al. 1985). These commodity research findings need to be tailored to fit farmers' needs and capabilities.

The objective of this experiment was to examine the productivity of an improved cassava and maize variety when intercropped with one or the other of two white yam cultivars.

Materials and methods

The experiment was conducted in the 1986/87 cropping season and located on acid sandy loam soils at the National Root Crops Research Institute's main research farm in the tropical rainforest zone of Nigeria. The site was plowed, harrowed and formed into ridges 100cm apart.

Yam and maize were planted the same day in all the plots during the middle of April 1986. The introduction of the cassava component was carried out at 0, 28 and 56 dap. Setts of the yams, each weighing about 150g, were planted one sett per hole at 100cm apart (10,000/ha) along the crests of the ridges. Cassava cuttings (six nodes length), interplanted at three-quarters length and buried at an angle of about 45°, were planted 100cm apart (10,000/ha) along the crest of the ridges, alternating with the yams at 50cm distance. Maize, at three seeds per hole, was also planted 100cm apart but staggered on both sides of the ridges (double row) and between the yam and cassava stands diagonally on opposite sides of the ridges so that after yam, maize followed before cassava and on the diagonally opposite side of the same ridge the maize followed the cassava.

The maize was thinned and/or supplied to 2 plants/stand at 14 dap (leaving maize plant densities at 40,000/ha), while the yam and cassava components were supplied at 21 dap.

The yam vines were trained at the rate of two opposite stands from two adjacent ridges per stake of about 2.5m above the ground surface.

Fertilizer (15-15-15 NPK) was side-drilled along the ridges to all the plots at 800 kg/ha, 56 dap.

The cassava component was introduced into the plots containing each of the two white yam cultivars, Nwopoko and Abii intercropped with maize, at 0, 28 or 56 dap.

The sole components of each of the three crops in the mixture were included as treatments to facilitate evaluation of LER, for the various combinations at the same levels.

Each of the crop combinations was grown both with and without fertilizer application.

Maize was harvested at 112, yam at 224, and cassava at 336 dap. At harvest, yields were measured for the crops in the middle five ridges, each 4m long, excluding the peripheral stands, and were converted to a per-hectare basis for meaningful comparisons.

The treatments (table 1) were arranged in a 3 x 2 x 2 factorial in a randomized complete block design replicated three times. Duncan's new multiple range test was used to compare the mean values of the treatments.

Results

Table 1 shows that in general yam yield increased with the delayed introduction of the cassava component whether fertilizer was applied or not. The best time to introduce the cassava was at 56 dap for maximum yield of the fresh tuber of white yam. With and without fertilizer, the fresh tuber yield of sole Nwopoko was better than its highest yield in the mixture by 55 percent and 53 percent respectively. The corresponding yields of sole Abii were 5 percent more and 10 percent less compared with the highest fresh tuber (10.5 t/ha) in the mixture.

Effect on the maize component

The maize component (grain at 14 percent moisture content) was not affected by the time of introduction of the cassava. Fertilizer application generally doubled the maize yields whether grown sole or as a mixture (table 1).

Effect on the cassava component

The cassava component fresh tuber yield decreased with its delayed introduction into the mixture (table 1). In the Nwopoko-based mixture, the loss in cassava fresh tuber yield from the highest-yielding plot compared with the sole component's fresh tuber yield was 6 percent, if fertilizer was not applied. With fertilizer, the corresponding yield difference was 33 percent in favour of the sole cassava component yield (31.5 t/ha). For the Abii combination with and without fertilizer the corresponding differences between the sole cassava and the highest mixture cassava tuber yields were 22 percent and 30 percent, respectively.

Discussion

The yam crop was the most sensitive component of the mixture. It appeared that planting the yam some 56 days ahead of the cassava ensured that by the time the cassava component became established and competitive, the yam plant had itself already become established and less sensitive to the interference of the cassava and maize. The Nwopoko cultivar appeared to be more sensitive (over 50 percent) to the intercropping than the Abii and less responsive to fertilizer application. The cassava component was less suppressed by intercropping than the yam possibly because it stayed longer in the field. Thus, it had enough time to recover from the suppressive influences of the maize and yam when these were withdrawn from the interplant interactions at 112 and 224 dap respectively.

The maize was least affected since at the early stages of growth of the three crops in the mixture (28 days from emergence of the maize plant), when maize is most sensitive to inter- and intra-plant interferences (Nieto, Brondo and Gonzalez 1968), neither the yam nor the cassava had developed sufficiently to have any interference influences on the maize crop.

The trial suggested that for optimum productivity of the crops grown in the mixture, the cassava component should generally be introduced at 56 dap when all three crop yields had the fewest reductions simultaneously. Similarly, if maximization of yam production is the goal while intercropping is still desired, the cassava component should be introduced at 56 dap. For maximum yield from the cassava, the three crops should be planted at the same time.

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Table 1. Effects of fertilizer and time of introducing cassava on the biological yields of yam/maize/cassava intercropping

Crop combination	Time of introducing cassava (days after planting) (dap)	Fertilizer application rate (t/ha)	Crop yields (t/ha)		
			Yam	MAaize	Cassava
1 Nwopoko-maize-cassava	0	0	3.1f	1.91cd	25.0bc
2 Nwopoko-maize-cassava	28	0	6.1bc	1.92cd	13.3g
3 Nwopoko-maize-cassava	56	0	4.5cdef	1.94cd	11.0h
4 Nwopoko-maize-cassava	0	800	2.7f	3.33ab	21.0d
5 Nwopoko-maize-cassava	28	800	4.7cdef	3.09ab	15.0f
6 Nwopoko-maize-cassava	56	800	17.0	3.27ab	18.4e
7 Abii-maize-cassava	0	0	3.0f	0.85e	18.8e
8 Abii-maize-cassava	28	0	3.8def	1.14de	15.0f
9 Abii-maize-cassava	56	0	3.9def	1.91ed	11.0h
10 Abii-maize-cassava	0	800	3.2ef	2.57c	24.7c
11 Abii-maize-cassava	28	800	6.1bc	2.77abc	14.2fg
12 Abii-maize-cassava	56	800	10.5b	4.14a	21.1d
13 Nwopoko	sole	0	15.0a	—	—
14 Nwopoko	sole	800	15.4a	—	—
15 Abii	sole	0	5.3cd	—	—
16 Abii	sole	800	11.0b	—	—
17 Maize	sole	0	—	1.61de	—
18 Maize	sole	800	—	3.06ab	—
19 Cassava	sole	0	—	—	26.7b
20 Cassava	sole	800	—	—	31.5a

Note: In the same column means followed by similar letters are not significantly different according to Duncan's new multiple range test at 5 percent level of probability.

EFFECTS OF FERTILIZER AND TIME OF INTRODUCING CASSAVA ON THE PERFORMANCE OF YAM-MAIZE-CASSAVA INTERCROP: 2. LAND USE MAXIMIZATION AND MONETARY YIELD PERFORMANCE OF YAM-MAIZE-CASSAVA MIXTURE

R. P. A. Unamma, A. Udealor and F.O. Anuebunwa

Abstract

The experiment, which began in 1986, evaluated the land equivalent ratios (LER) and monetary yield productivity of intercropped cassava (*Manihot esculenta* cv. TMS 30572), maize (*Zea mays* cv. TZSR-W), and white yams (*Dioscorea rotundata* cvs. Nwopoko or Abii) as influenced by the time of introducing cassava into the mixture and whether fertilizer (15:15:15 NPK at 80 kg/ha) was applied at 21 days after planting (dap) yams and maize or not. The trial was conducted under tropical rainforest acid sandy loam (Umudike) conditions.

It was beneficial to introduce the cassava component into the mixture either at the same time as the other two components, or at 28 or 56 days after planting, whether fertilizer was applied or not. The LER for the various combinations ranged from 1.547 (when cassava was introduced at the same time as yams and maize and no fertilizer applied) to 2.940 (when cassava was introduced at 28 dap yams and maize, and fertilizer was used) for the Abii-based mixture. For the Nwopoko-based mixture, the LER ranged from 1.926 (cassava introduced at 28 dap and fertilizer applied) to 2.376 (cassava introduced at same time and fertilizer not applied).

Monetarily, the best time to introduce cassava into the Nwopoko-based mixture was 28 dap, when money realized was 23 percent more than with the farmers' common practice of interplanting the cassava component at 56 dap yams and maize and not applying fertilizer, which yielded ₦5,366. With fertilizer, similar amounts were realized whether the cassava was interplanted at the same time as the yam/maize or at 28 dap, with monetary yields being ₦6,644 and ₦6,041 naira when cassava was introduced at 0 and 28 days respectively, (i.e. 24 and 13 percent better than the common practice of introducing cassava at 56 dap yam/maize and not applying fertilizer).

The Abii-based mixture showed no significant differences among the monetary yields if fertilizer was not used. But when fertilizer was applied, the yield increased from 39 percent over the farmers' common

practice when cassava was interplanted at 0 dap, to 133 percent when it was introduced at 56 dap .

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The commonest cropping pattern in the eastern agricultural zone of Nigeria involves yams, maize and cassava in a mixture. Depending on the farmers' goals, preferences and resources, other crops, particularly vegetables such as *Telfairia occidentalis* (Ugu), may be included. The yam or, less frequently, the maize component is usually planted first or both are planted the same day. The cassava is invariably introduced about eight weeks after the yams are planted, in order, say the farmers, to minimize the suppressive influence of the cassava on the yams (Okigbo 1978; Unamma et al. 1985).

The farmers' reasoning for introducing the cassava component at eight weeks after yam sounds logical but lacks scientific proof. Moreover, while this practice, which ties up the land and prevents it being used for the next cropping season, was acceptable where land and labor were not limited, it cannot stand the test now that land is becoming limited and planned, intensive, and sustainable cropping systems are being developed for maximum productivity per unit area of land. Therefore, it is necessary to develop alternative practices that will eliminate the disadvantages inherent in the farmers' practices but that the farmers will accept.

Materials and methods

The materials and methods were the same as those described in the preceding paper ((Unamma, Ezulike and Udealor).

The experiment was conducted in the 1986/87 cropping season and located on acid sandy loam soils at the National Root Crops Research Institute's main research farm in the tropical rainforest zone of Nigeria. The site had previously carried a maize-cowpea intercrop and was under siam weed (*Chromolaena odorata*) and guinea grass (*Panicum maximum*) fallow for two years. The site was plowed, harrowed, and formed into ridges 100cm apart.

Yams and maize were planted the same day in all the plots during the middle of April 1986. The introduction of the cassava component was carried out at 0, 28 and 56 dap. Setts of the yams, each weighing about 150g, were planted one sett per hole at 100cm apart (10,000/ha) along the crests of the ridges. Cassava cuttings (six nodes length), interplanted at three-quarters length, buried at an angle of about 45° at the appropriate times and at 100cm apart (10,000/ha), were planted along the crest of the ridges alternating with the yams at 50cm distance. Maize, at three seeds per hole, was also planted 100cm apart but staggered on both sides of the ridges (double row) and between the yam and cassava stands diagonally on opposite sides of the ridges so that after yam, maize followed before cassava and on the diagonally opposite side of the same ridge the maize followed the cassava.

The maize was thinned and/or supplied to two plants/stand at 14 dap, while the yam and cassava components were supplied at 21 dap.

The yam vines were trained at the rate of two opposite stands from two adjacent ridges per stake of about 2.5m long above the ground.

Fertilizer (15-15-15 NPK) was side-drilled along the ridges to all the plots at 800 kg/ha, 56 dap.

The cassava component was introduced into the plots containing each of the two white yam cultivars, Nwopoko and Abii intercropped with maize, at either 0, 28 or 56 dap.

The sole components of each of the three crops in the mixture were included as treatments to facilitate evaluation of the LER for the various combinations at the same management level.

Each of the crop combinations was grown both with and without fertilizer application.

Maize was harvested at 112, yam at 224, and cassava at 336 dap. At harvest, yields were measured for the crops in the middle five ridges, each 4m long excluding the peripheral stands, and were converted to a per-hectare basis for meaningful comparisons.

LER was used to evaluate the effects of intercropping on the crop mixture with or without fertilizer application.

A common unit was obtained for the fresh tuber yield of yam, cassava and dry maize grain (14 percent moisture content) by converting them to their respective monetary values as at the nearest market near the time of harvest. These values were used to compare the results of the treatments' mean values on a per-hectare basis.

The treatments were arranged in a 3 x 2 x 2 factorial in a randomized complete block design replicated three times. Duncan's new multiple range test was used to compare the mean values of the treatments.

Results

Land equivalent ratio

Table 1 suggests that more land will be saved by intercropping either of the two white yam cultivars (Nwopoko and Abii) with maize and cassava than by any other crop combination. For the Nwopoko cv, it appeared that if fertilizer was not applied, it was better to introduce the cassava at 0 or 28 dap, but if fertilizer was applied, the cassava could go in at 0 or 56 dap. With the Abii cv., application of fertilizer improved the LERs, while the time of introducing the cassava component appeared to be best at 28 or 56 dap whether fertilizer was applied or not (table 1).

Monetary yield

All the sole components except maize out-yielded their respective mixture components, although if fertilizer was not applied, the Abii cv. underyielded some of its yields in the mixture.

With or without fertilizer the Nwopoko cv. grown alone gave yields more than double its yields in any of the mixtures, and a 53 and 55 percent greater monetary yield than its highest mixture yield (₦3,990).

Apparently, the Nwopoko cv. is more adversely affected by intercropping than the Abii cv. Without fertilizer, the productivity of Abii grown alone was poorer than some of those of the mixtures.

For maximum monetary yield from the mixture, the cassava component was best introduced at 56 dap either of the two white yams and maize if fertilizer was applied. If fertilizer was not applied, the best time to introduce the cassava appeared to be at 28 dap (table 2).

Discussion

The results of this experiment tended to confirm that the farmers' practice of introducing the cassava component at 56 dap gave more monetary yields than earlier introduction. Therefore, where land is not limited, and farmers have the resources to clear more area, and where the cassava cannot easily be processed and stored, the practice appears to be acceptable.

However, where land is limited, this trial suggests that the cassava component could be introduced at 0, 28 or 56 dap to save more land for other purposes.

Although the trial suggests that if the amount of income that flows into the farmers' pockets per unit of land were the farmers' only goal, the crops should be grown sole. The farmers take a number of other factors into consideration, some of which are not easily quantifiable. These include the spread of the harvest offered to the farmer in the absence of effective processing and storage facilities, the insurance offered against failure of any of the crops in the mixture had they been planted sole with all the associated production practices, such as land preparation, weeding and time and labor requirements for fertilizer application.

We are collecting economic data to enable us to evaluate the economic viability of the practices tested.

The fertilizer rate used was based on earlier trials that recommended 800kg 15-15-15 NPK applied at 21 dap for yam-maize-cassava intercrop planted at the same time (Nnoke et al. 1987). However, we also took soil samples at planting and at harvest, and these are being analyzed.

At the end of this season we shall be in a position to make a more reliable recommendation about the alternative practices under comparison.

Table 1. Land equivalent ratio as affected by intercropping, ime of introducing cassva, and fertilizer application to yam/maize/cassava intercrop, Umudike 1986

	Crop combination	Time of introducing cassava, days after planting (dap) yams and maize	Fertilizer application rate (kg/ha)	LER
1.	Nwopoko/maize/cassava	0	0	2.376
2.	Nwopoko/maize/cassava	28	0	2.191
3.	Nwopoko/maize/cassava	56	0	1.986
4.	Nwopoko/maize/cassava	0	800	2.093
5.	Nwopoko/maize/cassava	28	800	1.926
6.	Nwopoko/maize/cassava	56	800	2.119
7.	Agammiri/maize/cassava	0	0	1.547
8.	Agammiri/maize/cassava	28	0	1.745
9.	Agammiri/maize/cassava	56	0	2.07
10.	Agammiri/maize/cassava	0	800	2.029
11.	Agammiri/maize/cassava	28	800	2.940
12.	Agammiri/maize/cassava	56	800	2.719
13.	Nwopoko	Sole	0	1.00
14.	Nwopoko	"	800	1.00
15.	Agammiri	"	0	1.00
16.	Agammiri	"	800	1.00
17.	Maize	"	0	1.00
18.	Maize	"	800	1.00
19.	Maize	"	0	1.00
20.	Cassava	"	800	1.00

Table 2. Effect of fertilizer and time of cassava introduction on the gross monetary yield of yam/cassava/maize intercrop.

Crop combination	Time of introducing cassava days after planting yam/maize (dap)	Fertilizer application rate (kg/ha)	Crop yield (₦/ha)			
			Yam (Y)	Maize (M)	Cassava (C)	Y+M+C
Nwopoko.maize/ cassava	0	0	1,767	1,242	3,500	6,509
"	28	0	3,477	1,248	1,867	6,592
"	56	0	2,565	1,261	1,54C	5,366
"	0	800	1,539	2,165	2,940	6,644
"	28	800	2,679	2,009	2,105	6,041
"	56	800	3,990	1,755	2,576	8,321
Agammiri/maize/ cassava	0	0	1,710	552	2,627	4,889
"	28	0	2,160	741	2,100	5,007
"	56	0	2,223	1,242	1,540	5,005
"	0	800	1,824	1,671	3,453	6,948
"	28	800	3,477	1,801	1,983	7,261
"	56	800	5,985	2,691	2,959	11,675
Nwopoko	Sole	0	8,550		—	8,550
Nwopoko	"	"	800	8,778	—	8,778
Agammiri	"	0	3,021	—	—	3,021
Agammiri	"	800	6,270	—	6,270	
Maize	"	0	—	552	—	
Maize	"	800	—	1,989	—	
Cassava	"	0	—	—	3,738	
Cassava	"	800	—	—	4,477	

Note: Market prices—yam ₦650, cassava ₦140, and maize ₦400 per ton.

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CASSAVA-BASED CROPPING SYSTEMS AT THE NATIONAL ROOT CROPS RESEARCH INSTITUTE, IGBARIAM SUBSTATION

J.E.G. Ikeorgu

Location

Igbariam is about 110km northwest of Enugu and about 40km northeast of Onitsha in Anambra State, Nigeria. It is on latitude 6°20'N and longitude 6°53'E, at an elevation of 160m above sea level. Igbariam is at the transition zone between rainforest and Guinea savanna. The vegetation is best described as derived savanna. With a bimodal rainfall pattern, most of which falls during the early growing season, this location receives about 1,600-1,900mm of rainfall annually. Although the soil type is generally referred to as ultisol, no detailed soil classification and analysis of this rural location have been made. Physical soil analysis, however, shows the soil to be 18-30 percent clay, 10-12 percent silt, and about 60-66 percent sand. The soil has low base status and low CEC.

Cassava-based trials

The following cassava-based intercropping trials were started in 1986:

(a) Effects of fertilizer and time of cassava introduction and maize on economic yields of intercropped yam, maize and cassava in a humid ultisol.

(b) Effects of different maize varieties on the yield of cassava/maize intercrops.

(c) Preliminary study on the effects of improved cassava varieties on intercrop yields of associated minor crops.

Experiment 1a: Effects of fertilizer and time of cassava introduction on the performance of yam/maize/cassava intercrops

This trial is similar to the one at NRCRI, Umudike and differs from it only in location. Details of materials and methods are similar to those given by Unamma, Ezulike and Udealor in a separate report in this volume (see reference).

In 1986, the trial began on 22 April. All yams (150 setts) and maize (TZSR-W) together with the first set of cassava (ODAP) were planted. Subsequent cassava introductions were 28 and 56 days later. Compound fertilizer (15-15-15) at the rate of 80 kg/ha was applied to 50 percent of all plots while the others received no fertilizer. Fertilizer was applied four weeks after initial planting. All other cultural practices were carried out as required.

Maize was harvested 120 days after planting and oven-dried to 14 percent moisture content. Yams were harvested seven months after planting, while cassava was harvested 12 months after planting. The second year trial was planted later in the year because of the late arrival of the rains. Only the maize from the 1987 trial has been harvested; it has not yet been analyzed.

Table 1. Economic yields of intercropped yam, maize and cassava when cassava was introduced at three sequences in 1986

Crop production	Crop yield (t/ha)		
	Yam	Maize	Cassava
1. Yam/maize - F + cassava 0 dap	3.05	3.40	17.55
2. Yam/maize - F + cassava 28 dap	4.50	3.00	12.53
3. Yam/maize - F + cassava 56 dap	4.50	3.65	1.61
4. Yam/maize + F+ cassava 0 dap	4.10	4.90	25.88
5. Yam/maize + F+ cassava 28 dap	5.80	4.80	20.33
6. Yam/maize + F+ cassava 56 dap	5.00	5.40	1.65
7. Sole crop without fertilizer	8.00	3.30	26.03
8. Sole crop with fertilizer	11.95	5.20	30.95
LSD (0.05)	3.23	1.09	8.4

Notes: dap = days after planting.
±F = with (+) or without (-) fertilizer

The economic yields of yams, maize and cassava from the 1986 experiment are summarized in table 1. Although only 150g yam setts were planted, yam yields were generally low. There was no significant difference between intercropped yam grown with fertilizer and grown without fertilizer. However, yam grown sole with fertilizer yielded better than without fertilizer. Maize grown with fertilizer in both sole and mixed plots gave a higher grain yield than without fertilizer. Variations in time of introduction to the yam/maize mixture produced significant yield differences among cassava roots. Intercropping cassava with yam and maize at the time of planting or 28 days later gave significantly higher cassava yields than introduction of cassava 56 days later, whether fertilizer was applied or not.

This first-year result shows clearly that fertilizer is essential for yam/maize/cassava intercrops, especially for high yields from the maize component. Planting cassava at the same time or 28 days after planting yam and maize in a yam/maize/cassava mixture gives the highest cassava root yields.

Experiment 1b: *Effects of fertilizer and time of intercropping maize on the performance of cassava/maize*

This experiment recognizes that cassava/maize intercropping is also widely practiced among small-scale farmers in the humid tropics. It is a productive mixture and has lower input requirements than yam/maize or yam/maize/cassava cropping systems. However, in a trial, maize planted at the same time as cassava reduced cassava root yield by 28 percent. This trial was set up to determine the most appropriate time for the maize component to be intercropped with cassava to produce the least interspecific competition and highest combined yield.

This result of the 1986 trial is summarized in table 2. The experiment indicated that the best time to introduce maize to cassava is either at the same time the cassava component is being planted or three weeks later. As was noted earlier, for any productive cassava-based cropping system, application of fertilizer is essential. Although higher cassava root yield was achieved when maize was delayed six weeks, the system was most productive when maize was introduced at three weeks.

Experiment II: *Effect of different maize varieties on the yields of cassava/maize intercrops*

Compatibility in cassava/maize intercrops depends largely on low interspecific competition and the ability of the maize component to transmit sufficient light energy to the lower-canopy cassava. Many of the maize varieties currently being associated with cassava have fluffy leaves which shade the cassava. This trial was set up to evaluate the suitability of seven maize varieties for intercropping with cassava.

Table 2. Economic yields of intercropped cassava and maize grown with or without fertilizer when maize was introduced at three sequences in 1986

Crop combination	Maize grains	Cassava root yields (t/ha)		
		TMS 30572	U41044	Mean
1. Cassava - F+ maize 0 wap	1.28	10.31	7.06	8.69
2. Cassava - F+ maize 3 wap	0.78	8.66	11.33	9.25
3. Cassava - F+ maize 6 wap	0.63	9.46	9.83	9.65
4. Cassava + F+ maize 0 wap	3.03	11.69	11.61	11.65
5. Cassava + F+ maize 3 wap	3.43	13.63	13.61	13.62
6. Cassava + F+ maize 6 wap	0.79	18.34	15.92	17.13
LSD (0.05)	1.63	4.65	3.98	4.23

Note: wap = weeks after planting

Seven maize varieties, including a local check, were planted with cassava TMS 30572 on 24 April 1986 in 5m x 8m plots. The trial had an

RCB design with three replicates. Sole crops were planted at optimum populations beside the intercropped plots. It was not possible to repeat the trial in 1987 since most of the seeds preserved from the 1986 trial were killed during oven-drying. The trial will be repeated in 1988.

Yields from the 1986 trials are presented in table 3. There are indications that TZESR, an early-maturing maize variety, was most compatible with cassava. However, because of the low grain yield potential of TZESR (3.2 t/ha) compared with hybrid maize 8321-8 (7.71 t/ha) and Population 49 (5.51 t/ha), the higher-yielding maize varieties may be more productive in cassava/maize mixtures than TZESR. This will be verified in 1988.

Table 3. Economic yields of intercropped cassava and different maize varieties and percent PAR reaching the cassava component at seven wap in 1986

Crop combination	Fresh cassava	Maize grain (t/ha)		% Par reaching cassava 7 wap
		sole	inter-cropped	
1. Sole cassava	18.98a	—	—	100
2. Cassava + TZESR-W	16.06ab	3.20	2.80	90.3
3. Cassava + 8425-8	11.54cd	6.00	5.70	69.0
4. Cassava + FERKE 81	11.69cd	4.99	4.25	64.3
5. Cassava + Pop 49	13.59bcd	5.51	3.37	82.5
6. Cassava + TZSR-W	11.03d	7.46	4.36	63.7
7. Cassava + 8321-8	15.84b	7.71	5.24	85.2
8. Cassava + local maize	14.28bc	3.28	1.73	85.0
LSD (0.05)	2.98	2.17	1.68	14.8

Notes: wap = weeks after planting
Par = photosynthetically active radiation
The cassava cultivar used was TMS 30572.

Experiment III: *Preliminary study of the effects of improved cassava varieties on the yield of associated minor crops*

There have been reports from small-scale farmers that most of the improved cassava cultivars recommended to them are too shady for their minor crops. A trial involving two-crop mixtures of cassava and maize, egusi melon, okra, groundnuts and cowpeas was set up in May 1986. Because of the failure of egusi melon (due to late planting) and cowpeas (planted too early), it was decided that the trial should be conducted in two seasons. Minor crops usually planted early should be grown with cassava early in the season and those usually grown late should be intercropped late. This will be done in 1988. It is hoped that the 1988 trial will include studies in plant arrangements and populations.

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INTRODUCTION OF CASSAVA THROUGH MAIZE IN A HUMID ENVIRONMENT

J.B. Oyedokun, T.A. Akinlosotu and M.O. Omidiji

Abstract

In the forest zone of southwestern Nigeria, the first planting of cassava (*Manihot esculenta*) through maize (*Zea mays*) at the beginning of the rainy season (14 April 1986) produced significantly higher yields (15.8 t/ha) than the second planting (10.5 t/ha), which was similar to the last planting (9.4 t/ha).

Yields were adversely affected during critical stages of growth by drought and damage by cane rats and other rodents (37 cassava stands and 20 percent cassava tuber loss). Infestation by cassava mealybug was 19 percent. Fertilizer increased maize yields significantly despite rodent attacks.

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A dominant simple crop mixture in southwestern Nigeria is cassava (*Manihot esculenta*) with maize (*Zea mays*) intercrop, since cassava is tolerant of competition (Omidiji et al. 1983; Ezumah et al. 1986). Cassava is planted by most farmers once maize is established just before it matures, or after it is harvested. This implies that cassava can be planted at any time from the onset to the end of the rains. However, it is necessary to determine the optimum time to introduce cassava through maize for profitable yields with or without fertilizer application. This paper reports an experiment recently conducted with this objective.

The experiment was located at Moor Plantation, Ibadan (7°23'N; 3°51'E) in the rainforest zone of southwestern Nigeria. The soils at the research site are Alfisols, ferric luvisols of Ibadan series. These are very dark brown, loamy sand topsoils over brown to strong brown clay loam subsoils with yellowish-brown variegations.

Plot size was 8m x 8m with 90cm x 90cm spacing. Three dates (14 April, 5 May and 26 May 1986) of planting two varieties of cassava (local Odongbo and TMS 30572) were factorially combined with and without recommended fertilizer dose. The design was a randomized complete block with four replicates.

The fertilizer treatments were: F_0, no fertilizer; and F_1, 75kg N; 13.1kg P (30kg P_2O_5) and 24.9kg K (30 kg K_2O) per hectare. N, P and K were applied as 15-15-15 compound fertilizer and urea, by hand along both sides of the ridges at 43 days and 72 days after planting respectively and mixed thoroughly with the soil. The delay in application was due to lack of rainfall during April/May 1986.

Plots were hand weeded twice before the cassava canopy had formed. Data collection included precropping soil sampling for chemical analysis, establishment counts, plant growth characteristics, costings of cultural operations, and pests and disease incidence.

Results and discussion

Early maize grain yields (1986)

Time of planting cassava or cassava variety did not affect the yields of maize, but fertilizer increased maize yields significantly ($P<0.01$), 1.93 t/ha, compared with 1.26 t/ha without fertilizer (table 1). Drought in April/May adversely affected maize establishments. Moreover, cane rats (*Thryonomys swinderianus*) damaged maize plants extensively, reduced yields and increased field variation. Table 2 shows some uniformity in percent damage (transformed data) to maize plants by noxious cane rats, which accounted for a 39.3 percent loss of plants.

Cassava tuber yield (1986/87)

Fresh tuber yields of cassava harvested at the end of July 1987 are presented in table 3. The earliest time of planting cassava (14 April 1986) gave the highest yield (15.8 t/ha), which was significantly higher than both 10.5 t/ha for the second planting date and 9.4 t/ha for the third planting date. There were no significant differences between second and third planting dates, cassava varieties or fertilizer treatments.

The low yields were partly due to low precipitation during the critical periods of growth. In addition, damage to cassava plants and tubers by cane rats and other rodents accounted for a 36.5 percent loss of plants and a 19.6 percent loss of tuber, while 19 percent of the stands were infested by cassava mealybug (CMB).

CMB infestation

Occurrence of CMB was influenced by both time of planting cassava and fertilizer treatment (table 4), but the interaction of the two factors was not significant. CMB infestation increased sharply as planting was delayed with the severest occurrence in the last time of planting. Fertilizer application decreased CMB infestation significantly, though this was not reflected in higher tuber yields.

Cane rat damage

The level of cane rat damage to cassava plants was influenced significantly only by time of planting (table 5). Cane rat attacks increased as planting was delayed, with the severest incidence in the last time of planting. There was no variation in attacks on cassava tubers by other rodents (table 6).

Conclusion

This report highlights the importance of site selection for experiments and the necessity for adequate crop protection, especially against vertebrate pests. Yields contained herein could have been at least doubled but for the destructive rodents.

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Table 1. Early maize yields (t/ha) under cassava + maize intercrop, IAR&T, 1986

Fertilizer	Odongbo		TMS 30572		
	F_0	F_1	F_0	F_1	Mean
T_0	1.01	1.24	1.20	1.49	1.24
T_1	1.49	2.58	1.22	1.82	1.78
T_2	1.27	1.89	1.40	2.51	1.77
Mean	1.26	1.90	1.27	1.94	1.59

Table 2. Percent damage to maize plants by cane rats

Fertilizer	Odongbo		TMS 30572		
	F_0	F_1	F_0	F_1	Mean
T_0	46.9	45.5	41.4	45.3	44.8
T_1	31.5	34.9	37.4	38.6	35.6
T_2	38.6	42.4	35.2	34.0	37.6
Mean	39.0	40.9	38.0	39.3	39.3

Table 3. Cassava tuber yields (t/ha) under cassava + maize intercrop

Fertilizer	Odongbo		TMS 30572		
	F_0	F_1	F_0	F_1	Mean
T_0	14.6	15.9	15.0	17.8	15.8a
T_1	10.0	11.0	10.4	10.6	10.5b
T_2	8.7	8.8	9.2	10.9	9.4b
Mean	11.1	11.9	11.5	13.1	11.9

Table 4. Percent infestation of cassava by cassava mealybug

Fertilizer	Odongbo		TMS 30572		
	F_0	F_1	F_0	F_1	Mean
T_0	15.8	11.1	19.0	11.1	14.3b
T_1	26.0	13.4	18.0	11.3	17.2ab
T_2	28.9	19.5	27.2	29.3	26.2a
Mean	23.6	14.7	21.4	17.3	19.2

Table 5. Percent damage to cassava by cane rats

Fertilizer	Odongbo		TMS 30572		
	F_0	F_1	F_0	F_1	Mean
T_0	28.6	26.8	37.1	24.4	29.2b
T_1	34.8	31.0	36.1	49.0	37.7ab
T_2	47.6	38.4	41.5	42.8	42.6a
Mean	37.0	32.1	38.2	38.7	36.5

Table 6 . Percent damage to cassava tuber by rodents

Fertilizer	Odongbo		TMS 30572		
	F_0	F_1	F_0	F_1	Mean
T_0	22.0	20.5	21.7	18.4	20.7
T_1	17.8	18.7	18.6	19.8	18.7
T_2	21.9	11.5	23.8	20.1	19.3
Mean	20.6	16.9	21.4	19.4	19.6

ECONOMICS OF FERTILIZER APPLICATION BY DIFFERENT METHODS IN A CASSAVA-MAIZE INTERCROP SYSTEM

F.I. Nweke, H.C. Ezumah and M. Agu

In 1985 the amount of fertilizers used was equivalent to 0.33kg per ha of arable land and FACU (1986) projected a zero growth rate for fertilizer use in the near future in Nigeria. These data can be explained by the Federal Government not only withdrawing most of its fertilizer subsidy but also devaluing its currency through the introduction of a second-tier foreign-exchange market, thus making fertilizers particularly expensive in Nigeria. Therefore, "incremental benefits from fertilizers will accrue only through better utilization" (FACU 1986, p. 20).

Flink (1982) observed that fertilizer problems extend beyond the correct form and quantity applied to the method of application. Banding is preferred to broadcasting for higher crop yields because nitrogen (N) fertilizers are volatile and if exposed will evaporate, while phosphorus fertilizers are immobile in soil water and therefore require banding to reach plant roots easily (Flink 1982). Consequently, the banding method of fertilizer application is recommended for most crops. However, most smallholders in southeastern Nigeria continue to apply fertilizer by broadcasting and only rarely by banding (Ezeilo 1979). The objective of this study is to determine the rationale behind this practice. The banding method may result not only in higher yields but also in higher labor inputs for fertilizer application and harvesting than broadcasting. It is not clear whether the extra yield justifies the extra labor input.

Cassava-maize intercropping is a popular crop combination in the acid soil (pH 4-5) of the Isienu area in southeastern Nigeria where the experiment was conducted. The Isienu area lies within the dry savanna vegetation zone. Major crops grown are root and tuber crops, especially yam (*Dioscorea* spp.), cassava (*Manihot esculenta*) and cocoyam (*Colocasia* spp.) as well as maize (*Zea mays*) and pigeonpea (*Cajanus cajan*). These are generally grown in various mixtures or relays. For example, a cassava-based crop mixture carrying cassava, maize and a wide range of minor crops is popular, while maize and a wide range of minor crops followed by pigeonpea is a common relay cropping practice. Farms are generally on small plots averaging about 0.05 ha. All operations are performed manually with hand-tools .

Materials and methods

Three methods of fertilizer application were used in a cassava + maize intercrop system. The treatment, which comprised banding, broadcast and no fertilizers (control), was laid out in a randomized complete block design. The effective area of each treatment plot was 0.0lha.

Before fertilizer application, the land was plowed by tractor, harrowed and ridged across. The ridges were 1m apart. Planting took place in April 1985 and March 1986. Two ridges served as discards between replications and around the entire field. A 1-m guard row demarcated the plots and the ridges were tied at 2-m intervals to check on overflow of fertilizer from one treatment to another.

An improved maize variety known as Western Yellow (widely accepted locally and provided by the University of Nigeria farm) and IITA's TMS 30572 cassava were the crop varieties used. Both the maize and the cassava were planted on top of the ridge. Cassava was planted at 1-m intervals, giving a population of 10,000/ha, and maize was planted at 0.3cm, giving a population of 33,300/ha after thinning. The 30-cm cassava cuttings were planted at an angle of 30° and buried up to the penultimate node. The maize was sown at a depth of 2cm.

Fertilizer was applied at 75N: 75K: 40P: 20Mg kg/ha from urea, muriate of potash, single superphosphate, and magnesium sulfate, respectively. These fertilizers were applied in 2-cm bands 4cm from the plants on one side of each row at a depth of 2.5cm in the banded plots and broadcast evenly for the other treatment. The fertilizer application, carried out by a single person, was timed.

Weeding was done manually with hand-tools twice a year six weeks after planting. Weeding was also done by one person in each experiment and timed. Weeds were collected and weighed wet.

Maize was harvested at 110 days and cassava one year after planting and the yields were recorded. The maize yield was converted to a 14 percent moisture level.

An analysis of variance based on the F-test was used to determine the level of significance of difference among means. Judgment as to whether banding was economical and more efficient than broadcasting was based on marginal benefit to marginal cost ratio analysis.

Results and discussion

Yields of cassava and maize

The effects of the three methods of fertilizer application on maize grain and cassava fresh root yields are shown in table 1. Non-application of fertilizer resulted in a highly significant ($P<0.001$) reduction of maize grain and cassava root yields during both years (table 1). There were differences between the band and broadcast methods of fertilizer application.

A combined analysis of variance of the two-year data for maize and cassava yields gave no significant year effects, nor of year x fertilizer treatment interaction; therefore, both the economic and agronomic interpretations of the data can be based on a combined analysis of the fertilizer treatment effects, which was significant ($P<0.001$) [table 1].

Maize yield without fertilizer was only about 6 percent of the yield obtained with fertilizer. Consequently, it is futile to attempt to grow maize in the Isienu soil environment without the application of fertilizer. Even the cassava yield was adversely affected since only 6 t/ha were produced compared with 17.6 t/ha with fertilizer. The yield without fertilizer was only 34 percent of the yield from fertilized plots. The generally poor crop yields in the absence of fertilizer are attributed to the poor soils at Isienu (table 2). They are highly acidic (pH 4.4), low in organic matter (organic carbon 0.80 percent), very low in N and have low exchangeable cations (table 2). Since fertilizers must be used on these soils, the most economic methods are examined.

Fertilizer application and weeding labor

Table 3 shows that fertilizer application labor was significantly different ($P<0.01$) between fertilizer banded plots (21.01 man-days/ha) and fertilizer broadcast plots (only 6.41 man-days/ha). However, weeding labor was not different between the fertilizer banded plots (41.18 man-days/ha) and the fertilizer broadcast plots (41.62 man-days/ha). This indicates that under experimental conditions it was not clear whether broadcasting of fertilizers results in more weed growth than banding. Table 3 shows that weed weight was also not different between the fertilizer banded plots (2.5 t/ha) and the fertilizer broadcast plots (2.6 t/ha).

Marginal benefit to marginal cost ratio

Although the banding method of fertilizer application resulted in significantly higher biological yields of both cassava and maize than the broadcasting method, its superiority depends upon the prices of the intercrop products as against wage rate. This is particularly important in the smallholder cropping system where all farm operations are performed manually; labor is by far the largest cost item and is therefore in most cases the limiting factor.

It was assumed that the fertilizer application, weeding and harvesting labor inputs were the only items of cost which would differ between production based on fertilizer application by banding and application by broadcasting. Consequently, only these items were costed at the current local nominal farm wage rate of ₦6.50 per man-day. The products were valued at the current local retail market prices of ₦0.12 per kg for cassava and ₦0.77 per kg for maize.

In Table 4, the marginal cost of production based on fertilizer banding over production based on fertilizer broadcasting represents the differences in the costs of fertilizer application and in weeding labor inputs between the two production methods. Similarly, the marginal benefits represent the differences in returns from cassava and from maize between the two production methods.

The marginal-benefit-to-marginal-cost ratio is 0.96, showing that the production of a cassava-maize intercrop based on the broadcasting method of fertilizer application appears to yield a higher net monetary return than production based on the banding method at the current local farm wage and product price relationships. However, a sensitivity analysis indicates that only marginal changes in wage rate (5 percent reduction), maize price (7 percent increase) and cassava price (8 percent increase) will equalize the marginal costs and the marginal benefits.

Conclusions

The above analysis suggests that intercrop production based on the broadcasting method of fertilizer application is clearly not superior to production based on the banding method in terms of net monetary return. In spite of this, however, farmers in the study area continue to use the broadcasting method for their produce even though production using the banding method seems to result in a statistically significant higher biological yield. This is probably because of the opportunity cost of the difference in labour between the two methods in other activities.

The value of labor for other farm and non-farm activities in which the same farmers engage influences their decision with respect to the additional labor input for applying fertilizer to in their crops.

Caution must be exercised in accepting the above conclusions since they are not based on real farm situations, although attempts were made to obtain reasonably accurate labor input measurements. The same person was used to apply the fertilizers and to weed all the plots, which removed any differences in working rates, and the person took a long break after every two plots, which reduced any fatigue effects. The inclusion of harvesting labor would have modestly increased the marginal cost of fertilizer banding production over that of broadcasting but this is unlikely to have made any significant difference, if at all, in the conclusions drawn.

Table 1. Effects of methods of fertilizer application on maize grain and cassava root yields (tons/ha) under intercropping in Isienu area of southeastern Nigeria during two seasons (years)

Fertilizer treatment	1985/86		1986/87		Average	
	Maize	Cassava	Maize	Cassava	Maize	Cassava
No fertilizer	0.08	5.80	0.09	6.20	0.09	6.00
Broadcast	2.00	17.10	2.18	17.60	2.09	17.40
Banded	1.96	16.80	2.32	18.70	2.14	17.80
Mean	1.33	13.20	1.53	14.20	1.44	13.70
LSD 0.05	1.09	5.14	1.17	7.30	0.82	4.05
CV %	33.20	34.74	29.63	31.80	33.96	37.10

Table 2. Chemical and textural characteristics of Isienu soil (sample = 0 - 15cm layer).

Chemical	
pH	4.40
Organic C (%)	0.80
Total N (%)	0.06
P (ppm)	14.10
Exch. cations	MEQ/100g
Ca	0.25
Mg	0.04
Mn	0.10
K	0.01
Na	0.06
Total acidity	1.37
CEC (Meq/100 g)	1.82
Textural	Sandy loam
Sand (%)	76
Silt (%)	14
Clay (%)	10

Table 3. Effects of methods of fertilizer application on fertilizer application and weeding labor inputs (man-days/ha) and on weed weight (tons/ha) under cassava-maize intercrop in the Isienu area of southeastern Nigeria

Fertilizer treatment	1985/86			1986/87			Average		
	Fert. app. lab.	Weeding lab.	Weed wt.	Fert. app. lab.	Weeding lab.	Weed wt.	Fert. app. lab.	Weeding lab.	Weed wt.
No fertilizer							0.00	39.25	7.39
Broadcast							6.41	41.62	19.69
Banded							21.01	41.18	17.28
Mean							9.14	40.68	14.79
LSD 0.05							0.91	2.65	10.65
CV (%)							3.50	2.30	25.40

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MAIZE VARIETY AND POPULATION IN A CASSAVA-MAIZE INTERCROP

J. Arthur, H.C. Ezumah and E.V. Doku

Intercropping cassava with maize is one of the most popular mixed cropping combinations under rainfed agriculture in the tropics. These two crops of varying growth duration and rhythm supply the bulk of the calorific requirements of the inhabitants of the humid and subhumid tropics (Ezeilo 1979; Moreno and Hart 1979).

One practical advantage of intercropping is an increase in land productivity per unit area. Maximization of yield necessitates the use of optimum plant populations of component crops (Baker 1981; Freyman and Venkateswale 1977) and the minimization of above and below ground competition for growth (Trenbath 1976) through the use of suitable varieties and improved crop protection measures. Considerable work has been done on the suitability of improved varieties bred in monocrop situations in intercropping systems. Varieties that perform well in a monoculture may not do so in an intercropping system and may adversely affect the growth and yield of the associated crop(s). It has been shown that plant height, maturity period and canopy architecture of maize are important factors in maize-bean mixed cropping systems (Wahua et al 1981; IITA 1982).

Kang and Wilson (1981) and Guritno (1984) obtained variable results with improved maize varieties in a maize-cassava mixture of varying populations, probably because of the maize genotype used. The cassava yield was also reduced at higher maize populations; the degree of reduction was related to the associated maize variety. Research workers have attributed this yield reduction of component crops to increased competition for light, moisture and soil nutrient with increasing populations. It is assumed that differences in maize plant height and canopy architecture observed in maize-bean associations result in the varying amounts of light transmitted to the lower canopy in a cassava-maize intercrop system (IITA 1982, 1983).

This paper describes attempts to obtain a clearer picture of the plant characteristics necessary for those maize plants intended for use in a cassava-maize intercrop system. The feasibility of intercropping cassava with more maize than the recommended optimum is also reported.

Materials and methods

Five maize varieties ranging from the short, early-maturing IK84A-2135 with spreading leaves to the late-maturing, erect-leaved hybrid 1368 x 5012 (table 1), were interplanted within cassava variety TMS 30572 planted at two different spacings. A systematic parallel row arrangement was used within a strip split-plot design. Cassava spacing was laid out in two strips facing each other; maize varieties were randomized within each cassava spacing. The cross plots between the strip plots of cassava spacing and the maize variety were split into five subplots. These were systematically assigned to five maize populations. Treatments are shown in table 2. The sole-crop optimum for maize and cassava at 4,000 plants/ha and 10,000 plants/ha respectively was also planted. Three replications were made.

Cassava and maize were planted at the same time in flat alternate rows in May 1986 at IITA, Ibadan, Nigeria. Maize populations were achieved by systematically varying the distance between plants. Within rows all plots were fertilized with a basal application of 300 kg/ha of 15-15-15 following a side dressing of nitrogen at the rate of 45kg urea/ha four weeks after planting. No extra fertilizer was given to the cassava nor any supplemental water. Hand weeding was carried out twice between maize planting and harvesting and thereafter when necessary. Data on crop performance at eight weeks after planting, four months after planting and seven months after planting and yield of crop economic components were collected and statistically analysed. Yields from the monocrops were used as standardizing factors in computing land equivalent ratios (LER).

Results and discussion

Effects on maize

Variations in agronomic characteristics in maize were to be expected and are not reported. Results showed that an increasing maize population in the intercrop delayed days to 50 percent silking and increased maize plant height, stem and root lodging. Ear weight decreased with an increasing maize population. Grain yield increased from 10,000 plants/ha, peaked at about 80,000 plants/ha and declined thereafter. The relationship between the maize popualtion and its effect on the crop are given in table 3.

The effects of the maize population on agronomic characteristics observed in the study have been reported by Early et al. (1967); Rutger and Crowder (1967) and Dungan, Lang and Pendleton (1958). All indicated that these effects are mainly a result of competition for light, moisture and soil nutrients. A high incidence of lodging at high populations produced taller plants with weaker stems.

Effects on cassava

Observations at different cassava growth stages indicated the various effects of maize on the cassava. At all stages, plant height and internode length increased with an increasing maize population in the intercrop. Stem girth, branches and leaves per plant decreased with an increase in maize populations. These results agree with those of Kang and Wilson (1981) who observed that at four to five months after planting, intercropped cassava was etiolated with poor branching and smaller foliage. Enyi (1973) and Hunt, Wholey and Cock (1977) attributed plant height and internode trends observed with increasing population to competition for light. Wahua (1985) also reports that plants produce more leaves and branches when they have adequate supplies of light, nutrient and soil moisture.

Apart from stem girth maize variety did not significantly affect other cassava plant features observed at eight and seven months after planting. At four months after planting, only plant height and internode length were significantly affected by maize variety as shown in tables 4-6. Trends indicate that plant height and maturity period have an effect on cassava. Cassava intercropped with late maturing maize varieties had larger stems (table 4) at eight weeks after planting since the late maturing maize varieties were no longer exploiting environmental resources to the maximum, unlike early maturing maize varieties. Consequently, the cassava plants were ensured optimum use of growth factors.

The etiolated cassava plants observed under late maturing maize varieties four months after planting (table 5) probably resulted from enforced shade. Findings agree with Wahua (1985) with regard to the responses of cowpea to different maize varieties. The implication of the non-significant effect except for stem girth of maize variety on cassava plant characteristic seven month after planting (table 6) is that the cassava plants had recovered from the effects of the maize varieties, unlike the effects of the maize population which were still evident.

Tuberous root weight, number of roots per plant, average root weight and root yield per plant decreased linearly with increasing maize population in the intercrop. Diversion of assimilates into tissue synthesis for stem and internode elongation caused by increasing plant population as under shade conditions appear to cause these effects (Hunt, Wholey and Cock 1977).

Mixture productivity

Land equivalent ratio values indicated the high productivity of the cassava-maize intercrop system. The LER for cassava decreased with increasing maize population in the intercrop (see figure 1). On the basis of maturity, the early maturing varieties, IK84A-2135 and IB84A-203 gave the highest LER. On the basis of plant height, the short maize variety IK84A-2135 again showed its superiority over all other maize varieties (see figure 1). These observations indicated that early maturity and shortness are desirable characteristics for incorporation in maize varieties for use in cassava-maize intercrops. Total LER showed that the optimum population for the short, early-maturing variety is 80,000 plants/ha. This population in the intercrop gave the heighest LER of about 1.90 (see figure 1). The other maize varieties, on the other hand, could be interplanted at an optimum population of 40,000 plants/ha to give the best combination. These recommendations are applicable if natural fertility is supplemented with recommended amounts of fertilizers.

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Table 1. Characteristics of maize and cassava test crops studied.

Maize variety	Characteristics
IK84A-2135	Open-pollinated, short, early maturing with spreading leaves
IB84A-203	Open-pollinated, tall, early maturing with spreading leaves
TZSR-Y-1	Open-pollinated, tall, late maturing with spreading leaves
1368 x 5012	Hybrid, tall, late maturing, with erect leaves
9450 x 4001	Hybrid, tall, late maturing with spreading leaves
Cassava variety	
TMS 30572	Low-branching, rapid canopy closure, good recovery from insect attack, high yielding, good gari and fufu characteristics, preferred in the West African subregion to other varieties

Table 2. Treatment levels of strip split-plot layout in a systematic parallel row arrangement

Factors	
Cassava spacing—2 levels	(i) 100cm x 100cm (ii) 100cm x 67cm
Maize variety—5 levels	
Maize population—5 levels	(i) 10,000 plants/ha (ii) 20,000 plants/ha (iii) 40,000 plants/ha (iv) 80,000 plants/ha (v) 160,000 plants/ha

Table 3. Effects of maize population on maize plant characteristics and yield

Characteristics	Regression equivalent	Correlation coefficient (R^2)
Days to 50% silking	$Y = 53.6 + 5.03\ (10^{-5})\ x$	0.91^a
Plant height at harvest	$Y = 172\text{-}07 + 1.23\ (10^{-4})\ x$	0.77
Stalk diameter	$Y = 17.3 - 4.4\ (10^{-5})\ x$	0.96^b
Root lodging	$Yc1 = 958 + 0386\ x$	0.95^b
	$Yc2 = 767 + 0.58\ x$	0.95^b
Stem lodging	$Y = 340 + 0.11\ x - 4.35\ (10^{-7})\ x2$	0.99^b
Ear weight	$Y = 92.76 - 4.9\ (10^{-4})\ x$	0.95^b
Grain yield	$Y = 546 + 0.034\ x - 1.62\ (10^{-7})\ x2$	0.94^a

Notes: *a Significant at 5% level* *b Significant at 1% level*

Table 4. Effect of maize variety on the agronomic characteristics of cassava 8 weeks after planting

Maize variety	Plant height (cm)	Stem girth (mm)	Internode length (mm)	Leaves per plant
IK84A-2135	60.5	9.4	24.8	19.2
IB84A-203	64.5	9.6	30.5	19.7
TZSR-Y-1	60.4	10.7	28.7	17.4
1368 x 5012	67.8	10.3	28.6	19.8
9450 x 4001	65.8	11.0	25.8	19.9
Mean	63.8	10.2	27.7	19.2
LSD 5%	ns	0.7	ns	ns

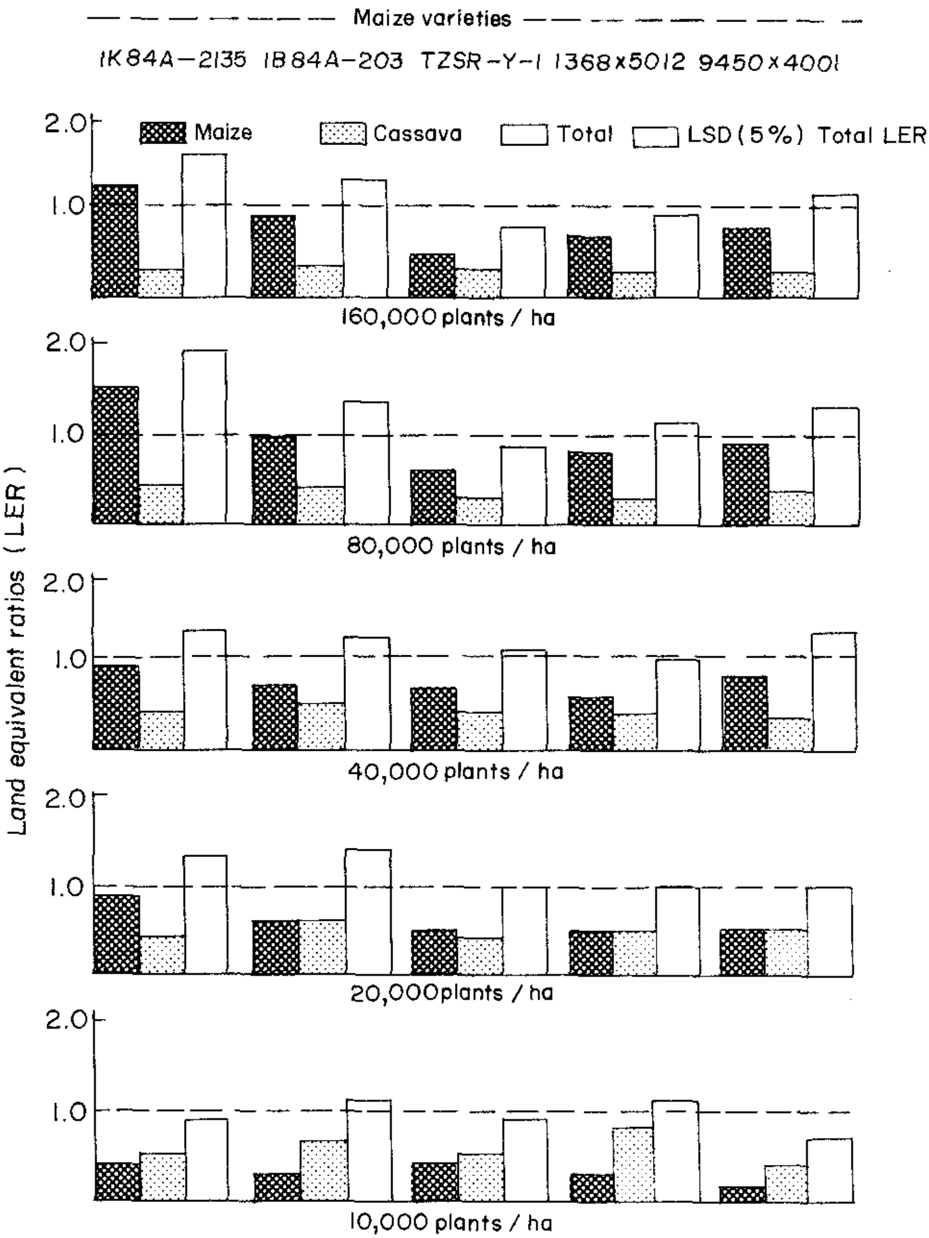
Table 5. Effect of maize variety on the agronomic characteristics of cassava at maize harvest

Maize variety	Plant height (cm)	Stem girth (cm)	Internode length (mm)	Branches/ per plants	Leaves/ per plant
IK84A-2135	98.7	1.5	16.6	3.1	48.6
IB84A-203	108.3	1.6	17.7	3.7	53.7
TZSR-Y-1	98.8	1.5	18.1	2.3	43.6
1368 x 5012	110.4	1.6	18.3	3.4	52.1
9450 x 4001	103.4	1.5	18.8	2.5	45.1
Mean	103.9	1.5	17.9	3.0	18.6
LSD (5%)	15.3	ns	1.3	ns	ns

Table 6. Effect of maize variety on the agronomic characteristics of cassava at seven months after planting

Maize variety	Plant height (cm)	Stem girth (cm)	Internode length (mm)	Branches per plant	Leaves per plant
IK84A-2135	119.5	1.83	10.3	10.6	84.5
IB84A-203	132.7	1.87	10.4	12.8	101.5
TZSR-Y-1	116.1	1.69	12.4	8.3	65.6
1368 x 5012	131.8	1.92	10.2	12.4	95.6
9450 x 4001	124.4	1.79	10.7	10.7	88.3
Mean	124.9	1.82	10.8	10.9	87.1
LSD (5%)	ns	0.20	ns	ns	ns

Figure 1. Land Equivalent Ratios for different populations of maize varieties in intercrop



CASSAVA-GROUNDNUT INTERCROPPING IN ZAIRE

N.B. Lutaladio, F.E. Brockman, K.B. Landu, T.A.T. Wahua and S.K. Hahn

Abstract

Field experiments were conducted from 1980 to 1985 in southwest Zaire to assess the productivity of cassava-groundnut intercropping systems and determine the effect of different crop management practices on the yield of the two associated crops.

Planting cassava in double rows with groundnuts at 0.4m x 0.2m resulted in the highest yields and the greatest monetary returns. The competitive ability of the two crops depends on their growth habit, planting arrangement and densities, time of planting and soil fertility level.

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Cassava-groundnut intercropping is practiced in many parts of Central Africa, particularly in south-western Zaire where it is the most common crop combination. The two crop species are highly compatible and the combination offers many advantages in terms of soil fertility, overall crop yields and the quality of food for human nutrition (Lutaladio, Wahua and Hahn 1987).

In Zaire, the two crops are usually planted simultaneously. Cassava is commonly planted on ridges in paired rows with about 0.5m between the two rows and 1.5 to 2m between the rows of adjacent pairs. Groundnut is sown in the wider inter-row space.

During the process of varietal improvement, the Zaire national cassava research program (PRONAM) considers it important to determine how newly developed varieties of different plant types react to different crop management factors such as cropping systems, planting arrangements, cassava and groundnut densities and time of planting.

The experiments reported here were designed to assess the productivity of the cassava-groundnut intercropping system and determine the effect of different crop management practices on the yield of the two associated crops.

Materials and methods

From 1980 to 1985, a series of cassava-groundnut intercropping experiments was conducted at Mvuazi station, Zaire (5°27'S, 14°54'E, elevation 450m) on an ultisol (sandy clay loam) with a low base saturation and a pH of between 3.5 and 5 (1 soil: 2.5 water).

In the 1980-82 experiments, two cassava varieties (an improved standard, 02864 and a local, Mpelolongi) were intercropped with groundnuts in two planting arrangements (cassava planted in equidistant rows, 1m apart or in a double-row arrangement with alternate row spacing of 0.5 and 1.5m) and with two groundnut spacings (0.2m x 0.2m and 0.4m x 0.2m). For comparison, monocrop cassava was grown in the two planting arrangements and monocrop groundnuts at the two spacings. A split-plot design was used with four replications. Cassava cultivars were the main treatments and planting patterns/groundnut spacing the sub-treatments. The sub-plot size was 8m x 6m. All plot yields were expressed on a hectare basis. Mixture productivity was determined by means of the Land Equivalent Ratio (LER) and gross monetary returns.

In another trial carried out between 1982 and 1984 a new improved variety named Kinuani was compared with the local Mpelolongi variety under two cropping systems (monocropped or intercropped with groundnuts) at two fertility levels (no fertilizer or 600 kg/ha of 17-17-17) at two densities (10,000 or 20,000 plants/ha) with or without leaf harvesting. A design with two replications was used. The plot size was 7m x 6m. At harvest, plot yields were expressed on a hectare basis.

The 1983-85 experiments were conducted in order to determine the effect of the following factors on the yield of intercropped cassava and groundnuts:

• cassava plant type (Kinuani—profusely branching, and clone 5052—erect with little branching);

• planting arrangement (cassava planted in paired rows with 40cm between the two rows of the pairs and 2m between rows of adjacent pairs, and cassava in rows equally spaced at 1.2m);

• time of cassava planting (with groundnut, and three weeks after groundnut);

• cassava density (8,333 and 16,667 plants/ha) and groundnut density (83,333 and 166,667 plants/ ha).

A design with two replications was used. Plot size was 7m x 6m. Cassava storage root yield, groundnut yield and LER were determined as described in other experiments.

Results and discussion

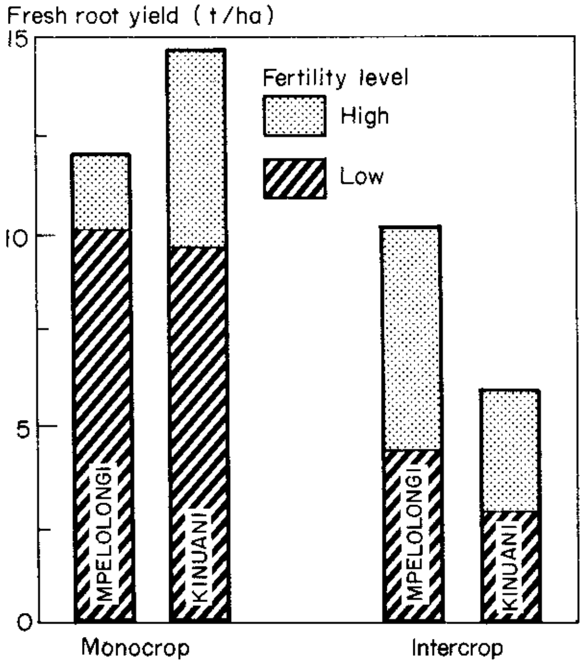
1980-82 experiments

The storage root yield of cassava intercropped with groundnuts was higher when groundnuts were sown at a low plant population (0.4m x 0.2m) than at a higher plant population (0.2m x 0.2m), irrespective of the cassava planting pattern (table 1). This is apparently a result of high interspecific competition in the combination where groundnuts were introduced at 0.2m x 0.2m. The groundnut yield was not significantly affected by the planting patterns of cassava. This seems to result from the fact that the groundnuts were well developed before the cassava could make sufficient use of environmental resources in order to be competitive. Groundnut yield was higher at 0.4m x 0.2m than at 0.2m x 0.2m, as a monocrop and as an intercrop in both cassava planting arrangements (table 2). This is attributed to high plant-to-plant competition in the groundnuts sown at 0.2m x 0.2m. Such a high population of groundnuts could be the cause of excessive mutual shading leading to a reduction in the net assimilation rate (NAR) and therefore to a reduction in yield. It seems that the population obtained with 0.2m x 0.2m spacing was above the optimum under the conditions of this study. The land equivalent ratios of cassava and groundnut intercrops were all above 1.0, showing that a higher productivity per unit area was obtained by intercropping cassava with groundnuts than by growing the two crops separately (table 3). However, the productivity of the system tended to decrease with the high groundnut plant population (0.2m x 0.2m) perhaps because of the increased competition. The highest returns were obtained from cassava grown in paired rows intercropped with groundnuts at 0.4m x 0.2m. (table 4). It appears that the economic returns from this cassava-groundnut intercropping may vary with changes in planting patterns and plant population which affect the yield of the two crops.

1982-84 Experiments

Although cassava storage root yields of both Kinuani and Mpelolongi varieties were not affected by leaf harvesting or by plant density, intercropping with groundnuts reduced the yield of the two cassava varieties by 64 and 33 percent respectively as compared to the monocrop (table 5). The significant difference in the magnitude of the response of the two varieties to intercropping is probably due to the comparatively slow early growth of Kinuani. When the interaction between variety, cropping system and fertility level was analyzed, it appeared that Kinuani gave a higher yield than Mpelolongi only when grown as a monocrop at a high fertility level. This confirms the observation that the improved variety Kinuani will perform better than the local variety if planted as a sole crop at a high fertility level (figure 1). The yield of the groundnut intercrop was also significantly less at a high fertility level while that of the intercropped cassava at the high fertility level was more than double that at the low level (table 6). It seems that at high fertility levels, cassava is more competitive with groundnuts. A point of particular interest is that the application of lime causes a marked increase in groundnut yields (PRONAM 1985). This is receiving further attention since lime is produced in Zaire and could be available at low cost.

Figure 1. Yield of two cassava varieties under two cropping systems at two levels of soil fertility



1983-85 experiments

Results show that cassava variety was the only factor with a significant effect on storage root yield and that Kinuani produced a higher yield than clone 5052 (table 7). A similar difference in yield between the two varieties was observed in the monocrop treatments. On the other hand, groundnut density was the only factor wich significantly affected the yield of the intercropped groundnuts. In addition, the time of cassava planting had a significant effect on total productivity per unit area with the LER being higher when cassava was planted at the same time as groundnuts. Delaying cassava planting for three weeks after groundnuts could reduce cassava yield by about 37 percent (PRONAM, 1984). The overall productivity per unit area of intercropped cassava and groundnuts was about 60 percent greater than that attained by growing the two crops in a monoculture.

Conclusion

Cassava is well suited for intercropping with groundnuts since it does not impose much competition at the beginning of its growth cycle. But the competitive ability of the two crops will depend on their growth habit, planting arrangement and densities. The time of planting and soil fertility level are also important and have biological implications.

Planting cassava in double rows with groundnut at 0.4m x 0.2m spacing resulted in the highest yields of cassava and groundnuts in the mixture and provided the greatest biological efficiency and highest economic returns. However, a single-row (1m x 1m) cassava system could also be used in intercropping without causing significant yield reductions of the associated groundnuts.

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Table 1. Storage root yield of cassava grown alone and intercropped with groundnut in different planting patterns

Treatment combinations	Yield (t/ha)	
	1980-81	1981-82
Cassava DR	18.2	15.8
Cassava SR	17.6	14.6
Cassava DR + groundnut (0.2m x 0.2m)	13.0	13.2
Cassava DR + groundnut (0.4m x 0.2m)	19.1	13.3
Cassava SR + groundnut (0.2m x 0.2m)	12.9	10.4
Cassava SR + groundnut (0.4m x 0.2m)	15.6	12.5
LSD (0.05)	5.0	2.0

Source: Lutaladio 1986.

Note: DR = double rows; SR = single rows

Table 2. Grain yield of groundnut at two plant populations grown alone and with cassava in different planting patterns

Treatment combinations	Grain yield (kg/ha)	
	1980-81	1981-82
Groundnut (0.2m x 0.2m)	1,690	1,040
Groundnut (0.4m x 0.2m)	1,730	1,090
Cassava DR + groundnut (0.2m x 0.2m)	1,330	875
Cassava DR + groundnut (0.4m x 0.2m)	1,710	1,005
Cassava SR + groundnut (0.2m x 0.2m)	1,410	835
Cassava SR + groundnut (0.4m x 0.2m)	1,570	1,035
LSD (0.05)	250	175

Source: Lutaladio 1986.

Note: DR = double rows; SR = single rows

Table 3. Land equivalent ratio (LER) of cassava and groundnut as affected by planting patterns and crop combinations in two cropping years

Crop combinations	Partial LER		Total
	Cassava	Groundnut	LER
Cassava DR	1.0	—	1.00
Cassava SR	1.0	—	1.00
Groundnut (0.2m x 0.2m)	—	1.00	1.00
Groundnut (0.4m x 0.2m)	—	1.00	1.00
Cassava DR + groundnut (0.2m x 0.2m)	0.72	0.82	1.54
Cassava DR + groundnut (0.4m x 0.2m)	0.87	1.04	1.91
Cassava SR + groundnut (0.2m x 0.2m)	0.77	0.82	1.38
Cassava SR + groundnut (0.4m x 0.2m)	0.94	0.97	1.91

Source: Lutaladio 1986.

Note: Mean of two cultivars in two seasons
DR = double rows; SR = single rows

Table 4. Gross returns of cassava and groundnut as affected by planting patterns and crop combinations in two cropping years

Crop	Cassava		Groundnut		Total
	Yield (t/ha)	Gross return (Z)	Yield (kg/ha)	Gross return (Z)	
Cassava DR	17.0	34,000	—	—	34,000
Cassava SR	16.1	32,200	—	—	32,200
Groundnut (0.2m x 0.2m)	—	—	1,355	20,325	20,325
Groundnut (0.4m x 0.2m)	—	—	1,410	21,150	21,150
Cassava DR + groundnut (0.2m x 0.2m)	12.7	25,400	1,102	16,530	41,930
Cassava DR + groundnut (0.4m x 0.2m)	14.6	29,200	1,332	19,980	49,180
Cassava SR + groundnut (0.2m x 0.2m)	11.5	23,000	1,122	16,830	39,830
Cassava SR + groundnut (0.4m x 0.2m)	14.0	28,000	1,305	19,575	47,575

Source: Lutaladio 1986.

Note: Mean of two cultivars in two seasons
DR = double rows; SR = single rows
Gross returns: *Cassava—Z 2.00/kg of storage roots;*
Groundnut—Z 15.00/kg of grain

Table 5. Effect of several agronomic factors on the yield of two cassava varieties

Variety	Fertility level		Cropping system		Plant density		Leaf harvesting		Mean
	low	high	mono-	inter-	10,000 /ha	20,000 /ha	with	with-out	
Mpelolongi	7.3	11.2	11.1	7.4	8.9	9.6	9.6	8.9	9.2
Kinuani	6.3	10.3	12.2	4.4	8.6	8.0	8.1	8.5	8.3
Mean	6.8	10.8	11.7	5.9	8.8	8.8	8.8	8.7	8.8
LSD (5%) for									
Main effects		1.4							
Interactions		1.9							

Source: PRONAM, 1984

Note: The variety X cropping system interaction was highly significant

Table 6. Effect of level of soil fertility on yield of intercropped cassava and groundnut

Fertility level	Cassava fresh root yield (t/ha)	Groundnut fresh pod yield (kg/ha)
Low	3.7	873
High	8.1	549

Source: PRONAM, 1984

Note: The effect of fertility level on yield of both cassava and groundnut was highly significant

Table 7. Maize effects of cassava variety, time of cassava planting , cassava planting arrangement, cassava density and groundnut density on yield of intercropped cassava and groundnut and on land equivalent ratio (LER)

Treatment	Cassava fresh root yield t/ha	Groundnut fresh pod yield	LER kg/ha
Cassava variety	*	ns	
Kinuani	5.76	3023	1.29
5052	4.61	2678	1.19
Time of cassava planting	ns	ns	
with groundnuts	5.23	2924	1.32
three weeks after groundnuts	5.15	2777	1.17
Cassava planting arrangement	ns	ns	
equidistant rows	5.01	2981	1.25
double rows	5.36	2720	1.23
Cassava density	ns	ns	
10,000 plants/ha	5.21	2814	1.23
20,000 plants/ha	5.16	2888	1.25
Groundnut density	ns	**	
63,333 plants/ha	4.97	2522	1.14
166,666 plants/ha	5.41	3179	1.34

Source: PRONAM 1985.

Notes: * significantly different at 0.05
** significantly different at 0.01
ns: not significantly different

SUMMARY OF COMMENTS ON TECHNICAL PAPERS

From papers presented on intercropping with cassava, the following points are salient:

1. Intercropping other crops with cassava helps to minimize the output of land resources.

2. A significant difference exists between total yields from fertilized cassava crop mixture and non-fertilized mixtures; hence the use of fertilizer helps to boost yield.

3. Various times of introduction of various crops in cassava-based mixtures were recommended; for instance, maize could be brought in at planting or 28 days after planting cassava.

4. Some cultural methods that could help to control pests were highlighted; for instance, fertilizer application reduces incidence of mealybug on cassava, and intercropping, especially with spreading prostrate crops, reduces weed infestation.

5. The preference of farmers in Nsukka area for the broadcasting rather than the banding fertilizer application method was attributed to the high opportunity cost of the extra labor involved in the banding method. The farmers value such labor highly and use it on other activities.

6. Shortness and earliness were attributes advocated for maize varieties intended to be used in a cassava mixture with a population of 80,000 stands per hectare as appropriate.

7. In a cassava+groundnut intercrop, the best cropping pattern is determined by varietal growth habit, plant arrangement and density of component crops in the mixture as well as time of planting and soil fertility.

It was generally noted that most of the results from the different locations appeared to have similar trends. With standardized methods for various data collection, it may be possible in future to remove the impression that agronomic research results are location-specific.

Session V

RESPONSE OF A CASSAVA-MAIZE INTERCROP TO NITROGEN IN TWO-YEAR SEQUENTIAL CROPPING

H.C. Ezumah, F.I. Nweke, N.D. Kalabare and A. Karunwi

Abstract

Two open pollinated (early maturing and late) and a hybrid maize intercropped with cassava at three sites, a perhumid ultisol soil, a humid and a subhumid alfisol soil, at five nitrogen levels did not result in reduction of intercropped cassava root yields at humid and subhumid ecologies. Optimum N level for maize yield varied from 80 to 160 kg/ha depending upon site and maize variety. The hybrid maize grown in the subhumid environment required higher N rates than the composites. Cassava gave negative response to N at the perhumid site and only weak response at the humid site but root yield increased with N in the subhumid alfisol soil. Net benefits from intercropping maize with cassava were higher when association was with hybrid maize at the subhumid site. Supplementary nitrogen may not be required in intercropping systems of maize with improved cassava, TMS 30572, since the peak response for the intercrop system averaged across the three ecologies was 120 kg/ha N. Nitrogen applied during the first year significantly affected the second year responses for maize.

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The most commonly observed cropping sequence in humid areas of Nigeria following land clearing are those in which nutrient-demanding crops such as maize and yams are followed by less nutrient-demanding crops such as cassava and cocoyams. Vegetables may be included in the cropping cycle. Cassava seems to be displacing other major crops and is rapidly taking over compound farms and less humid areas (Nwosu 1977). Sequences in which cassava and maize are followed by (fb) cassava+ maize fb fallow are now common, particularly in southern Nigeria, southern Ghana, Republic of Benin and southern Togo. A study of the cassava + maize fb cassava + maize fb fallow in 2-year cropping cycles was undertaken in three ecologies, commencing in 1985 to determine the nitrogen response, sustainability and monetary returns from the system. Previous reports have shown that hybrid maize responded to N at levels greater than 220 kg/ha (IITA 1983).

Materials and Methods

The sites, representing the three ecologies, were Warri (perhumid ultisol soil), Okolu (alfisol soil) and Mokwa (subhumid, alfisol soil). The commonest limiting nutrients for plant growth in these environments are usually N and K and sometimes P (Takyi 1976; Agboola and Obigbesan 1974; Ofori 1976; Obigbesan and Fayemi 1976; Okeke et al. 1979; and Okeke et al. 1982). In this study, P and K levels were kept constant at 60 kg/ha and N level varied from 20 kg/ha to 320 kg/ha at rate functions of 20, 2 x 20, 2^2 x 20, 2^3 x 20, and 2^4 x 20 kg/ha. N. Three maize varieties, the early maturing (90-day) streak resistant TZESRW, late (110-120 day) TZSRW and a hybrid (8321 x 180) were intercropped with TMS 30572 cassava at the five N levels in the five sites representing the three ecologies.

The three maize varieties and five N levels treatment factors were arranged in randomized complete block at each site. There were four replications per site. The plot size was 6m x 8m. Cassava and maize were planted in alternating rows. Cassava spacing was lm x 1m while the maize was spaced at lm x 0.25m for 10,000 and 40,000 plants per ha. respectively, for the cassava and maize in the intercrop systems. All the kg/ha of P and of K were applied at planting. Half the N was applied as seedbed and the second half applied four weeks after planting. Both crops (cassava and maize) were planted the same day.

Soil samples (0-10cm depth) were obtained prior to planting at the end of the first year, and at the end of the second year. Yields were obtained at 12 months for cassava roots and when cobs were dry for maize. Maize-grain yield is reported at 14 percent moisture; cassava root is fresh tuber.

Statistical analysis

A major objective of the trials was to determine the effect on yield of two sequences of cassava + maize in each of three sites where N was varied. Therefore the two-year data were combined per site and analyzed as split plot, with the year or season effects as the main plot and the combinations of maize variety + N levels as subplot. The choice of split plot in the combined analysis was rationalized since the treatment factors were not re-randomized during the second year. Significant Year x N interaction indicates influence of first year N application on second year response by test crops.

Results and Discussion

Maize Grain Yield

The analysis of variance showed significant effects (1 percent) of maize variety, N level, and season (year) on maize grain yield at each ecology. Interactions of nitrogen and season (year) were also significant (table 1). The hybrid maize gave a higher yield than the other varieties. The lowest yield was obtained from TZESRW, the early maturing maize variety, while the hybrid maize (8321 x 18) yielded highest, especially in the subhumid (by 62 percent) over TZESRW and humid (by 38 percent) and perhumid (by 50 percent) environments. In the humid alfisol site, the grain yields of late composite (TZSRW) and hybrid maize were not different.

Nitrogen effects on Maize Grain

At Warri, (the perhumid environment) and Okolu, (humid), maize grain yield peaked at about 160 kg N/ha and 80 kg N/ha in 1985 and 1986 respectively (figures 1 and 2). At Mokwa, there was no response to N application in 1985 but in 1986, the best maize grain yield was obtained at 160 kg N/ha(figure 3). Therefore irrespective of ecology, the N level for high maize grain yield under intercropping with cassava was between 80 and160 kg/ha. Weak response during the first year of cropping is attributable to soil N immediately after land clearing. The N level generally recommended for maize in the forest zone ranged from 80-120 kg/ha, (NAFPP 1976; Kang et al. 1980; Ikeorgu 1984). The 1986 rainfall was low, and deviated negatively from usual levels; this could contribute to variances in yields (table 2).

Cassava Root Yield

Significant effects ($P > 0.001$) were observed for nitrogen, years (season) and nitrogen x year interaction on cassava root yields (table 3). Maize had no effects on cassava root yield (table 4).

Very mild response to N was observed in the 1985 cassava yield but in 1986, increasing N reduced cassava root yield at Warri, the perhumid environment (figure 4). The highest cassava root yield was obtained at 40-80 kg N/ha at Okolu, the humid environment (figure 5). At Mokwa, however, very mild response was observed in 1985 with no distinct peak. The 1986 response was rapid up to 120 kg N/ha and tapered off beyond 120 kg N/ha for cassava root (figure 6).

Therefore, the response of intercropped, two sequential cropping of cassava and maize to N varied with ecology—ranging from declining root yields at Warri (perhumid ecology) to distinct peaks at Okolu (humid) and mild response only during the second year at Mokwa (subhumid). Reduced cassava root yield with N fertilization was also reported by Kang and Wilson (1980) in an alfisol soil in southern Nigeria.

Cassava + Maize

Economic analysis of nitrogen response in the cassava and maize intercrop involving the determination of the net-benefit analysis from production costs and returns indicated that in Warri, the perhumid environment, negative marginal net-benefits were obtained when nitrogen application was increased from 20 to 40 kg/ha. The highest net benefits were recorded at 20 kg N/ha for all the maize varieties in this ecology irrespective of maize variety (table 5). At Okolu (humid), the highest net benefit was realized at 80 kg N/ha by intercropping TMS 30572 with the three maize varieties. In the perhumid and humid environments, returns from cassava tended to complement lower incomes associated with relatively low yields from maize. In the subhumid environment at Mokwa, the net benefit peaked at 160 kg N/ha for the TMS 30572 + TZESRW intercrop, whereas the response at 320 kg N/ha resulted in highest benefits for the TMS 30572 + TZSRW and TMS 30572 + hybrid intercrops. The inclusion of cost of capital which constituted 40 percent of the cost of fertilizer and application in the variable costs as opportunity cost and risk premium to the farmer for the committed capital did not affect the decisions earlier stated on the net benefits; however, it indicated that the farmers could afford such investments.

Although the exact optimum N level for highest monetary returns under cassava + maize intercropping varied with ecology, the peak response for the intercrop system averaged across the three ecologies was 120 kg N/ha, comparing favorably with that required by maize as a monocrop which ranged from 80 kg to 160 kg N/ha.

The use of benefit cost ratios analysis as economic indicators showed that the investment is viable with the benefit cost ratios greater than 1 for all the intercrops in all the ecologies (table 6).

Conclusions

Cassava and maize intercropped across a wide range of environments in humid/subhumid tropical ultisols and alfisols in Southern Nigeria under varying N fertilizer rates show:

1. That maize variety—whether early maturing open, late maturing open or hybrid—had no significant effect on cassava root yield under intercropping. However, the range in maize types was limited to only three at recommended intercrop population of 40,000/ha (IITA 1984; Kang and Wilson 1980).

2. The best N level for maize yield ranged from 80 kg/ha to 320 kg/ha irrespective of ecology. It appears some maize types such as the hybrid require higher N rates.

3. From net benefit analysis, it was ascertained that application of N at high rates in the perhumid environment presented by Warri gave negative marginal returns over very little dosage of between 20 and 40 kg/ha. At Okolu, N rates of 80 kg/ha resulted in the highest level of benefit. In the subhumid ecology the benefits reached their peak at 160 kg N/ha for the TMS 30572 + TZESRW intercrop while it was at 320 kg N/ha for TMS 30572 + TZSRW and TMS 30572 + Hybrid intercrops.

4. Significant Y x N interactions for maize and cassava yields indicate that N applied during the first year (1985) influenced response by maize and cassava to N applied during the second year (1986). Second-year responses to N fertilizer were generally higher at the lower N rates and tended to decline as N rates increased.

Figure 1. Effect of N on the grain yields of maize in 1985 and 1986 averaged over three maize varieties in a perhumid environment (Warri)

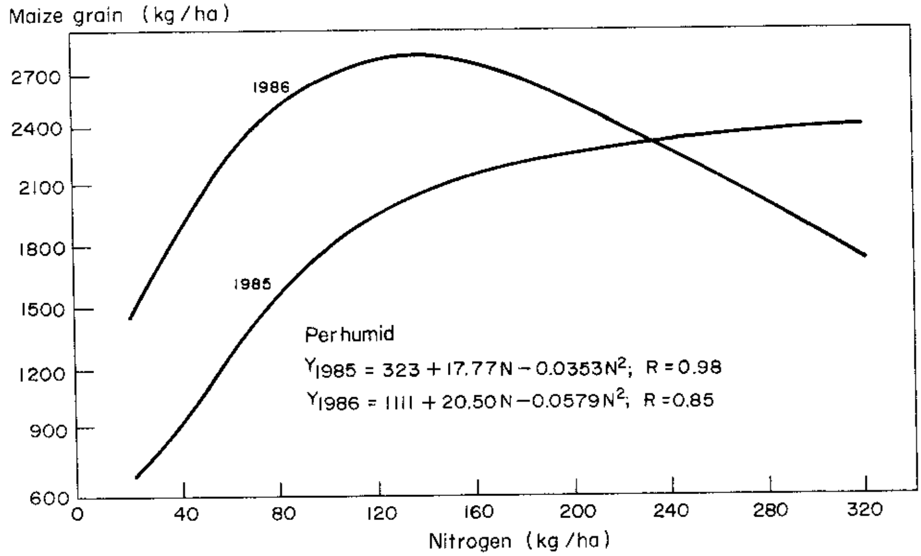

Figure 2. Effect of N on the grain yields of maize in 1985 and 1986 averaged over three maize varieties in a humid environment (Okolu)

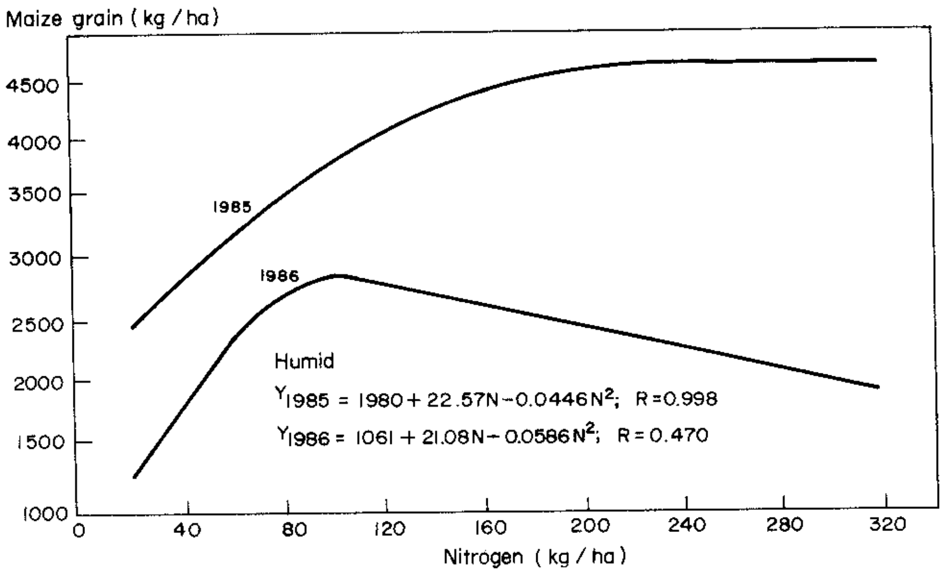

Figure 3. Effect of N on the grain yields of maize in 1985 and 1986 averaged over three maize varieties in a subhumid environment (Mokwa)

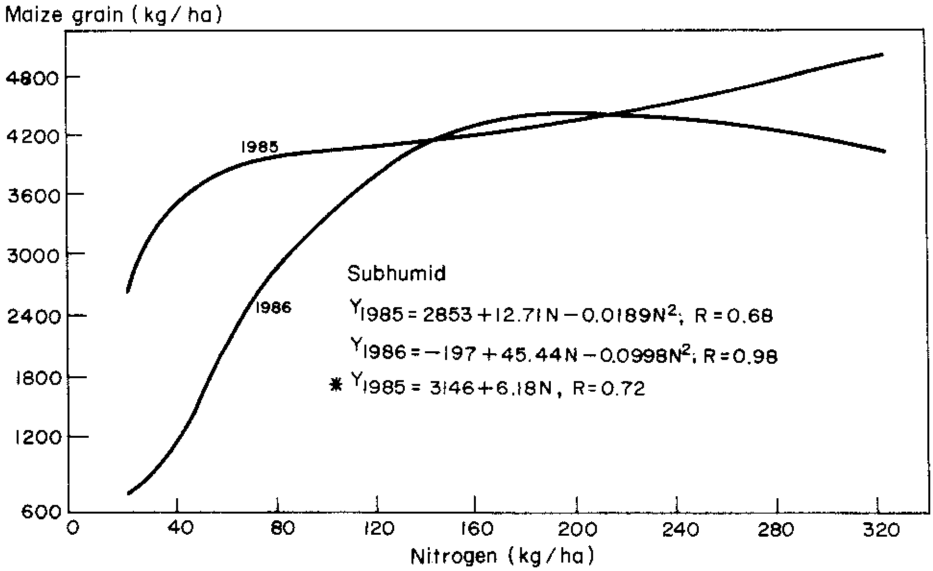

Figure 4. Effect of N on the root yields of cassava in 1985 and 1986 averaged over three maize varieties in a perhumid environment (Warri)

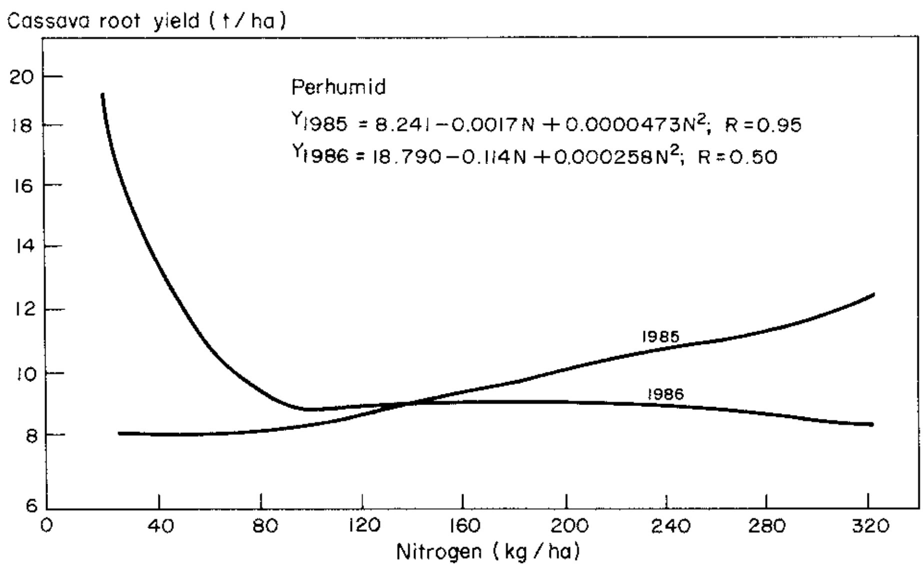

Figure 5. Effect of N on the root yields of cassava in 1985 and 1986 averaged over three maize varieties in a humid environment (Okolu)

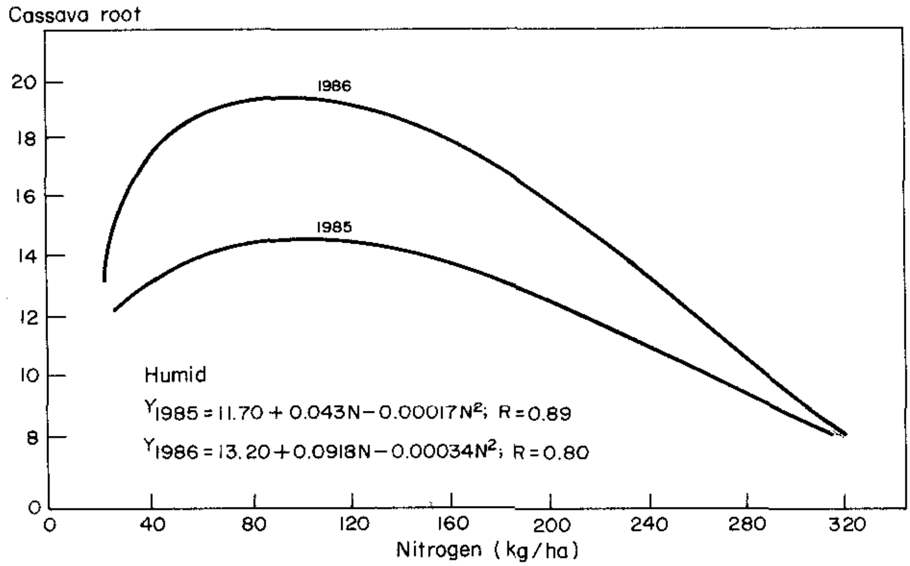

Figure 6. Effect of N on the root yields of cassava in 1985 and 1986 averaged over three maize varieties in a subhumid environment (Mokwa)

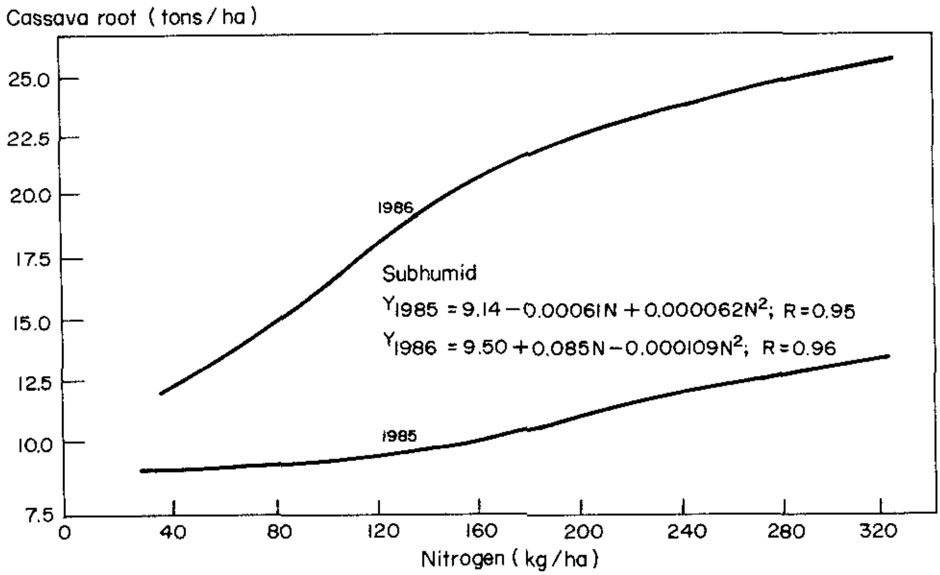

Table 1. Summary of analysis of variance of three maize varieties grown with cassava at five Nlevels in three environments for 2 years in sequential cropping systems (maize grain yield)

Source of variation	Warri (perhumid)	Okolu (humid)	Mokwa subhumid)
Maize variety	**	**	**
N levels (N)	**	**	**
Years (Y)	**	**	**
MV x N	NS	NS	NS
MV x Y	NS	NS	NS
n x Y	**	**	**
MV x N x Y	NS	NS	NS

Note: NS = not significant; ** = *significant at the 1% level*

Table 2. Total annual rainfall (mm) at experimental sites

Year	Warri (perhumid)	Okolu (humid)	Mokwa (subhumid)	Year mean
1985	2 987	1 735	1 158	1 960
1986	2 433	1 322	955	1 570
Mean	2 710	1 529	1 073	1 771

Table 3. Summary of analysis of variance of maize varieties grown with cassava at five N levels in three environments for 2 years in sequential cropping systems (cassava yield)

Source of variation	Warri (perhumid)	Okolu (humid)	Mokwa subhumid)
Maize variety	NS	NS	NS
N levels (N)	**	**	**
Years (Y)	**	**	**
MV x N	*	NS	NS
N x Y	**	**	**
MV x N x Y	NS	NS	NS

Note: *NS = not significant; ** = significant at 1% level; * = significant at 5% level*

Table 4. Effects of maize variety on cassava root yield at 3 locations

Maize variety	Warri (perhumid)	Okolu (humid)	Mokwa (subhumid)
TZESRW	10.5	14.0	13.9
TZSRW	10.5	13.6	12.8
Hybrid	10.6	14.0	14.1
SE	0.34	0.64	0.83
Mean	10.5	13.9	13.6
CV (%)	18.9	22.8	31.6
Annual rainfall	2 710	1 529	1 073

Table 5. Production costs and returns from cassava/maize intercrop in humid, subhumid and perhumid ecologies

Okolu				
	Nitrogen levels	Tms 30572/ TZESRW	Tms 30572/ TZSRW	Tms 30572/ hybrid
Gross field benefit (cassava ₦150/ton, maize ₦500/ton)	20	2098.00	2576.50	2771.00
	40	2988.50	3481.50	3107.50
	80	3571.00	3898.00	3947.00
	160	3655.50	3779.50	3758.50
	320	2264.00	2536.50	2864.50
Total variable costs	20	1369.60	1380.42	1483.26
	40	1413.86	1433.71	1518.76
	80	1494.65	1507.02	1612.95
	160	1611.64	1642.57	1742.57
	320	1838.39	1868.87	1971.13
Net benefits	20	728.40	1196.08	1287.74
	40	1574.67	2047.79	1588.74
	80	2076.35	2390.98	2334.05
	160	2043.86	2136.93	2015.93
	320	425.61	667.63	893.37
Net benefits minus cost of capital	20	713.84	1181.52	1273.18
	40	1387.06	2020.99	1561.94
	80	2025.07	2339.70	2282.77
	160	1943.62	2036.69	1915.69
	320	232.09	474.11	699.85

Note: Fertilizer cost = $145/ton (unsubsidized); cost of capital = 40 percent of the costs of fertilizer and application as opportunity cost and risk premium

Table 5 (continued)

Warri				
	Nitrogen levels	Tms 30572/ TZESRW	Tms 30572/ TZSRW	Tms 30572/ hybrid
Gross field benefit (cassava ₦150/ton, maize ₦500/ton)	20	2272.00	2346.00	2487.00
	40	1958.50	1905.00	2120.50
	80	1856.00	2122.00	2264.50
	160	2075.50	2443.50	2668.50
	320	2252.50	2178.50	2626.00
Total variable costs	20	1361.09	1361.35	1464.44
	40	1398.65	1393.49	1498.65
	80	1468.87	1478.41	1584.60
	160	1591.53	1610.35	1712.15
	320	1820.09	1823.50	1953.34
Net benefits	20	910.91	984.65	1022.56
	40	559.85	511.51	621.85
	80	387.13	643.59	679.90
	160	483.97	833.15	956.35
	320	432.41	355.00	672.66
Net benefits minus cost of capital	20	896.35	970.09	1008.00
	40	533.05	484.71	595.05
	80	335.85	592.31	628.62
	160	383.73	732.91	856.11
	320	238.89	161.48	479.14

Note: Fertilizer cost = $145/ton (unsubsidized); cost of capital = 40 percent of the costs of fertilizer and application as opportunity cost and risk premium

Table 5 (continued)

	Nitrogen levels	Tms 30572/ TZESRW	Tms 30572/ TZSRW	Tms 30572/ hybrid
Mokwa				
Gross field benefit (cassava ₦150/ton, maize ₦500/ton)	20	2025.50	2021.50	2486.50
	40	2305.00	2591.00	2824.50
	80	2434.00	3256.00	3851.50
	160	4034.00	3982.50	4049.50
	320	4150.00	4629.50	5297.00
Total variable costs	20	1365.47	1375.01	1488.93
	40	1414.12	1430.10	1530.61
	80	1480.73	1519.40	1629.19
	160	1626.84	1655.20	1768.86
	320	1866.49	1892.32	2011.86
Net benefits	20	660.03	646.49	997.57
	40	890.88	1160.90	1293.89
	80	953.27	1736.60	2221.81
	160	2407.16	2327.30	2280.64
	320	2283.51	2737.18	3285.14
Net benefits minus cost of capital	20	645.47	631.93	983.01
	40	864.08	1134.10	1267.09
	80	901.99	1685.32	2170.53
	160	2306.92	2227.06	2180.40
	320	2089.99	2543.66	3091.62

Note: Fertilizer cost = $145/ton (unsubsidized); cost of capital = 40 percent of the costs of fertilizer and application as opportunity cost and risk premium

Table 6. Economic indicator from intercropping cassava and maize in different ecologies

Ecology	Benefit cost ratios (cost = 1.00			
	Nitrogen levels	Tms 30572/ TZESR	Tms 30572/ TZSRW	Tms 30572/ hybrid
Okolu	20	1.53	1.87	1.87
	40	2.11	2.43	2.05
	80	2.39	2.59	2.45
	160	2.27	2.30	2.16
	320	1.23	1.36	1.45
Warri	20	1.67	1.72	1.70
	40	1.40	1.37	1.41
	80	1.2	1.44	1.43
	160	1.30	1.52	1.56
	320	1.24	1.19	1.34
Mokwa	20	1.48	1.47	1.67
	40	1.63	1.81	1.85
	80	1.64	2.14	2.36
	160	2.48	2.41	2.29
	320	2.22	2.45	2.63

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TESTING THE FEASIBILITY OF ASSOCIATING CASSAVA AND OTHER FOOD CROPS IN OIL PALM INTERCROPPING SYSTEMS

I.I. Onwubuya and F.K. Eneh

Abstract

Two trials were set up in 1978 and 1980 to find the best method of intercropping oil palm with conventional food crops. One of the experiments comprised seven treatments of which oil palm was the main crop. The second experiment also comprised seven treatments which involved only cassava and oil palm. Results obtained from the first experiment showed that the mean height, girth and leaf number per palm were similar among the treatments with the exception of the oil palm/cassava and the oil palm/plantain mixtures which performed significantly below ($P<0.05$) the others. Sex ratios for the oil palm were significantly lower in these two treatments than in the rest. A similar trend was observed for the fresh fruit bunch (ffb) yield per hectare. In the second experiment virtually all the intercropped treatments significantly ($P<0.05$) outyielded the control treatment (no intercropping). On economic grounds, all the intercropped treatments in the first experiment showed positive net revenues suggesting that their total revenues were large enough to cover the costs involved in intercropping oil palms with food crops. The oil palm/cassava system appeared to be the most attractive in terms of offsetting the establishment cost of the oil palm. It is concluded that intercropping oil palms with food crops during the early years of oil palm establishment, apart from having no significant adverse effect on ffb yield, is advantageous in reducing the establishment cost of oil palms.

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The need to intercrop young oil palms arises from a number of factors of which the most important is the man/land ratio. In sparsely-populated areas in the oil-palm belt, the need for intercropping oil palms with food crops may not be very obvious. Intercropping oil palm in such areas is motivated by economic factors relating to labor-use maximization and to the early food crop income which can be used to offset part of the initial investment in the oil-palm main crop, or sustain the farmer and his family until the oil palm begins to generate revenue.

In areas where increases in human population have had a depressing effect on the available arable land per man, intercropping is considered solely as a means of maximizing land use. Oil-palm farmers in such land-deficit areas are known to intercrop young oil-palms with food crops. In fact, World-Bank-assisted small-holder oil-palm projects in Nigeria slowed down in some States mainly because oil-palm farmers refused to adhere to sole cropping systems as demanded by the Bank. These farmers insisted on intercropping young oil-palms with annual and short-period perennial food crops as a means of dealing with the problem of dwindling arable land resulting from population pressure and urbanization. These farmers plant various kinds of food crops as intercrops in young oil-palm fields at densities which they determine subjectively. In such intercropping systems, husbandry practices may call for increased labor input and the crop associations may intensify or reduce the incidence of pests and crop diseases and there may be possible changes in the soil chemistry as well. All this creates a need for vigorous and intensive research on the intercropping of oil palm and other crops.

From the early 1940s to the middle 1960s, experiments on the intercropping of food crops with oil palms were embarked upon by the Nigerian Institute for Oil Palm Research (NIFOR) in different locations (Sparnaaij 1957). Although the results obtained were consistent in suggesting that oil palms could be intercropped with various food crops in the first few years of establishment, such experiments were not detailed enough to give rise to any recommendation package. However, a method of interplanting oil palms and cocoa has been recommended (Onwubuya, Iremiren and Kolade 1981).

Thus, the objective of this study was to examine the merits of intercropping oil palms with food crops. Food crops which were commonly intercropped with oil-palms were selected to fit in with accepted local food cropping practices.

Materials and methods

Experiment 1

Field 64 at NIFOR's Main Station, near Benin City, Nigeria, was used for the experiment. *Tenera* oil palms had been previously planted in 1957 in the field which had been opened from a high secondary forest cleared by burning. These palms were felled in December 1977, the undergrowth cut and the area burned in early April 1978. The soil was acid sand with a pH of about 5.6 (Vine 1956).

Extension work seeds (*Dura* x *Pisifera*) used for the experiment were raised in the nursery in May 1977 and transplanted to the field in May 1978 at 8.8m triangular spacing. The area planted was 4.2ha with a total palm population of 630 of which 380 were experimental while 350 were guard palms.

The experiment comprised seven treatments as follows:

- oil palm intercropped with *Pueraria phaseloides* as control
- oil palm intercropped with maize and pineapple
- oil palm intercropped with cassava
- oil palm intercropped with yam
- oil palm intercropped with cocoyam
- oil palm intercropped with plantain
- oil palm intercropped with yam, okra and spinach followed by cassava.

The experiment was a randomized block design which was replicated four times. The plot size was 670m^2. Thus, there were ten experimental palms per plot.

A week after the planting of the oil palm, seeds of *Pueraria phaseloides* which were acid scarified were manually planted in Treatment A plots to provide a leguminous cover. Maize and pineapple were planted using zero tillage. The spacings for each of these two crops were 75cm between two rows and 25cm within a row, giving a population of about 3,500 stands per plot planted to alternate with each other. Cassava, yams and cocoyams were planted in their respective plots at 1m intervals, each giving a population per plot of 670 stands. Some stands were very close to the palms. Plantains were planted at 3m intervals giving a population per plot of 74 stands. Okra and spinach were randomly planted in the G plots. When yam in Treatment G had advanced in growth, cassava was introduced in August 1978. A local variety of cassava characterized by profuse branching right from the base was used. Replanting of Treatments D and E with yams and cocoyams respectively was carried out again.

Measurements of height, girth and leaf number per palm were made at three-monthly intervals. Flowering observations started in September 1979 and the fresh fruit bunch (ffb) yield recording commenced in 1983.

Experiment 2

Part of Field 64 was used for the experiment. The old palms were felled in December 1979, and debris packed and burned in March 1980. The area planted to oil palms was 1.73ha with a total plant population of 266 of which 168 were experimental and 92 guard palms.

There were seven treatments as follows:

- oil palm intercropped with *Pueraria phaseoloides* (control)
- local variety of cassava planted at 1m intervals
- TMS 1525 cassava variety planted at 1m intervals
- TMS 30211 cassava variety planted at 1m intervals
- local variety planted at 2m intervals
- TMS 1525 casava planted at 2m intervals
- TMS 30211 cassava planted at 2m intervals.

TMS 1525 and TMS 30211 are high-yielding varieties that have an erectophile growth pattern and do not usually branch from the base. The three cassava varieties were planted 2m away from palm stands. The experiment was a randomized block design which was replicated three times. The plot size was 0.053ha ($530m^2$). Recording of mean height and girth per palm started in 1980 while yield recording started in 1985.

In both experiments all the cultural management practices were adopted. For example, in the control plots, the oil palms were ring weeded and the interlines slashed to knee level. The yam, cocoyam, cassava and pineapple plots were weeded and cultivated. The planted plots were also kept free of weeds but not cultivated. Fertilizer application to oil palms was carried out on a routine basis.

Records of labor and non-labor inputs were used to obtain the total production costs for each treatment over the intercropping period. Input and output prices used reflected the 1985/86 values. These prices were the mean values per kg of the various inputs or outputs obtained at interval times between June 1985 and May 1986. Labor input was costed at six Naira (₦6.00) or US$1.7 per man-day.

Results

Experiment 1

Palm growth. Tables 1 to 3 show the mean height, girth and leaf number per palm from 1978 to 1981. In each year, there were significant differences ($P<0.01$) between the mean heights per palm in different treatments. However, the superiority of one treatment over the others was not consistent from year to year. In 1978, Treatment C had the greatest height while Treatment A (control) had the least. There was a reversed trend from 1979 when the least height was recorded in Treatment C and the greatest in Treatments G, D and E in 1979, 1980 and 1981 respectively. The differences between the mean girth (circumference of the crown) per palm were also highly significant

(P<0.01). Treatment C had the least girth. Differences between the number of leaves produced per plant per year were significant (P<0.05). Evidently more leaves were produced per palm in the intercropped treatments except Treatments C and F than in the control.

Flower production. The average male and female flower production per palm in each treatment is shown in table 2. Between September and December 1979, male flower production had commenced in all the treatments. The lowest value was recorded in Treatment C. Production of the female flower was low in all the treatments and in C and F, production was non-existent. Table 5 shows the percentage sex ratios obtained in 1980 and 1981. The differences between the treatments were highly significant (P.<0.01). In both years, Treatment E had the highest sex ratios while Treatments C and F had the lowest. Sex ratios obtained from Treatment A (control) in both years was considerably lower than those from the rest of the treatments except C and F and, in 1981, the differences between either E or C and A were significant (P<0.05).

Fresh fruit bunch yield (FFB). The fresh fruit bunch (ffb) yield per hectare is presented in table 6. In 1983 and 1985, the differences between the treatments were highly significant (P<0.01). The differences fell slightly short of significance (P<0.01) in 1984. The differences between the yields averaged over three years were also highly significant (P<0.01). Treatments C and F consistently produced fewer bunches—about 60 percent of the quantity produced by Treatment B which gave the overall highest yield. However, the differences between Treatments A, B, D, E and G were not significant (P<0.05).

Experiment 2

Measurements taken for height, girth and palm leaf number were inconsistent. Furthermore, the initial measurements of these growth parameters were not taken. Hence, their values are not presented.

FFB yield. Harvesting of ffb started in 1985. The data for that year are presented in table 7. All the intercropped treatments except Treatment G highly significantly (P<0.01) outyielded the control (no intercropping with food crops). All the intercropped treatments but 6 compared favourably with one another irrespective of the spacing used.

Discussion

The results obtained so far indicate that intercropping of oil palms with food crops has no adverse effect on the growth and yield of the former. As a matter of fact, it would appear that intercropping stimulates the growth and yield of oil palms. These findings agree with Toovey (1947), reported in Sparnaaij (1957), for oil palm and food crops. Evans (1960) and Andrews (1972), working separately on a mixture of cereal crops, arrived at a similar conclusion.

The ffb yield differences between the control and Treatments B, D, E and G were not significant. However, the differences became more pronounced when compared with C or F. Cassava in C is characterized by fast growth, profuse and violent branching from the base and planting of cassava strictly followed the pattern usually adopted by peasant farmers so that, in most cases, it was very close to the palm stands. This, perhaps, produced a shading effect that affected the early growth and development of the palms.

In Treatment G, where oil palms were planted in the first instance with yams there was probably sufficient penetration of light which enhanced the early growth and development of the palms. When cassava was later introduced in August of the same year, the oil palms had already established and growth and development were not impaired. Thus, the ffb yield obtained from G was significantly higher than that from C. The implication was that light might have been limiting in Treatment C. This observation was confirmed from the second experiment where the planting arrangement for cassava was such as to allow a greater amount of sunlight to be intercepted by the oil palms. Thus cassava, whether local or improved, did not adversely affect the yield of the oil palms.

Similarly, light was, perhaps, a limiting factor in Treatment F where oil palms were intercropped with plantain. Hence, the yield of oil palms in this treatment was significantly lower than in the control.

It was clear that ffb yields from Treatments B, D, E and G were similar to that from A (control) and, in some cases, better. This observation could be attributable to the cultural practices adopted in those treatments. While the leguminous cover and weeds in A were slashed to knee height, B, D, E and G plots were cultivated in the process of weeding. This practice probably increased aeration of the soil, moisture conservation and reduced competition from the weeds. A similar conclusion was drawn by Sparnaaij (1957) to the effect that it was cultivation per se applied to food crops intercropped with oil palms rather than the presence of those crops in the mixture that was responsible for the positive intercropping effect.

All the treatments involving intercropping (Treatments B to G) showed positive net revenues at the end of the intercropping period (see table 12). This means that the total food crop revenue resulting from each treatment was large enough to offset the cost involved. The magnitude of the food crop net revenue is also an indication of the extent to which the establishment cost of the oil palms in a given treatment can be covered. The oil palm/cassava system with a net revenue of ₦5,263.00 per hectare over the period, appeared to be the most attractive in terms of offsetting the establishment cost of the oil palm. This was followed by Treatment B (oil, maize, pineapple mixture) and by E (oil palm/cocoyam), F (oil palm/plantain) and G (oil palm/yam followed by cassava). Treatment D (oil palm/yam) produced the least net revenue over the intercropping period.

Yields of the intercropped food crops cannot, however, be considered in isolation from the effects of the intercrops on yields of oil palms. Treatment C, which is the most attractive in terms of revenue, reduced ffb yield by 31 percent or ₦1,353.00. However, the resulting net revenue more than compensated for this decrease in ffb yield. Moreover, since the ffb yield can be improved by choosing a good planting time and arrangement for cassava such that shading of the palms will not occur, Treatment C can be recommended on economic grounds. Treatment F, which also significantly depressed oil-palm yields by 37 percent, produced a net revenue that was large enough to offset the loss in the yield of the oil palm main crop. As in C, the ffb can be improved by reducing the plantain population per unit area of land in order to ensure adequate interception of light by the oil palms. Treatments B and F increased the oil-palm yields by 13 and) 6 percent respectively and in addition produced positive net revenues. Thus, an intercropping system involving oil palm/maize/pineapple or oil palm/cocoyam can be regarded as economically sound at the given input and output quantities and prices (see tables 8-12).

Similarly, Treatments D and G can be regarded as economically feasible. Although, they produced lower ffb yields than the control, the differences were not significant ($P<0.05$).

In conclusion, intercropping of oil palms with food crops in the early years of establishment does not adversely affect the oil-palm yield provided that, for some crops like cassava and plantain, planting is such as to allow sufficient interception of light by oil palms. In the case of cassava, relay planting, in which cassava follows later in the season, is suggested. For plantain, planting density per unit area of land should be lower than that recommended.

Even with these results, comprehensive agro-economic and crop protection packages for improving oil-palm/food crop farming systems in smallholder agriculture are not yet possible. Thus, new experiments have been set up at NIFOR and elsewhere to test intercrop densities, the role of leguminous cover, weed control measures and the effect of livemulch-food crops in systems where oil-palm or coconut is intercropped with various food crops. Crop pests and diseases are also being investigated. The experiments are relatively new so that relevant data are not yet available.

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Table 1. Mean height per palm (cm)

Treatment	1978	1979	1980	1981
A	166.2	303.9	402.5	509.6
B	166.5	303.8	428.9	518.6
C	196.4	293.8	371.8	471.6
D	183.4	342.7	442.8	507.4
E	186.4	307.4	425.8	511.6
F	180.1	331.5	438.3	502.5
G	174.3	350.7	415.4	507.2
LSD AT P.< 0.05	11.0	42.9	23.7	27.9
CV	4.15	9.05	3.81	3.72

Table 2. Mean girth per palm (cm)

Treatment	1979	1980	1981
A	105.4	231.6	256.8
B	121.1	247.3	282.2
C	61.1	206.7	188.3
D	115.8	232.8	270.3
E	110.7	243.5	272.2
F	82.6	209.8	213.2
G	100.4	229.8	272.6
LSD at P. < 0.05	15.8	17.0	23.0
CV	5.0	6.2	6.5

Table 3. Mean leaf production per palm

Treatment	Initial number	1978	1979	1980	1981
A	9.5	9.1	18.8	20.2	19.6
B	9.6	9.7	19.7	21.6	21.2
C	9.9	8.5	12.9	18.0	17.5
D	9.9	9.4	20.4	20.4	20.6
E	9.7	8.6	18.5	21.1	21.0
F	10.0	8.9	18.0	17.9	18.1
G	9.3	9.2	18.4	19.7	20.2
LSD AT P. < 0.05		1.18	2.45	2.55	2.57

Table 4. Table of means for male and female inflorescence production per palm from September to December 1979

Treatment	Mean male per month	Mean female per month
A	1.2	0.1
B	1.5	0.2
C	0.3	0.0
D	1.3	0.4
E	1.5	0.6
F	1.3	0.0
G	1.2	0.1

Table 5. Mean % sex ratio per palm

Treatment	1980	1981
A	50.0	40.3
B	53.6	48.2
C	23.9	37.7
D	59.9	45.7
E	66.9	56.5
F	28.0	55.4
G	44.4	55.4
LSD at P. < 0.05	21.2	10.0

Table 6. Mean fresh fruit bunch field per hectare (kg)

Treatment	1983	1984	1985	Mean 1983-1985
A	6,183	9,188	8,760	8,043.7
B	8,202	10,456	8,618	9,091.7
C	3,840	7,560	5,213	5,537.7
D	6,177	8,408	9,435	7,986.7
E	6,660	9,462	9,428	8,516.7
F	3,813	6,675	4,632	5,040.0
G	6,117	9,303	6,963	7,461.0
LSD AT P .< 0.05	2,024	2,961	2,558	2,514.3

Table 7. Mean fresh fruit bunch yield per hectare (kg) in 1985 (2nd experiment)

Treatment	FFB yield
1	3,971.3
2	6,910.5
3	5,284.6
4	6,635.5
5	6,122.5
6	4,721.8
7	6,535.3
LSD AT P . < 0.05	1,812.4

Table 8. Annual labor requirements in man-days per hectare

	Treatment	1978	1979	1980	1981
A	Oil palm sole	—	—	—	—
B	Oil palm	—	—	—	—
	Maize	56	56	56	—
	Pineapple	13	10	10	10
C	Oil palm	—	—	—	—
	Cassava	65	85	65	85
D	Oil palm	—	—	—	—
	Yam	130	130	130	—
E	Oil palm	—	—	—	—
	Cocoyam	59	59	59	—
F	Oil palm	—	—	—	—
	Plantain	55	47	47	22
G	Oil palm	—	—	—	—
	Yam	130	—	130	—
	Cassava	65	85	—	—

Table 9. Labor and non-labor costs of the food crop components of the intercropping systems

	Treatment	Labor costs at ₦6.00 per man-day				Non-labor costs				Total production cost (₦/ha)
		1978	1979	1980	1981	1978	1979	1980	1981	
A	Oil palm sole	—	—	—	—	—	—	—	—	—
B	Oil palm Maize Pineapple	414.00	396.00	396.00	60.00	250.50	30.00	30.00	—	1,576.80
C	Oil palm Cassava	390.00	510 .00	390.00	510.00	166.67	—	166.67	—	2,133.34
D	Oil palm Yam	780.00	780.00	780.00	—	1,779.20	1,779.20			
	1,779.20	—	7,677.60							
E	Oil palm Cocoyam	354 .00	354 .00	354 .00	—	250.00	250.00	250.00	—	1,812.00
F	Oil palm Plantain	330.00	282.00	282.00	132.00	552.00	—	—	—	1,578.00
G	Oil palm Yam Cassava	1,170.00	510.00	780 .00	—	1,945.87	—	1,779.20	—	6,185.07

Table 10. Food crop yields in kg per ha

Treat-ment	Cropping system	Yield in kg/ha				Total yield over the period
		1978	1979	1980	1981	
A	Oil palm sole	—	—	—	—	
B	Oil palm					
	Maize	2,600	2,000	1,500	—	6,100
	Pineapple	—	2,200	1,800	1,600	5,600
C	Oil palm					
	Cassava	—	29,205	—	20,105	49,310
D	Oil palm					
	Yam	7,931	3,976	2,153	—	14,060
E	Oil palm					
	Cocoyam	6,287	3,496	1,575	—	11,858
F	Oil plam					
	Plantain	—	3,709	2,431	2,137	8,277
G	Oil palm					
	Yam	4,892	—	2,994	—	7,886
	Cassava	—	18,713	—	—	18,713

Table 11. Price per unit kg of the food crops

Crop	Price per kg (in ₦)
Maize	0. 80
Pineapple	0. 25
Cassava	0.15
Yam	0. 60
Cocoyam	0. 45
Plantain	0. 50

Source: Obtained fromfood crop price survey carried out at intervals in 1985 and part of 1986.

Table 12. Total revenue, total production cost and net revenues at end of intercropping period (1978 - 1981); food crops only

	Treatment	Total revenue (₦)	Total cost of production (₦)	Net revenue at end of period
A	Oil palm sole	—	—	—
B	Oil palm Maize Pineapple	6,200.00	1,576.80	4,623.20
C	Oil palm Cassava	7,396.50	2,133.34	5,263.16
D	Oil palm, Yam	8,436.00	7,677.60	758.40
E	Oil palm Cocoyam	5,336.10	1,812.00	3,524.10
F	Oil palm Plantain	4,138.50	1,578.00	2,560.50
G	Oil palm, Yam Cassava	7,538.55	6,185.07	1,353.48

TRENDS IN CASSAVA PRODUCTION IN THE ABAKALIKI AREA OF ANAMBRA STATE AND IMPLICATIONS FOR FARMERS

E.C. Okorji and O. Okereke

Abstract

Cassava, although one of the major staple foodcrops in the Abakaliki area of Anambra State, is not accorded as much attention as yams and rice, especially in terms of farm resource allocation. For instance, not only is the land area allocated to cassava significantly small in relation to other crops but it also more often than not has poor quality soil. This is mainly because cassava is regarded as a women's crop, since cassava products do not feature in any cultural activities (farming festivals, chieftaincy titles, etc.) that accord high social status to men in the area.

The size of farm land cultivated per household has increased in response to rising demand for and prices of food products; yam-based crop mixtures (YBCM) and rice are favoured at the expense of cassava-based crop mixtures (CBCM), despite the comparatively high productivity of resources in CBCM. Cassava output, however, has increased, largely as a result of increased cropping density and the introduction of improved cassava varieties. Returns to cassava producers are relatively low because of the limited land area cultivated and the, dominance of low-yielding local varieties as well as the fact that a negligible proportion is processed as "gari" and starch which attracts higher prices per unit weight equivalent than cassava tubers.

The mass adoption of improved cassava varieties, use of agro-chemicals and the provision of processing facilities will significantly increase the output, quality, storability and value of cassava products in the study area.

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Cassava (*Manihot* spp.) is one of the major staple foodcrops in Anambra State. In some respect it is a substitute for yams (*Dioscorea* spp.). Although both cassava and yams are major staples, cassava production is usually not accorded as much attention as yams in terms of farm resource allocation. This situation is not so much based on food security and cash values as on certain non-quantifiable values where yams, for instance, have a far greater sociocultural significance than cassava among the people (Okorji and Obiechina 1985).

With the rising population and the recent ban on rice imports to Nigeria, there has been an increased demand for other staples including cassava products and, as a consequence, food products have risen in price. Changes are expected in the production trends of most staple food crops because of rising demand and prices particularly for such crops as cassava for which there is an increased availability of improved varieties. This paper thus examines the trends in cassava production in response to changes in economic and other factors, and the implications for farmers in the Abakaliki area of Anambra State.

Nature of data

Most of the data used for this paper were obtained from two separate studies conducted in the Abakaliki area of Anambra State during the 1981/82 and 1983/84 farming seasons. The two studies involved samples of 48 and 162 farming households respectively. Questionnaires were given twice weekly to the household heads and their first wives for the 12-month duration of each study. Information was collected on cropping systems, and the sources and pattern of farm resource allocation for different crops. In addition, physical measurements of the sizes of farms, inputs and output etc. were taken. This paper, however, is based largely on information from the 37 farming households that participated in both studies; reference is also made to other recent studies conducted in this area and elsewhere in the state.

Cropping systems and resource allocation

Cassava is commonly grown in combination with other crops such as yam, cocoyam, maize, legumes and vegetables. There were very few cassava sole crops grown during the survey period. In fields where cassava was grown in combination with yam and other crops, yams were considered the main crop. Such cropping is referred to in this study as a yam-based crop mixture (YBCM). Where there was no yam, cassava was considered the main crop and the cropping was referred to as a cassava-based crop mixture (CBCM). Rice was grown as a sole crop in the area.

There were more and larger fields where cassava was grown in combination with yams and other crops (YBCM) than cassava fields without yams (CBCM). On average, a household cultivated four YBCM fields, one CBCM and two rice fields. Though cassava was grown in YBCM, the cropping densities of it and the other intercrops in such fields were generally very low. Cropping density and output of cassava were significantly higher in CBCM than in YBCM (Okorji and Obiechina 1985). Greater emphasis is therefore given in this paper to CBCM because such fields give a better representation of cassava production in the area.

Land preparation for cassava production started early in the year, but planting began mostly in March and April. Cassava stems were planted on mounds with an average of about four stands per mound in mixed-crop fields, and between five and six stands in the few cassava sole-crop fields; no defined planting distance between crop stands was maintained in the fields. The intercrops in CBCM fields (maize, cocoyams, legumes and vegetables) were planted three to four weeks later, when the cassava had sprouted, and they were also staggered on the mounds with no precise planting pattern. This system differs from that of other areas of southeastern Nigeria, where cassava is grown either on ridges or on flat soil, with fairly uniform spacing. In general, not much attention was given to cropping patterns and other management practices adopted for cassava production in the study area, more for sociocultural than for economic reasons.

The pattern of resource allocation among crops was such that CBCM was least favoured. Table 1 shows resource allocation among crops by household for the 1981/82 and 1983/84 seasons. For each of the two periods surveyed, less than 10 percent of farm land was devoted to CBCM. Uplands and swamp land were available in the study area. Rice and most YBCM fields were located in swamp land while CBCM fields were limited to uplands. Swamp land has relatively high fertility because it receives alluvial deposits from river floods. Bachmann (1981) estimated a yield of 7.6 tons per hectare (t/ha) in swamp land and 4.2 t/ha in upland fields for yams, and 11.6 t/ha in swamp and 9.5 t/ha in upland fields for cassava in Nteje, Anambra State. Thus, not only was the smallest area of farm land allocated to production of CBCM relative to other crops but it was usually of poor-quality soil. The allocation of labor and capital resources to CBCM followed a similar pattern to land allocation in the study area. This pattern of resource allocation to cassava determined cassava production trends fairly accurately since it related to the value set on cassava by the people.

Productivity of cassava enterprise

Table 2 shows a summary of cost-return analyses for YBCM, CBCM and rice enterprises for the survey period. CBCM recorded the highest net return per hectare for the two periods compared with other crops in the study area. Resource inputs (land, labor and cash) were most productive in CBCM compared with other crops, suggesting that farmers could perhaps optimize farm returns if the required attention were given to CBCM.

A comparison of the cost and return involved in the production of CBCM and sole crop cassava showed that although the output of cassava per hectare was higher in the cassava sole crop, gross and net returns were higher in CBCM. This partly explains why mixed cropping is preferred to sole cropping for cassava production in the area. It is also possible that mixed cropping is preferred because it provides an insurance against loss of heavy capital and labor input if the the main crop fails (Norman 1971; Nweke 1980). The traditional system of allocating a comparatively small proportion of household land to women also contributes to the dominance of CBCM over cassava sole crops in the study area. At present, land does not constitute a major constraint on farming in the area, but the amount generally devoted to women's crops, of which cassava is the most important, is extremely limited. This stereotyping of food crops in the study area according to sex thus influences the pattern of resource allocation and is an important element to consider in the introduction of modern crop production technology.

Trends in Cassava Production in the Study Area

Supply has increasingly lagged behind demand for food products, so prices for food products have risen in the study area. For example, price increases of 50 percent were recorded for vegetables, cocoyams and maize; 67 percent for legumes; 75 percent for cassava; 14 percent for rice; and 110 percent for yams in 1983/84, compared with their 1981/82 average market values. In general, the size of farm holding cultivated per household increased mainly because of the increase in demand for and prices of food products. These increases did not, however, achieve the desired impact on the pattern of resource allocation to cassava in the study area during the survey period. Contrary to expectations, the land area allocated to CBCM decreased, while that for YBCM and rice increased, even though resource inputs proved most productive in CBCM.

Efforts made by farmers to increase cassava output centered largely on increased cropping density and the use of improved cassava varieties (see table 3). The extent to which either of these contributed to the increased yield recorded in this study was, however, not determined. Improved cassava varieties constituted between 16 and 20 percent of the cassava stems used by the household. Many farmers still have no access to improved cassava varieties, mainly because the quantity provided by the State Ministry of Agriculture and Natural Resources was grossly inadequate, and the varieties available at local markets were sold at exorbitant prices.

The bulk of the marketed cassava was sold as tubers in spite of the higher prices per unit weight equivalent of such processed products as gari. The processing of cassava is yet to be popularized in the study area. The higher return from gari than from cassava tubers is, however, inducing more farmers to embark on gari processing which until recently was exclusively undertaken by middlemen from the urban centers. An increased output of cassava will increase the prospects for gari and to some extent starch, since most of the cassava tubers surplus to household requirements would be processed into these forms. Consumption of gari, for example, is not common among rural people, who prefer cassava fufu, tapioca and cassava flour meals in addition to yams.

Although a higher percentage increase was recorded per unit price of yams, it seemed that more than a proportionate amount of household farm resources was allocated to this crop. Given that less than 20 percent of the total yam output was sold on average per household, the preference given to yams a had negligible impact on improving farmers' economic position; about 40 percent of the total output of yam was consumed in the home, 30 percent kept for replanting, and about 10 percent for use in cultural celebrations and for gifts. This is even more apparent when it is realized that the cropping densities and hence output of the intercrops in YBCM were restricted in order to minimize competition with yams, the man's crop, even though relatively large proportions of the total intercrop output were marketed by the household. This situation becomes difficult to justify, considering that such cassava products as gari and starch recorded more than a 150 percent rise in unit prices (see table 4).

Implications for farmers

Increased cassava output will result in increased sales and revenue for the household. At present cassava output per household in the study area is limited by the constraints imposed on the resource allocation to CBCM from which about 92 percent of the total cassava output/ha is derived. Revenue from cassava and hence farmers' welfare can be improved in the study area, mainly by the mass adoption of high-yielding varieties and improved cultural practices (Gebremeskel et al. 1986). The present yield of about 7.15 t/ha is significantly low (see table 5) compared with yields of between 13 to 22 t/ha for different IITA cassava varieties (Ekpere et al. 1986). Increased cassava output will be achieved when farmers in the area are encouraged to apply fertilizer and other agrochemicals to cassava fields; most farmers, for instance, did not apply fertilizer to their yam and cassava fields because they believed that such chemicals were harmful to root and tuber crops and might also be so for human beings who eat them.

Increased revenue from cassava products may consequently influence the pattern of resource allocation so that a household may decide to allocate more land and other resources to cassava cropping. This increased revenue may, however, not be sustained since increased output and supply may eventually bring the price of cassava down. Though farmers regulate the supply of cassava to some extent by harvesting at need, the fields will be required for subsequent cultivation and they will be compelled to harvest and sell their cassava; moreover, the opportunity cost of resources invested in unharvested cassava may be higher than the extra revenue from delayed sales.

The welfare of cassava producers in the study area could be sustained and possibly improved by developing the different cassava products. The provision of cassava-processing facilities should be embodied in any cassava production package aimed at improving farmers' welfare; processing will improve the quality, storability and value of cassava products. The establishment of agro-industries using cassava products as raw materials will lead to increased cassava production and returns for the farmers.

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Table 1. Resource allocation among crops by household for one survey period

Resource	1981/82			1983/84		
	YBCM	CBCM	Rice	YBCM	CBCM	Rice
Land (ha)	2.54	0.31	0.48	3.12	0.21	0.69
Labor (days)	432	33	118	524	24	160
Cash cost (₦)	702.79	48.35	188.59	1145.27	46.45	305.60

Table 2. Summary of cost-return analyses for YBCM, CBCM and rice for the survey period

	1981/82			1983/84		
	YBCM	CBCM	Rice	YBCM	CBCM	Rice
Gross return/ha (₦)	853.00	711.00	1261.00	1810.75	1487.59	1608.60
Total cost/ha (₦)	839.30	389.25	972.60	1459.14	515.35	979.24
Net return/ha (₦)	13.70	321.75	288.40	351.61	972.24	629.36
Gross return/man-day (₦)	5.02	6.20	5.12	8.95	13.77	9.62
Net return/₦ cash outlay	0.05	2.06	0.73	0.96	4.39	1.42
Gross return/total cost	1.02	1.83	1.30	1.24	2.89	1.64
Cash cost/ha	276.69	155.96	392.90	367.07	221.19	442.90

Table 3. Input-output relationships for cassava produced per household during the survey period, with estimates for the 1986/87 farming season

Crop	1981/82		1983/84		1986/87	
	Input (kg/ha	Output kg/ha)	Input (kg/ha)	Output (kg/ha)	Input (kg/ha)	Output* (kg/ha)
YBCM	22.8	578.00 (1,468.12)	26.5	660.60 (2,061.07)	34.3	864.40 (2,743.80)
CBCM	214.0	6,042.00 (1,873.02)	265.8	7,152.50 (1,502.03)	289.6	7,993.00 (1,518.70)
Total output		(3,341.14)		(3,563.10)		(4,267.50)

Note: Figures in parentheses represent realized output from land areacultivated.
* Average values for output-input ratios for 1981/82 and 1983/84 seasons were used for estimation; input values are known but survey farmers are yet to harvest for the season. Land area allocated to YBCM was 3.18ha; CBCM 0.19ha; and rice 0.84ha in 1986/87.

Table 4. Average unit prices of cassava products during the survey period

Cassava	Unit price (₦)kg)		
	1981/82	1983/84	1985/86
Tuber	0.08	0.14	0.16
"Akpu"	0.71	0.88	1.01
Gari	0.26	0.66	0.69
Starch	0.20	0.52	0.53

Note: Extracted from on-going study on regional demand for yam and other food products in southeastern Nigeria (including Abakaliki)—IDRC supported project.

Table 5. Output and returns/ha of CBCM enterprise during the survey period

Product	1981/82			1983/84		
	Unit price (₦)	Quantity (kg)	Value (₦)	Unit price (₦)	Quantity (kg)	Value (₦)
Cassava	0.08	6,042	483.00	0.14	7,152.50	1,001.35
Cocoyam	0.08	1,009	80.70	0.12	1,227.6	147.31
Maize	0.08	218	17.50	0.12	290.9	34.91
Legumes	0.36	216	77.80	0.60	288.6	173.16
Vegetables	0.60	86	51.60	0.90	145.4	130.80
Total			711.00			1,487.59

ON-FARM PERFORMANCE OF IMPROVED CASSAVA VARIETIES IN IMO STATE, NIGERIA

P.S.O. Okoli

Imo State is one of the many states in Nigeria currently implementing an Agricultural Development Project (ADP), funded by the State Government, the Federal Government of Nigeria, and the World Bank. A major objective of the project is to increase food-crop production and the incomes of smallholder farmers and fishermen. One strategy is the creation of a reorganized and revitalized extension service managed according to the principles of the Training and Visit (T&V) extension system, a central feature of which is two-way linkage with research. Extension agents report farmers' problems to researchers. Research, in turn, provides production recommendations (such as improved crop varieties) to be adapted by extension workers, as necessary, to make the best use of the specific local environment and farmers' resources, thus responding to problems put forward by the extension workers (Benor and Baxter 1984).

Cassava (*Manihot esculenta* Crantz) is one of the main staple food crops of Imo State on which the project is expected to have an impact. Project initiatives would include the promotion and multiplication of the improved varieties. A number of disease-resistant or tolerant varieties have been released by IITA and the National Root Crops Research Institute (NRCRI), Umudike, in the last ten years. These improved varieties have been evaluated, and trials at several locations confirm that they give consistently better yields, better resistance to pests and diseases, and greater response to crop inputs than the local varieties (World Bank 1985). The performance of the improved cassava varieties, however, varied depending on the location, and most of the trials were conducted on-station (NRCRI; IITA 1983). In order to evaluate the performance of the improved varieties at the farm level, trials were commenced in Imo State in 1984 by the On-farm Adaptive Research (OFAR) team in the state, comprising staff of NRCRI, Imo ADP and the Federal Agricultural Co-ordinating Unit (FACU). The objectives of two of the trials reported here are:

Trial I: (a) to compare the yields of some improved cassava cultivars when intercropped with maize by farmers under their conditions;

(b) to determine the acceptability of the improved varieties to farmers.

Trial II: to evaluate, on farm, the current recommended and traditional cassava/maize packages.

Materials and methods

The studies were undertaken in 1984 at Bende, Olokoro/Oboro and Uzuakoli villages of Umuahia Extension Zone of Imo State. The rainfall pattern in the area (as recorded by the NRCRI Umudike Station which covers the area) shows a bimodal character with two distinct growing seasons (April to August and September to November). The total annual rainfall varies from 1,500mm to 2,700mm. The soils in the three locations are all ultisols. The soils in Bende and Uzuakoli belong to the Bende-Ameke Association: red and brown soils derived from sandstones and shales and formed where shales intercalate with sand, and the topography is rolling. At the uplands, concretionary gravel may be formed (Oputa et al. 1983). The Olokoro soil belongs to the Amakama-Oji-Oguta Association: deep, porous brown to reddish-brown soils derived from sandy deposits; on the summits of low mounds and the sides of gentle slopes, the soils are imperfectly drained.

Trial I

The farmer-managed trial (Odurukwe et al. 1986) was set up in a randomized block design with five replications at each location. Plot size was 5m x 5m. Four improved cassava cultivars (TMS 30211, TMS 30572, TMS 30555) and an Umudike Selection (U/41044) were tested in the three locations. Cassava was planted on 1-m ridges or mounds, giving a population of 40,000 plants per hectare between the second and third week of May 1984. Compound fertilizer (400 kg/ha of NPK 15-15-15) was applied by side placement at 3-4 weeks after planting and weeds were manually controlled. Cassava was harvested in May 1985.

Trial II

The improved practice consisted of (a) planting in 1-m straight mounds, ridges, or flat; (b) use of improved cassava varieties (TMS 30572, 30211, 30555) at 10,000 plants/ha and maize at 40,000 plants/ha; (c) application of fertilizer (NPK 15-15-15) at the rate of 400 kg/ha at three to four weeks after planting (Anuebunwa et al. 1986). The traditional practice consisted of (1) planting in mounds or flat in a disorderly or haphazard arrangement (2) seeding 3-5 maize grains per hole and 2-4 cassava cuttings per mound or spot; and (3) no fertilizer application. The trial was set up in a randomized block design with five replications at each location.

Results

Trial I

TMS 30572 outyielded the other cultivars on average (Table 1). The highest yields were obtained from Uzuakoli, the lowest from Olokoro/Oboro. TMS 30572 outyielded TMS 30211 and TMS 30555 by an average of 20 percent across locations and out-yielded U/41044 by an average of 30 percent across locations. Participating farmers also rated TMS 30572 as the best cultivar on the bases of growth pattern, tuber yield, and production of planting materials.

Trial II

Table 2 shows that the improved package outyielded the traditional package under the experimental conditions.

Discussion

The results show that improved cassava varieties outyielded the local varieties at the farm level. They also indicate the likely site specificity of the improved cultivars and the need for adequate on-farm testing before recommendations are made. Despite the superior yield of the improved varieties over that of local varieties, farmers have been slow to adopt them. This reluctance has been attributed to several factors (World Bank 1985), such as:

(a) unfamiliarity—most farmers have never had the opportunity to try them and therefore do not know whether they will like them or not;

(b) unavailability of planting material;

(c) their high moisture content, which leads to poor net yield;

(d) the relatively unknown processing qualities (for gari and fufu) of the improved varieties compared with the known qualities of the local varieties.

On-station data exist to show that the gari and fufu qualities of improved varieties are not inferior to those of local varieties (NRCRI) but no such empirical evidence is known at the farm level. However, farmers who witnessed the performance of improved varieties in 1986 and 1987, bad years for cassava mosaic and spider mite, acknowledge the superiority of the improved varieties with the possible exception of the U/41044. In 1986 Imo ADP began testing the improved cassava varieties with over 300 farmers. The project has also established in 1987 over 20,000 (5m x 5m) demonstration or small plot adoption trials (SPAT) on improved cassava varieties. These activities are likely to answer the questions of overall superiority of and the uptake of improved varieties.

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Table 1. Yields (t/ha) of cassava cultivars and maize as influenced by intercropping with egusi on farmers' fields (1984/85)

Cassava	Location							
	Bende		Olokoro/Oboro		Uzuakoli		Mean	
	Cas-sava	Maize	Cas-sava	Maize	Cas-sava	Maize	Cas-sava	Maize
TMS 30211	14.4	2.09	11.9	3.30	16.4	2.93	14.9	2.77
TMS 30572	18.6	1.74	14.1	4.33	23.3	3.01	18.7	3.03
TMS 30555	15.5	1.76	9.9	2.26	26.7	3.44	15.4	2.49
U/41044	12.7	1.50	11.8	3.32	14.6	2.87	13.0	2.56
Means	15.3	1.77	12.4	3.30	18.8	3.06	15.5	2.71

1. LSD (p = 0.05 level):	Cassava yield	Maize yield
a) Comparisons among locations:	2.4 t/ha	0.37 t/ha
b) Comparisons among varieties:	3.0 t/ha	not significant
c) Coefficient of variation:	25.97%	31.58 %

Source: Odurukwe, Unamma and Okoli, 1986

Table 2. Biological yields of improved and traditional cassava/maize intercrop production technologies, Umuahia ISADAP Area, 1984/85

Location	Technology	Crop yields			
		Cassava		Maize	
		Tuber (t/ha)	Stands at harv. (no./ha)	Tuber (t/ha)	Stands at harv. (no./ha)
Bende	**Improved**				
	TMS 30572	17.3	8,800	—	—
	i.c.w.				
	FARZ 34	—	—	4.4	19,000
	Traditional				
	Okporo Oji	13.9	20,000	—	—
	i.c.w.				
	Okabende	—	—	1.8	4,106
Olokoro/Oboro	**Improved**				
	TMS 30211	7.4	9,000	—	—
	i.c.w.				
	FARZ 34	—	—	No yield	No yield
	Traditional				
	Nwugo	7.5	14,500	—	—
Uzuakoli	**Improved**				
	TMS 30555	6.6	4,000	—	—
	i.c.w.				
	FARZ 34	—	—	5.7	25,000
	Traditional				
	Iwapaya				
	i.c.w.	7.1	8,500	—	—
	Okabende	—	—	2.9	3,520

Source: Anuebenwa, Oputa and Unamma 1986

Session V

THE PERFORMANCE OF SIX CULTIVARS OF WHITE YAM DERIVED FROM THREE SOURCES AND EVALUATED ACROSS THREE ZONES IN SOUTHERN NIGERIA

C.L.A. Asadu, H.C. Ezumah, F.I. Nweke and F.O.R. Akamigbo

Abstract

Growers of yam demarcate certain areas as being suitable for yam culture and the factors responsible are suspected to relate to both prevailing soil and aerial environments. No empirical evidence to substantiate this suggestions has been documented.

Two popular cultivars were selected from each of the three major yam-growing zones in Nigeria: one in subhumid savanna (Zakibiam), one in hydromorphic and gravelly soil (Abakaliki) and one in riverine alluvial deposits along the river Niger (Atani). The yield of the six cultivars was evaluated across all three test sites using a split-split plot design with location (source), fertilizer and cultivars as the treatment factors.

The study showed that location, fertilizer, cultivar and location x cultivar interaction effects were highly significant. The mean yields indicated that Zakibiam was the best location for the production of virtually all the cultivars while Atani was the worst except for the cultivar Agatu (source: Zakibiam). Agatu is likely to be more tolerant to higher soil acidity and poorer aeration prevalent in Atani soils than other cultivars.

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The production of yams in the tropics is extremely important since they are essential in the dietary pattern of the people (Anazonwu-Bello 1977). Coursey (1967) and Onwuemem (1978) state that yams are second to cereals as the most important food crop in west Africa. According to Coursey (1971), the cultivation of *Dioscorea rotundata* in West Africa is indigenous and not known elsewhere except as a comparatively recent introduction.

Only 12 of the 600 identified species of *Dioscorea* have been found to possess edible tubers. The most popular edible species in the tropics according to Ene and Okoli (1985) are *Dioscorea rotundata/D. cayenensis* complex, *D. alata, D. dumentorum, D. bulbifera* and *D. trifida*. The most important species in the world and the most widely grown and eaten in West Africa is *Dioscorea rotundata* (Okonkwo 1985). This species is generally referred to as white yam.

The 1974 FAO report indicates that Nigeria products 15 million tons of yams annually from 1.4 million hectares. This value, according to the report, represents 81, 73.4 and 76.8 percent of yams produced in West Africa, Africa and the world respectively. However, it has been predicted by Olayide (1979) that based on the 1984-1985 production level, the projected demand for yams in the country would continuously outstrip projected supply by 2.868 million tons and 4.508 million tons during the 1989-1990 and 1994-1995 periods respectively. This excess demand calls for an increased production of yams in the country.

Efforts made so far toward yam improvement have not been successful because of such problems among others as flower abortion and narrow genetic diversity, (Coursey 1967; IITA 1972; Sadik 1977; Onwueme 1978; Hahn and Honzyo 1983; Miege and Lyonga 1982; Okonkwo 1985). The selection of cultivars suited to the various ecological zones in the country would offer a promising alternative for increasing yam production to meet the ever-increasing demands. This approach requires a comprehensive ecological characterization and classification as well as on-farm trials in various ecologies with the participation of local farmers.

Three ecological zones may be identified in southeastern Nigeria where yam cultivation is prominent. These zones are within the area designated as the "yam zone" in West Africa (Ene and Okoli). The zone stretches from the coast up to latitude 12°N. It coincides with the rainforest, wood savanna and the southern parts of the open savanna forest of Nigeria where total annual rainfall exceeds 800mm and rains last for four months.

Yam growers and consumers tend to associate their preference for different cultivars of yam with their sources. Hence they believe that the sources of the tubers have a significant influence on the quality of the yam tubers. In Anambra State, for instance, such place names as Zak, Adani, Onitsha and Abakaliki are known to be associated with the yams from the places and consequently they attract different prices in the market. Furthermore, such statements as "yams are not grown there, or that soil is not good for yams," or "yams from that place are not good for pounding, but are better eaten boiled" are often heard among yam farmers and consumers. These statements suggest that different yam cultivars may require specific environments for optimal performance both in terms of tuber yield and quality characteristics. Empirical data to substantiate these claims by yam farmers, marketers and consumers are lacking.

The objective of this study was to assess the performance of six popular cultivars of white yam derived from three sources across three locations in the major yam-growing areas of southeastern Nigeria.

Materials and methods

Selection of sites and cultivars

Three sites within the "yam zone" in southeastern Nigeria were selected for the trials. They include Zakibiam (lat. 7°27'N, long. 9°29'E) in the subhumid savanna area of Benue State; Abakaliki (lat. 6°25'N, long. 8°05'E) in the forest savanna ecotone of Anambra State and Atani (lat. 6°01'N, long. 6°44'E) in the riverine alluvial deposit along the River Niger Basin near Onitsha in Anambra State.

The two most popular cultivars of white yam were selected from each of the locations. All six cultivars were used for the trials in each of the test sites. The cultivars selected and their sources are shown in table 1.

Experimental design

A split-split plot design was used with location, fertilizer and cultivar as the treatment factors at three, two and six levels respectively. These trials were conducted under two sets of management regimes—one by the farmer and the other by the researcher. Three cultivars, Igun, Agatu and Aga, were used on the researchers' plots. The tuber of each cultivar was cut into three setts and each sett grown in each of the three test sites in order to allow for any variations that might occur in the tubers themselves. The farmers only showed interest in participating in the trials when they were promised whole tuber setts and then used such setts on their plots. However, the sett weights in each case were in the range 400-450g.

The participating farmers were allowed a free hand in carrying out all operations relating to sowing, weeding, fertilizer application, mulching and staking as they had been used to doing on their plots. On the researchers' plots these operations were carried out under the supervision of the researcher. All the setts were grown in conical mounds in each location, although the size of the mounds differed in each of the locations. Soils from the locations were examined and samples collected and analyzed for various physical and chemical properties that might affect yam performance. The yield parameters assessed included tuber length, girth and weight; leaf area index (LAI); leaf density (LD—total number of leaves/length of vine); and number of tubers per plant. Tuber yield was assessed in kilograms per plant as well as tons per hectare.

Table 1. Selected cultivars and their sources

Source	Cultivar
Abakaliki	Igun (Nwopoko) Nyeji (Okpebe)
Zakibiam	Agatu Gbango
Atani	Aga (Adaka) Ekpe

Results and discussion

The results of the statistical analyses on the preliminary trial in 1985 and the 1986 data (table 2) indicate that location and fertilizer effects are highly significant (P = 0.001) on the girth of tubers; number of tubers per plant; yield in kilograms per plant and tons per hectare; final vine weight; and density. Furthermore, fertilizer effect is significant (P = 0.05) on length of tubers and leaf area index. The cultivar has a significant effect (P = 0.05) on length and girth of tubers as well as on leaf density.

Location x cultivar interaction effects are highly significant (farmer-managed trial, FMT) on the length of tubers, and yield in kilograms per plant and tons per hectare. This interaction effect is also highly significant (researcher-managed trial, RMT) on the girth of tubers and weight of vines. Location x fertilizer and cultivar x fertilizer interaction effects are respectively significant (P = 0.05) and highly significant (P = 0.01) regarding girth of tubers and leaf density. Location x variety x fertilizer interaction effects are not significant except on the girth (FMT). The disparities in the results obtained from FMT and RMT in some parameters might be due to the type of setts used in each case. It has been shown that whole tuber setts perform better than cut setts (Onwueme 1973) and they are therefore likely to respond more to locational effects. The major reasons are that they sprout readily and are less prone to rotting since there are no cut surfaces.

The mean economic yields evaluated in terms of kilograms per plant and tons per hectare of harvested tubers (table 3) indicate that the best location for high yam production in southeastern Nigeria is Zakibiam. Abakaliki and Atani locations are similar.

The mean yields resulting from fertilizer treatment indicate that much higher yields are obtained in each location when fertilizer is applied. Though the reports on yam response to fertilizer application have been scarce and inconsistent (Juo 1985), the finding in this study shows that there is a highly significant increase in yield with fertilizer application. Obigbesan and Agboola (1978) have indicated that yams constitute a heavy drain on the land and pointed out that a liberal dressing of fertilizer is necessary for increased yields.

Apart from the generally low nutrient contents of the soils of the three zones, the constraints that are more severe in the Abakaliki and Atani locations compared with the Zakibiam location are: lower base status of the soils (higher acidity); lower amount of water released between field capacity and permanent wilting point (lower available water capacity, AWC); and relatively higher sodium adsorption ratio (results not presented) which are known to affect the other physical properties of soils.

The interaction effects of location and cultivar on the mean yields (table 4) suggest that the best cultivars for the Zakibiam location are Gbango/Aga (sources: Zakibiam/Atani) and the worst is Agatu (source: Zakibiam). The best cultivars for Abakaliki zone are Gbango/Ekpe (sources: Zakibiam/Atani) while Nyeji and Igun (source: Abakaliki) are the worst for Abakaliki. At Atani the best cultivars are Agatu/Nyeji (sources: Zakibiam/Abakaliki) and the worst are Igun and Gbango from Abakaliki and Zakibiam respectively. This finding suggests that the most productive yams in terms of tuber yields are not grown in the locations studied and opens the way to introducing exogenous varieties.

Summary and conclusion

An experiment set up in a split-split plot design was conducted in southeastern Nigeria to evaluate the performance of six cultivars of while yam (*Dioscorea rotundata*) derived from three sources. The trials were conducted in three sites with farmers from each site participating. The study revealed that location, fertilizer, cultivar and location x cultivar interaction effects were significant. Fertilizer application helped to boost yield in all the locations. Yams at present grown in some major yam-growing areas in southeastern Nigeria are not necessarily the highest yielding in these environments. Farmers in the test sites have already started asking for cultivars that were found to perform better in their respective locations.

Table 2. Statistical results on the yield parameters

Yield parameter	Sources of variation	Probability level FMT	Probability level RMT
1. Length of tubers at harvest	Location x fertilizer	***	*
	Cultivar	***	*
	Location x cultivar	***	NS
2. Girth of tubers at harvest	Location	***	**
	Fertilizer	***	**
	Cultivar	*	***
	Location x cultivar	*	***
	Location x fertilizer	NS	*
	Location x cultivar x fertilizer	***	NS
3. Yield (kg/plant)	Location	***	**
	Fertilizer	***	***
	Cultivar	NS	NS
	Location x cultivar	***	NS
4. Yield (ts/ha)	Location	***	***
	Fertilizer	***	***
	Location x cultivar	***	NS
	Cultivar	NS	NS
	Location x fertilizer	NS	NS
5. No. of tubers/plant	Location	ND	***
	Fertilizer	ND	***
	Cultivar	ND	***
6. Dry weight of vine/plant (g)	Location	ND	***
	Fertilizer	ND	***
	Cultivar	ND	NS
	Location x cultivar	ND	***
7. Leaf area index (LAI)	Fertilizer	ND	***
	Cultivar x fertilizer	ND	**
8. Leaf density (LD)	Location	ND	***
	Fertilizer	ND	*
	Cultivar	ND	*

Notes: NS,*,**,***, Not significant, significant at 0.5, 0.01, <0.001 levels of probability respectively; FMT, RMT, farmer- and researcher-managed trials repectively; ND, not determined.

Table 3(a). Summary of treatment effects on yam tuber yields averaged over fertilizer treatments and yam varieties

	Tons/ha	
Zakibiam	14.40	10.95
Abakaliki	7.08	6.07
Atani	9.10	5.97
S.E ±	0.532	0.604
CV %	36.15	38.58
LSD 0.05	1.503	1.734

Table 3(b). Yield averaged over location (source) and cultivar

Fertilizer	Yield (tons/ha)	
	FMT	RMT
NF	8.17	5.93
F	12.22	9.40
S.E. ±	0.264	0.412
C.V %	12.70	8.56
LSD 0.05	0.786	1.316

Table 4. Location x cultivar interaction effects on mean tuber yield (FMT)

	Tons/ha					
Zakibiam	14.70	8.57	16.30	13.06	18.62	15.13
Abakaliki	6.33	7.69	7.74	6.35	6.55	7.83
Atani	7.65	10.85	8.86	10.02	7.65	9.28
LSD 0.05 =	5.203					
Means	9.56	9.04	10.97	9.81	10.94	10.75
SE ±	4.50	1.63	4.65	3.36	6.67	3.86

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MAIZE-GROUNDNUT ROTATION IN LOWLAND SOUTHWESTERN CAMEROON

F.C. Poubom (née Ngundam)

Groundnuts may have substantial beneficial effects on immediate subsequent non-legume crops, which may be ascribed to soil nitrogen differences. In Australia, Phillip and Norman (1961) reported yields of grain and straw of sorghumwhich were 77 percent and 56 percent higher for sorghum after groundnut than after sorghum, and the grain nitrogen was almost double. Nitrogen level of pearl millet was also found to be 50 percent higher after groundnut, (Phillip and Norman 1962). In Nigeria, the average yields of maize after seven years of continuous sorghum, cotton or groundnut, were 2,503, 3,568 and 4,478 kg/ha respectively (Lombin 1981). The same trend was observed in central Sudan when Gerakis and Tsangarakis (1969), reported poorer yields of sorghum following sorghum than groundnuts.

In the lowland humid areas of southwestern Cameroon, maize-groundnut-maize rotations are a common farming practice. Though farmers grow groundnuts in the first season (March-July), they are more popular in the second season (September-December). While groundnuts are mostly grown in association with maize, cassava, and egusi melon in the first season, they are more commonly found as a monocrop in the second season. They may also be intercropped with maize in this season, but at fairly low densities. The experiment therefore aimed to determine the residual effect of nitrogen from groundnuts on subsequent maize grain yields. If maize grown after groundnuts can benefit from residual nitrogen, then this would help the low-resource farmers (typical of the area) to benefit from the production of higher-yielding improved IRA maize varieties that are ready to be tested on their fields. These maize varieties are being improved under fairly low levels of fertilizer.

Materials and methods

The trial was carried out for three cycles, first season 1986, second season 1986 and first season 1987, at the IRA Ekona experimental station at Yoke, 100m above sea level. Soils are sandy in texture and the experimental plot prior to planting contained 1.40 percent organic carbon, 0.10 percent total nitrogen, 16.00 ppm of available phosphorus (Bray-2), 2.58 meq/100g of exchangeable cations and had a pH of 6.00 (Kcl; 1:2.5) (table 1).

The treatment factors studied included maize at three levels of fertilizer (0, 60, 120 kg/ha) for the first season and groundnut at two levels of fertilizer (0 and 30 kg/ha). During the second season the treatment was groundnut for all plots at zero nitrogen. At the third cycle all plots were planted to maize at three levels of nitrogen 0, 60 and 120 kg/ha (table 2).

Table 1. Chemical characteristics of soil at inception of experiment

Elements	Amounts in soil
Nitrogen (%)	0.10
Organic carbon (%)	1.40
pH	6.0
Exchangeable Ca	2.58
Exchangeable K	—
Available Bray-1, P	16

Maize plots were given a uniform dose of phosphorus at 60 kg/ha, for both first and third seasons. Fertilizer applications was split: half broadcast at planting and the other half side-dressed at five weeks. The experiment was a randomized complete block design with three replications. Randomization of treatments within blocks was carried out at first cycle and fixed for subsequent seasons. Plot size was 6m x 6m, and the maize was planted in 75-cm rows to give a plant population of about 53,333 plants per hectare. Groundnut was put in 40-cm rows at 20-cm intervals. Both crops were planted on 12 April and harvesting took place 109 days afterwards.

Table 2. Treatments and arrangement of maize/groundnut sequential cropping in Cameroon

	First season	Second season	Third season
1.	Maize 60kg/N/ha	Groundnut 0kg/N/ha	Maize 60 kg/N/ha
2.	Maize 60 kg/N/ha	"	Maize 120 kg/N/ha
3.	Maize 120 kg/N/ha	"	Maize 60 kg/N/ha
4.	Maize 120 kg/N/ha	"	Maize 120 kg/N/ha
5.	Maize 0 kg/N/ha	"	Maize 60 kg/N/ha
6.	Maize 0 kg/N/ha	"	Maize 120 kg/N/ha
7.	Groundnuts 0 kg/N/ha	"	Maize 0 kg/N/ha
8.	Groundnuts 0 kg/N/ha	"	Maize 60 kg/N/ha
9.	Groundnuts 0 kg/N/ha	"	Maize 120 kg/N/ha
10.	Groundnuts 30 kg/N/ha	"	Maize 0 kg/N/ha
11.	Groundnuts 30 kg/N/ha	"	Maize 60 kg/N/ha
12.	Groundnuts 30 kg/N/ha	"	Maize 120 kg/N/ha

Note: the experiment was set up in a randomized plot design with three replications.

The mode of cultivation was conventional (plowed and harrowed). A pre-emergent herbicide (Atrazine at the rate of 5-6 l/ha) was used to control weeds. Later on at five weeks after planting an additional hand-weeding operation was carried out. Maize was planted on flats and later moulded at five weeks while groundnuts remained on flats. Soil samples were taken at the 0-15cm level before and after each planting. All plot yields are expressed on a per-hectare basis.

Results and discussion

The average yields of dried grain maize and groundnuts for all three seasons are presented in tables 3 and 4. The analysis of variance was conducted separately for maize and groundnuts according to treatment arrangement during the three seasons.

For the groundnut-groundnut-maize sequence (table 3), the effect of nitrogen (0. 30 kg/ha during the first season with average yields of 1,320 and 1,325 kg/ha was not significant. Thus, there was no difference in groundnut grain yields for plots with and without fertilizer.

During the second season, there was no significant residual effect of first-season nitrogen on groundnuts on second-season groundnut yields, while for the third season, nitrogen applied to groundnuts during the first season followed by second-season groundnut did not leave any residual nitrogen for subsequent third-season maize.

However, there was a 24 percent (254 kg/ha) higher groundnut yield during the first season than during the second season.

In the maize-groundnut-maize sequence, during the first season, without nitrogen fertilizer, maize yields were lower than when nitrogen was applied. However, there was no significant difference in maize grain yields at nitrogen rates of 60 kg/ha compared with 120 kg/ha (table 4).

In the second season, there was no significant difference in yields in systems where groundnuts followed maize even at zero level of fertilizer during the first season compared with 60 and 120 kg/ha of nitrogen (table 4). However, yields of groundnuts from systems in which nitrogen fertilizer was applied to the preceding maize crop were generally higher by 200-400 kg/ha than yields from unfertilized plots. This may be due to the supplemental phosphorus given to the preceding maize crop.

The third-season maize grain yields from maize 0, 60, 120 kg/ha of nitrogen followed by groundnuts at 0 kg/ha and maize at 60 and 120 kg/ha nitrogen were not statistically different. However, there was an abnormal situation in which yields of maize were lower at 120, 0, 60 kg/ha nitrogen followed by nitrogen at 60, 0, 60 kg/ha (treatment 5, table 4). This might have been due to heavy damage by grasscutters during the growing season.

In conclusion, based on biological yields only, a low-resource farmer may save on nitrogen needed to grow maize by adopting systems 1 or 5 in table 4 (i.e. 60, 0, 60 or 0, 0, 60 kg/ha of nitrogen respectively). Increases of about 1,300 kg/ha (37 percent) of maize during the third season were realized in a maize-groundnut-maize system. Also, it would seem that in a system where groundnuts follow groundnuts followed by maize, there is no need to apply fertilizer since no significant differences exist between treatment means.

Table 3. Grain yields of groundnut and maize as affected by nitrogen rates and preceding crop

	Treatments	Groundnut (kg/ha)		Maize (kg/ha)
		First season	Second season	Third season
7.	G(0) fb G(0) fb M(0)	1,103	1,167	3,883
8.	G(0) fb G(0) fb M(60)	1,707	1,043	4,917
9.	G(0) fb G(0) fb M(120)	1,150	947	5,703
10.	G(30) fb G(0) fb M(0)	927	1,303	4,053
11.	G(30) fb G(0) fb M(60)	13.27	1,083	4,083
12.	G(30) fb G(0) fb M(120)	1,720	867	4,577
	LSD 0.05	76	756	2,613
	CV %	23.9	38.8	31.6
	Mean	,322	1,068	4,536
		(24% (252 kg/ha)		

Notes: G—Groundnut; M—Maize; fb—followed by; figures in brackets indicate levels of nitrogen in kg/ha

Table 4. Maize grain yields (kg/ha) as affected by N rates and season

		Maize (kg/ha)	Groundnut (kg/ha)	Maize (kg/ha)
		First season	Second season	Third season
1.	M(60) fb G(0) fbM(60)	3,987	1,690	5,037
2.	M(60) fbG(0) fb M(120)	3,843	1,557	5,930
3.	M(120) fb G(0) fb M(60)	4,757	1,440	3,997
4.	M(120) fb G(0) fb M(120)	4,027	1,542.4	5,967
5.	M(0) fb G(0) fb M(60)	2,547	1,247	4,337
6.	M(0) fb G(0) fb M(120)	2,497	1,243	4,689
	LSD 0.05	1,099	523	1,661
	CV %	18.2	24.9	20.1
	Mean	3,554	1,239	4,872

Notes: G—Groundnut; M—Maize; fb—followed by; figures in brackets indicate levels of nitrogen in kg/ha

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EFFECT OF FERTILIZER AND TIME OF INTERPLANTING MAIZE ON THE PERFORMANCE OF A YAM-MAIZE INTERCROP

R.P.A. Unamma, G.C. Orkwor and M. Ibedu

Abstract

This experiment was set up in 1986 at the National Root Crops Research Institute's farm, on a sandy loam soil, under tropical rainforest conditions. The trial evaluated the productivity of a yam/maize intercrop as influenced by times (0, 21, or 42 days after planting yam [dap]) of introducing the maize (*Zea mays* cv. FARZ 7) into yam (*Dioscorea rotundata* cvs. Nwopoko and Agammiri) and applying fertilizer (15-15-15 NPK, at 400 kg/ha) 21 dap.

With the Nwopoko yam cultivar, the optimum time for introducing the maize component into the mixture was at 42 dap with no fertilizer. This gave the best yield (₦5651), compared with ₦3976 obtained from the mixture when the maize was introduced at 28 dap or ₦2975 obtained when the maize was planted at the same time with no fertilizer. Using fertilizer, the optimum time to introduce the maize into the Nwopoko plot was simultaneously with the yams.

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Interplanting maize at the same time as the Nwopoko yam with fertilizer gave a monetary yield (₦5,172) comparable to that of the crop mixture in which maize was introduced at 42 dap without fertilizer, and significantly different from all the other monetary yields which ranged from ₦2,975 to ₦4,934.

For the Agammiri based mixture, the optimum time to introduce the maize component was at 42 dap whether fertilizer was applied or not. At this time the monetary yield of the mixture was ₦7,193 without fertilizer and ₦8,618 with fertilizer.

Under intercrop conditions and with the same management practices, the Agammiri white yam cultivar outyielded its Nwopoko counterpart. Yams mix-cropped with maize is one of the commonest practices employed in the southeastern, tropical rainforest zone of Nigeria. The practice is one of the cropping patterns the farmers use to tide over the "hunger period" (June-July) of the cropping season when most of the last season's stored seeds have been planted and little or nothing is left for food, since most of the other crops (except cassava) are immature in the field (Unamma et al. 1985). Most parts of this agro-ecological zone have limited arable lands—the majority of small-scale farmers have small fragments (0.5-1.5ha) of arable land. Consequently it is difficult to get rural farmers to embark on sole cropping since they tend to make as much use as possible of whatever land is available.

The farmers generally used the local maize variety (either Okabende or Okaezemmanu). These maize varieties are low yielding (0.5-0.8 t/ha). It is necessary to evaluate to what extent some of the improved maize varieties can fit into the farmers' mixed-crop systems for optimum productivity of the mixtures and the optimum time to introduce them.

The objective of this study was to evaluate the productivity of a yam-maize intercrop as influenced by times [0, 21, and 42 days after planting the yam (dap)] of introducing the maize (*Zea mays* cv FARZ 7] into yam (*Dioscorea rotundata* cvs. Nwopoko and Agammiri) and applying fertilizer 15-15-15 NPK at 400 kg/ha 21 dap.

Materials and methods

The experiment was conducted in the1986/87 cropping season, and was located on acid sandy loam soils at the National Root Crops Research Institute's main research farm in the tropical rainforest zone of Nigeria. The site carried soybean and cowpea intercropped with maize in 1983 before it was left under bush (*Panicum maximum* and *Chromolaena odorata*) fallow for two years. The site was plowed, harrowed and formed into ridges 100cm apart.

Yam was planted the same day in all the plots in the middle of April 1986. The introduction of the maize component was carried out at 0, 21 and 42 dap. Setts of the yams, each weighing about 150g, were planted one sett per hole at 100cm apart (10,000/ha) along the crests of the ridges. Maize at three seeds per hole was also planted 100cm apart but on both sides of the ridges opposite another stand (double row) and between two yam stands (with 50cm between yam and maize stands).

The maize was thinned and/or supplied to 2 plants/stand 14 dap, while the yam component was supplied at 21 dap.

The yam vines were trained at the rate of two opposite stands from two adjacent ridges per stake of about 2.5m long above the ground surface.

Fertilizer (15-15-15 NPK) was side-drilled along the ridges to all the plots at 400 kg/ha 56 dap. The sole components of each of the two crops in the mixture also received fertilizer and were included as treatments to facilitate evaluation of the land equivalent ratio (LER), for the various combinations at the same management level.

Each of the crop combinations was grown either with or without fertilizer. Maize was harvested at 112 and yams at 224 dap. At harvests, yields were measured for the crops in the middle five ridges, each 4m long excluding the peripheral stands, and were converted to a per-hectare basis for meaningful comparisons.

LER was used to evaluate the effects of intercropping on the crop mixture with fertilizer. A common unit was obtained for the fresh tuber yield of yam, and dry maize grain (14 percent moisture content) by converting them to their respective monetary values as at the nearest market near the time of harvest of the respective crops in the mixture. These values were used to compare the results of the treatment means on a per-hectare basis.

The treatments were arranged in a randomized complete block design replicated three times. Duncan's new Multiple Range Test was used to compare the mean values of treatments.

Results

Table 1 suggests that when using the Nwopoko white yam cultivar, the best time to introduce the maize component into the crop mixture was at 42 dap when fertilizer was not applied. When fertilizer was used the best time to introduce the maize was at planting time with the yams.

On the other hand, when the Agammiri white yam cultivar was used, the best time to introduce the maize component was at 42 dap whether fertilizer was applied or not.

Calculating the LER values for the Nwopoko-maize and Agammiri-maize intercrops, based on their respective highest monetized yield values, both cultivars gave about the same LER, of 1.148 and 1.164 respectively.

In all cases (except when maize was introduced into Agammiri at 42 dap) the sole Agammiri component significantly outyielded all the other yams grown in any of the combinations. The Nwopoko appears to be more sensitive to intercropping with maize than the Agammiri cv. The maize component appears to be less depressed by the intercropped yam cultivars.

Discussion

Only the Agammiri-maize intercrop gave as much monetized yield value as the sole Nwopoko or Agammiri. This was the case if the maize was introduced at 42 dap. From the results of this experiment, it appears to be more advisable to grow the yam as a sole crop if maximization of the yam tubers is the main production objective. However if for some other unquantifiable reasons the farmer has to grow the two crops in a mixture, it may be most advisable to introduce the maize component at 42 dap. At this time, the farmer would be obtaining the same yield as he would by growing them as a sole crop and still save 13-14 percent more land for other purposes. In this trial we have used what is considered the best selected yam cultivar and compared its performance with one of the Ohaji/Egbema (Imo State) cultivars (Unamma et al. 1985). The farmers of this area usually mix the yam and maize. The cultivar tolerated intercropping with maize. It was observed to be quite high yielding but rotted quickly, within two months of harvest.

The cultivar is being further investigated at Umudike to explore its potentials fully. The experiment is in its second year in the field. It is hoped that by the end of this cropping season we shall be in a position to provide more reliable recommendations on the yam-maize intercrop.

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Table 1. Yield of yam and maize as influenced by fertilizer and time of introducing the maize through yam-maize intercrop, Umudike, 1986

Crop combination	Time of introducing maize (days after planting yam [dap])	Fertilizer (15-15-15 NPK) rate (kg/ha)	Crop yields		
			Yam (₦/ha)	Maize (₦/ha)	Yam + Maize (₦/ha)[1]
Nwopoko-maize	0	0	3.6h[2]	1.42d	2,975
	21	0	5.8g	1.03e	3,976
	42	0	9.8bc	1.01e	5,651
	0	400	7.1ef	1.73c	5,172
	21	400	6.2fg	2.11b	4,906
	42	400	7.8de	0.75f	4,934
Sole Nwopoko	—	400	14.8a	—	8,436
Agammiri-maize	0	0	7.5def	1.72c	5,413
	21	0	9.0cd	1.06e	5,819
	42	0	11.9b	1.63f	7,193
	0	400	6.4efg	2.52a	5,286
	21	400	5.8g	2.15b	4,704
	42	400	14.4a	0.63f	8,618
Sole Agammiri	0	400	15.5a	—	8,835
Sole maize	0	400	—	2.59a	1,684

Notes: 1 Price of yam—₦570 per ton; price of maize—₦650 per ton..
2 In the same column, means followed by similar letters are not significantly different at 5% level of probability according to DNMRI.

METHODS FOR DETERMINING LEAF AREA IN SOME CROP PLANTS

O.T. Edje and D.S.O. Osiru

Yield is an important function of leaf area and there may be variations in leaf area due to differing treatments. For example, treatments may involve time of planting, plant density, rates of fertilizer, different crop varieties or genotype interaction in crops grown in association. Such treatments can cause variations in leaf area which in turn may lead to large variation in yields. Agronomists, crop physiologists and agricultural botanists often determine leaf area in an attempt to explain variations in crop growth, development and yield. This paper attempts to outline some of the methods most commonly used to determine leaf area in various crop plants.

Methods of determining leaf area

Several methods have been use to determine leaf area. These include:

- i. Cork borer or disc method.
- ii. Measurement of leaf length and width.
- iii. Planimeter.
- iv. Leaf area meter.
- v. Graph paper.
- vi. Tracing leaves on plain paper.
- vii. Regression method.

Cork borer or disc method

This is a destructive method used mostly for leaves that have irregular shapes. The following materials are needed.

a. **Plants.**

b. **Cork borer.** If none is available, cut a pipe with a thin wall, then sharpen it.

c. A **round file** for sharpening the cork borer.

d. A **pair of dividers** for determining the area of the cork borer.

e. A **ruler** for measuring the diameter of the cork borer.

f. **Envelopes or paper bags.** The envelopes (used ones will do) are for the leaf discs. If envelopes are not available, fold paper (including draft papers) into rectangles and staple them into envelopes.

g. An **oven** for drying the leaves.

h. Sensitive **scales** for determining the weight of the discs.

Method

a. *Leaf sampling*: Assume that the crop is cowpeas (*Vigna unguiculata* L. Walp) and that the net plot size is 1.0m long. The distance between rows is 0.75m. and the number of plants from the net plot is 80.

Because of time and labor constraint and the phenology of the crop, it is decided to take leaf discs from only three plants. Detach all the leaves (petioles and leaflets) from the plants. The petioles should be detached from the leaflets because the use of the cork borer method involves relating leaf weight to leaf area. The petiole weight is large relative to its area. Consequently, including the petiole as part of the leaf weight will distort the calculation.

From the detached leaves pick about 51-72 leaflets (in multiples of 3) at random. The number will depend on the stage of the crop's growth. To ensure that the leaves are representative of the different parts of the plant detach leaves from sample plants, mix thoroughly and then pick the required number at random.

The leaves should be washed before discs are obtained so that any soil that may be on them is not recorded as leaflet or disc weight.

b. *Cutting out leaf discs with the cork borer.* Wherever possible, the circumference of the cork borer should be close to the width of the leaflet. If the cork borer's circumference is too small, the chances are that the leaf disc will not be representative of the whole leaf. Conversely, using a much larger cork borer than the width of the leaflet would make it impossible to obtain complete discs.

Commercially available cork borers come in different sizes and are sometimes sold as a set. Each cork borer within the set will usually have a number. The number on the cork borer should be noted at each leaf area determination; the area of the cork borer can be determined by pressing the cork borer on a sheet of paper as if to obtain a disc from the paper. Then a pair of dividers can be placed on the cut mark to measure the diameter of the disc. The dividers are then placed carefully on a ruler to obtain the actual disc diameter. The area of the cork borer can then be determined by using the formula:

area = pi x radius squared

For example, if the cork borer diameter is 2.5 cm, its area will be:

$$\pi \times 1.25^2 = 4.9cm^2$$

The leaflets are counted and then stacked carefully with the largest leaflet at the bottom and the smallest at the top. The stacked leaves are placed on a sheet of cardboard and leaf discs obtained using the cork borer. The cork borer should be sharp enough to make a clean cut without tearing part of the lamina. The discs should be taken from the central portion of the leaflet and not too close to the butt (petiole end) of the leaflet, to avoid including a large proportion of the midrib which has high weight but low area.

Place the discs in an envelope. It may be necessary to push the discs out of the borer with a pencil or similar implement.

c. *Other leaves from the net plot.* The net plot has 80 plants and leaf discs were obtained from only 3. All the leaves are now stripped from the other 77 plants, and the petioles detached.

We now have four sets of leaves: the leaves from the 77 plants, which we shall call Portion A; the leaflets from the 3 plants which were not in the sample from which discs were taken (Portion B); the leaflets from which discs were taken (Portion C); and the discs themselves (Portion D).

d. *Oven drying.* Place all the leaflets from portions A,B, and C in one paper bag or used envelope, and portion D (the discs) in another. Set the oven at 100°C and leave the leaflets and discs in the oven for 36-48 hours. If the temperature is lower, increase the time. If you intend to carry out proximate analysis from the leaves, set the temperature between 70 and 80°C and dry the leaflets for 48 hours.

e. *Weighing.* After drying, weigh the leaflets using sensitive scales. If there is no desiccator, remove leaflets from oven gradually and weigh as soon as they are cool so that they do not absorb moisture from the atmosphere between removal from the oven and weighing.

f. *Calculation of leaf area.* The cork borer method is based on the relationship between the area of the discs, the weight of the discs and the weight of all the discs and leaflets i.e. portions A, B, C and D. It is a simple proportion. But it is important that the leaf discs in particular and the remainder of the leaflets be weighed as accurately as possible using sensitive scales. The measurement of weight in grams should be accurate to at least two decimal places.

Let us assume that:

a. Leaf area of one disc = 4.9cm^2
b. Total no. of discs = 51
c. Weight of 51 leaf discs = 1.13g
d. Weight of leaflets from portions A, B and C = 10.15g.

The leaf area of all 80 plants can be calculated using the following formula:

$$\frac{\text{Area of leaf discs [cm}^2\text{]}}{\text{Weight [g] of leaf discs}} = \frac{\text{Leaf area of all 80 plants}}{\text{Leaf weight [g] of all 80 plants}}$$

$$\frac{\text{51 discs x 4.9cm}^2}{1.13} = \frac{\text{Leaf area}}{\text{10.15 [A+B+C] + 1.13 [D]}}$$

$$\frac{249.9}{1.13} = \frac{\text{Leaf area}}{11.28}$$

$$\frac{249.9 \text{ x } 11.28}{1.13} = 2{,}494.58\text{cm}^2$$

$$\text{Leaf area} = 2{,}494.58\text{cm}^2$$

Determination of Leaf Area Index

Leaf Area Index (LAI) is the leaf area (one surface only) divided by the land occupied by the plants. It is a unitless figure. The leaves on a plant will vary with the stages of growth and development. However, the land area occupied by a plant does not vary. In the earlier example where 80 cowpea plants occupied 7,500cm^2 (100cm x 75cm), one plant was allocated 93.75cm^2 (7,500cm^2/80). The area actually covered by each plant at the early stages of growth and development will be less than what is allocated. However, with time the plant will grow to occupy all the allocated area and even exceed it, as when plant leaves between or within rows overlap with those of other plants.

In the above example where the leaf area of 80 plants was 2,494.56cm^2, the leaf area index will be 2,494.58 cm^2 divided by 7,500cm^2 (land area): 2,494.58/7,500 = 0.33.

Measurement of leaf length and width

i. *Cereals*

This method is used mostly in cereals. The leaf length and the widest part of the leaf are measured. It is advisable to use a tape that is longer than the length of the leaf to be measured; this eliminates error. The single leaf area is the product of the length and width (widest part), multiplied by 0.75. The factor 0.75 is used because it is assumed that if a cereal leaf is placed on a rectangle the same length as the leaf, the leaf will occupy three quarters of the rectangle.

The above measurement is just for one leaf. But maize plants have several leaves, and it may not be easy to measure all of them. A possible solution is to measure a sample, which can be all or some of the leaves on a plant. If all the leaves on a plant are measured from a plot that has three or more plants, then the average length and width of the leaves can be determined. For example, a net plot has six maize plants. All (unrolled) leaves (14) of one plant are measured and the average leaf length and width are 60cm and 5cm respectively. The average leaf area is $60 \times 5 \times 0.75 = 225cm^2$.

After measuring all the leaves on one plant, the leaves in all the six plants can be counted. Let us say that all the six plants have among them 82 leaves. The total leaf area is: $82 \times 225cm^2 = 18{,}450cm^2$. If one decides to measure only a few leaves, it is advisable to take about 3-6 leaves per plant (depending upon the stage of the crop's growth and development). These should be representative leaves from various parts of the plant. Then the average leaf length and width can be determined from the sample. By counting all the leaves in the net plot, the leaf area from the net plot can be calculated using the example above.

The leaf area index (LAI) can also be determined as described above. For example, if the six plants had a land area of $11{,}250cm^2$ (75cm between rows and 25cm between plants x 6 plants), LAI = 18,450/11,250 = 1.64.

ii. *Tobacco*

Leaf area in tobacco can be determined by measuring the leaf length and width (widest portion) and multiplying the resulting product by a factor of 0.6235.This factor is used on the assumption that a tobacco leaf when superimposed on a rectangle of the same length will occupy about two thirds of the rectangle.

Planimeter

This is used mostly for leaves with irregular slopes and relatively small leaves, eg, yams, cassava, groundnuts, cowpeas, soybeans and silver leaf. The arms of the planimeter impose restriction on the size of the leaf; hence it cannot be used for crops such as cocoyam, tobacco, or maize.

The leaves are laid on a flat surface and the tracing arm is "run" along the leaf edge. A steady hand is essential to avoid errors; it might be necessary to take 2-3 tracings and find the average. Several leaves or leaflets can be traced and the area accumulated provided the "wheel" has the capacity to accumulate several tracings within a plot.

Some makes of planimeters have a plate of a known area. The accuracy of tracings can be checked periodically against the plate.

Leaf area meter

The model could be a portable one which can be used for leaf area determination *in situ*, in which case the plant is not sacrificed; or a stationary one where the plant has to be sacrificed for the measurement. Portable leaf area meters can also be used as stationary ones.

Where the portable leaf area meter is used in the field, it is advisable to check that the battery is not weak, as this will increase the errors in leaf area determination.

In using both the stationary and the portable meter, leaves are wiped to remove soil and moisture and laid on a plastic sheet in monolayer. The plastic sheet normally comes with the leaf area meter. The sheet is then folded double over the leaves, and covered with a non-transparent cover such as is used in photocopying documents.

Graph paper

Irregular leaves of relatively small size (cowpea, soybean, groundnuts, cassava, yam, etc.) can be laid on graph paper and traced with pen or pencil along the margin. Leaf area is determined by counting the number of squares occupied by the traced area. Squares that are half and more are counted as whole while those less than half are discarded, on the "give-and-take" principle.

Grid method

Instead of graph paper, a piece of glass or stiff plastic, etched with a grid, can be used. The specimen leaf is laid on a flat surface; the grid is then placed on the leaf and the number of squares occupied by the leaf are counted as described for graph paper.

Modified grid method

This improvised grid method requires regular graph paper, two transparent overhead-projector sheets, a sheet of glass or stiff plastic about the size of a graph sheet, and a source of light.

The graph paper is stapled between the transparent sheets to keep it steady during use. The specimen leaf is sandwiched between the glass or plastic and the graph paper in its transparent sheets, and placed on an open-box frame, high enough (15-20cm) to accommodate a striplight or bulb. (The light source can be dispensed with if the outline of the leaf can be seen without it.)

Video-type leaf area meter

A video-type leaf area meter, Delta-T services, also exists for the determination of leaf area. This is a stationary instrument. The meter is calibrated before use. A stabilizer should also be used to avoid fluctuations and interference during readings as the instrument is very sensitive.

Regression method

The regression method is somewhat similar to the linear method described above in that some linear measurements have to be made. It was first developed by Hammer (1980) for cassava and later used in a modified form by Lutaladio (1986). It involves determining the most suitable equation for predicting leaf area by regressing the true leaf area of leaf samples on selected linear measurements. Lutaladio worked with three cassava cultivars and developed nine models of varying degrees of precision. He suggested, however, that for simplicity, leaf area in cassava can be determined using the equation:

$$Y = 6.11 \times L$$

where Y = leaf area of a leaf and L = the length of the mid-rib of the central lobe.

Deriving other data from leaf area measurements

i. *Specific leaf weight (SLW)*

This is obtained by dividing the leaflet weight by the leaf area. It is a measure of leaf thickness and diffusive resistance, eg, of gases during photosynthesis.

In the earlier example where the leaves from 80 plants weighed 11.28g and had an area of 2494.58cm^2 the SLW would be:

$$\frac{11.28g}{2494.58cm^2} \quad \text{or} \quad \frac{11.28g}{24.95dm^2}$$

ii. *Specific Leaf Area (SLA)*

This is the reciprocal of SLW. It is obtained by dividing leaf area by the leaflet weight. Again, where the leaf area is 2494.58 cm^2 and the leaf weight is 11.28 g, the SLA would be:

$$SLA = \frac{2494.58cm^2}{11.28g} = 211$$

iii. *Leaf Area Ratio (LAR)*

This is leaf area divided by total dry matter (DM) of the plant, usually the above-ground portion unless the roots are included.

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POST-HARVEST FACTORS OF CASSAVA PROCESSING AND UTILIZATION

Natalie D. Hahn

Cassava is a household food security crop serving as a basic staple for approximately 120 million people in Africa whose average cassava consumption exceeds 200 calories per day (Dorosh 1987). FAO reports that production of cassava has increased by 60 percent in developing market economies from 1961/65 to 1981. In the developing countries, roots and tubers provide 7.2 percent of calorie sources and 3.1 percent of protein (FAO 1986). Greater policy commitment at both national and international levels has focused on increasing production to meet the increasing urban demand for high-energy staples. A CIAT report on urban cassava markets in Latin America indicates the major impact of storage technology on the urban fresh-cassava market. For instance, yield increases of 67 percent were estimated to benefit Colombia by approximately US$5 million per year. An additional benefit of about US$2 million would be produced in the animal feed market. Thus, the expected value of storage technology could be four to five times that of production-oriented technology in Colombia (Janssen and Wheatley 1985).

However, in comparing food sources in developing countries (1980) and the approximate annual allocation of CGIAR centers' resources, roots and tubers rank low in providing 213 Kcal/day (9.1 percent) worldwide and a CGIAR funding level of only 12 percent in comparison with cereals which provide 1,414 Kcal/day (60.1 percent) and 40 percent of the overall CGIAR funding level. However, de Vries et al. (1967) have estimated that in terms of production of food energy per hectare, root crops, far from being inferior to grain crops, have in fact a considerably higher potential yield than cereals. Yet, in considering all expenditures, the majority of the CGIAR funding has gone into production research, and the overall processing and utilization expenditures are extremely low. The overall loss of food crops is, however, 25 percent (a conservative estimate) in the tropics. In individual cases losses may be much greater and it is suggested that losses of 35-50 percent at the farm level followed by 10-12 percent in middlemen's stores and a further 5 percent in markets may not be uncommon (Booth and Burden 1983).

This paper highlights some of the research on cassava utilization and processing and reports on a planned center for research into food-crops utilization as part of the IITA-UNICEF Program on Household Food Security and Nutrition. The paper proposes that research within the cassava-based cropping systems give greater attention to the processing and utilization components, conduct more off-site testing on the development and acceptability of new food products and efficient equipment, and establish closer links with national and international programs.

Necessity of cyanogenic controls

The chemical composition of the cassava root varies but the edible portion typically comprises 62 percent water, 35 percent carbohydrate, 1 percent protein and 1 percent mineral matter (Purseglove 1968). Cassava is relatively rich in vitamin C and calcium but poor in protein and other vitamins and minerals.

A high proportion of the protein content is lost during processing. Losses ranging from 50 to 87 percent of the original protein have been reported during the traditional preparation of foodstuffs from cassava in Cameroon; gari, for example, contains only 36 percent of the protein found in the raw root (Favier et al. 1971). Oke (1965, 1966b, 1968) has reported similar losses during the preparation of Nigerian cassava foodstuffs such as lafun, another fermented product, as well as gari.

Favier et al. (1971) estimated that in a diet based on cassava products in which 80 percent of the calorie requirement of an adult male is supplied by the cassava, only 7-23 percent of the protein requirements, according to the type of product, would be supplied by cassava. Bigwood and Adriaens (1954) calculated a similar figure for a diet based on cassava meal (Lancaster et al. 1981).

In developing appropriate processing technologies, the priority must be given to the control of hydrogen cyanide. Both tuber and leaves are cyanogenic because of their content of linamarin and lotaustalin. As in several other cyanogenic plants, the glucoside concentration in cassava leaves decreases with age (DeBruijn, 1973). In most varieties, the concentration of cyanogenic glycoside is appreciably higher in the tuber bark than in the flesh, the ratio being about 5 or 10 to 1. Usually, the higher cyanogen concentration is found at the proximal end of the root. Alternative food processing techniques which have been successful in reducing the acute toxicity of cyanogenic plants are exemplified by the variety of traditional ways devised to detoxicate the more poisonous varieties of cassava. These procedures are designed to allow cyanogens to come into contact with endogenous β-glucosidases, causing their hydrolysis. The liberated HCN may be eliminated by solution in water or by volatilization.

Writing on cyanogenic compounds in plants and their toxic effects, Poulton concludes that cassava products prepared by these traditional detoxication methods may still contain appreciable traces of HCN and unhydrolyzed cyanogenic glycosides. Oke (1968) reported the following HCN levels (in mg of HCN per kg tissue) in samples of several African cassava-based food products: fresh cassava, 380; gari, 19; fufu, 25; lafun, 10; and kpokpo-gari, 11. Kokonte, a flour prepared from sun-dried cassava chips, contains 20mg HCN/kg (Wood, 1965). In some areas of southern Nigeria, where ataxic neuropathy exists in almost epidemic proportions, purupuru, which contains 0.1μmol of cyanide per gram of tissue, is commonly eaten. Assuming the consumption of 3kg of purupuru per day, the total daily cyanide intake would be about 50mg, a figure close to the lethal dose for humans (60mg). Similarly, the large (0.8kg/day) intake of gari, with its linamarin content, by some populations means that such individuals may be exposed to approximately 20mg of HCN daily (Poulter, 1983).

Requirements in reducing post-harvest losses

It can be seen that post-harvest losses are important from both an economic and nutritional standpoint, and that the problem is technologically and scientifically complex. Nevertheless, greater success in increasing the net production of finally usable produce may frequently be achieved by reducing such losses rather than by increasing field or gross production (Booth and Burden 1983). Research by CIAT in Colombia shows that two essential requirements of any storage system are that (a) the produce should lose as little weight as possible during storage; and (b) it must be of acceptable quality after storage (Booth 1975). CIAT research has indicated that small quantities of roots can be preserved for several days using such simple techniques as reburial, coating in mud, and placing under water. Field storage experiments using structures similar to European potato clamps have shown that cassava roots can be cured successfully and stored for a period of one to three months, depending upon clamp design and prevailing ambient conditions. The basic design of these field clamps is as follows: a circular bed of straw or other material such as dried grass or dry sugar-cane leaves (approximately 1.5m in diameter and 15cm thick after it has been compacted) is placed on suitable well-drained ground. The freshly harvested roots are heaped in a conical pile on this straw bed. The pile of roots is then covered with a similar layer of straw and the entire clamp covered with soil to a thickness of 15cm. The soil is then removed from around the circumference of the clamp, forming a drainage ditch.

Another storage technique is called box storage, in which freshly harvested roots are packed with moist sawdust in 20-kg boxes. The moisture of the sawdust packaging is 50 percent; this maintains a high relative humidity that promotes curing and prevents excessive moisture loss, but does not wet the roots.

The summary of the CIAT research shows that successful curing and storage of cassava can be obtained both in storage boxes and in field clamps for at least two months The roots remain of acceptable quality for both human and animal consumption for at least eight weeks, and they have a longer shelf-life than freshly harvested roots, although certain quality changes such as sweetening and softening of the roots occur during storage (Booth 1975).

Another cassava storage technique is waxing, which involves dipping the roots in paraffin wax. This technique extends the storage life for up to three or four weeks (Booth 1974). A thesis completed by Ghanaian student A. Kwamie (University of Ghana 1985) on fresh and cured roots indicates that the maximum storage period for the cured roots is less than eight weeks but more than four weeks. She used a simple "basket system" technique for preserving fresh cassava to extend its shelf-life. Baskets were lined with plantain leaves containing moist wood shavings at 50 percent moisture, which allowed for aeration of the roots.

Effects of processing on the cyanide content of cassava

Cassava roots are traditionally processed by a wide range of methods to reduce their toxicity, improve their palatability and convert the perishable fresh roots into stable products. These methods comprise combinations of drying, soaking, boiling and fermentation of the roots. In an IITA-UNICEF study on the existing cassava storage and processing technologies in southern Nigeria, Mrs Janet Kwatia describes traditional cassava-processing technologies in two groups:

i) technology based on drying and dried products with or without fermentation;

ii) technology based on fermented cassava dough.

The following main products can be listed in the first group:

lafun (fermented cassava flour)
abacha (cassava noodles)
cassava flour (unfermented)
pupuru

The second group includes products developed from fermented cassava dough of which the most important are gari and fufu.

Kwatia explains the traditional and engineering improvements with regard to drying/frying, grating, and milling or grinding. She also outlines the alternative uses of cassava, including cassava flour for baking cassava starch for domestic and industrial uses and cassava chips as an ingredient for animal feed, as products that can be easily manufactured at the intermediate level of technology, opening up prospects for income-generating activities for rural settlements.

Research into cassava flour or starch as a component of the composite flour has shown that cassava flour can substitute 10-30 percent of wheat flour in bread. The decrease in protein content of composite flour through the introduction of cassava can be overcome by the addition of 5 percent soybean flour. Cassava starch can be produced as an end product, but it can also be used as a raw material for other products; over 100 derivatives of starch are known. Kwatia reports that industrial starch consumption is widespread in Nigeria where the largest consumers are the textile, paper and food-processing industries. Approximately 44,000 tons of starch were required to satisfy local industrial demand in 1983. The only large producer of cassava starch is the Nigerian Starch Mills Limited with a total plant capacity of 18,000 tons per annum. Another potential is the use of cassava root and foliage as ingredients of animal feed. Research has shown that cassava flour can be a good substitute for cereals in broiler rations at levels as high as 70 percent. Layers can be fed up to 50 percent of cassava meal, provided that their diets are well balanced in other nutrients. The digestibility of the cassava-based rations in swine is reported to be equivalent to, or even better than, cereal-based diets. Cassava is also reported to have increased milk production in the Nigerian White Fulani herd: the increase was approximately 22 percent, accompanied by higher percentages of butter fat, protein and non-fatty solids (Kwatia, 1987).

IITA-UNICEF program on household food security and nutrition

The establishment of an off-site research and training center for food crops utilization has been completed during 1987 with UNICEF financing. The 2-hectare plot for the center was donated by the community of Ijaiye in Oyo State and the recommendations of Mrs Janet Kwatia and national engineers formed the basis for the purchase and installation of equipment. Now built as a gari-processing plant, the center was officially opened on 20 August 1987. Economic assessments are at present being undertaken on the efficiency of the operations, including costs of the tubers, transportation required for purchasing tubers and marketing the gari and the overall efficiency of processing equipment as well as quality assessment of the gari. A marketing assessment is also being undertaken on the possibilities of expanding the center to include cassava starch processing . Research plans for 1988 include:

- overall equipment efficiency;
- economic returns for the gari;
- gari quality preferences and processing time for traditional and improved cassava varieties;
- testing of new cassava food products and products that use cassava starch and flour as a base;
- acceptability of new cassava food products with higher protein foods including soybeans and cowpeas. The products will be tested according to storage capabilities, processing time and local taste preferences as well as market potential.

Links with national and international institutes

A number of national institutions (FIIRO and the Federal and State Ministries of Agriculture) are working on cassava processing and utilization as well as the Rural Agricultural Industrial Development (RAIDS) group. In addition, important international programs focusing on processing and utilization have been initiated. The African Regional Center for Engineering Design and Manufacturing (ARCEDEM) has been established in Ibadan with support from the Economic Commission for Africa, UNIDO, the African Development Bank and UNDP. With an extensive research and training program, the center was founded with the objective of assisting African countries to develop engineering skills in the design and manufacturing of capital goods.

It is essential that information on these institutions be made available to IITA scientists for potential collaborative efforts but above all so that research and training programs are not duplicated. Other international programs that have impressive cassava utilization networks and practical field programs include the Intermediate Technology Development Group (UK), the United Nations Development Fund for Women, UNICEF, the German Agency for Technical Cooperation (GATE/GTZ), the Royal Tropical Institute (KIT) in Amsterdam and the Tropical Development Research Institute (TDRI) in London.

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Annexes

OPENING REMARKS GIVEN AT THE CASSAVA-BASED CROPPING SYSTEMS RESEARCH MEETING (22 July 1986)

Bede N. Okigbo

A cropping system consists of the *arrangements in time and space of one* or more crops and the associated management practices and technologies that satisfy farmers' objectives in a given ecological and socio-economic setting. Arrangements in time and space include combinations of crops, the spatial arrangements and sequences of cropping by which one or more commodities are grown in such a way as to favorably take advantage of space and time, and various events that occur in time and space.

As with farming systems or agricultural production systems, cropping systems differ from each other with respect to the following factors that interact in the production process: physico-chemical (soils and nutrients, climate with respect to temperature, rainfall, atmospheric pressure, radiation, etc.); biological (crops, animals, weeds, pathogens); technological (tools, machines, practices); managerial (experience, training, decision-making, skills, etc), and socio-economic (credit, infrastructure, policies, etc.). Objectives of any cropping system include subsistence, commercial and raw materials, hobby or pastime, each of which may in varying degrees be of interest to the farmer. Any cropping system aims at attaining some quantitative productivity in terms of yield. Whether we are interested in maximizating, optimizing or attaining any level of productivity, the yield factor is, generally speaking, of major concern to us. This yield factor is a function of resources, consisting mainly of certain factors of production such as land, labor and capital, interacting with a range of inputs some of which are sometimes regarded as synonymous with resources and are managed in such a way that a unique set of numbers, quantities, timing and sequences ensures attainment of desired objectives. The number, quantity, timing and sequences are each further associated with a qualitative element which is what also makes the science and business of agriculture something of an art. It is mainly through research that we can more reliably determine these numbers, quantities, timing and sequences of manipulation of the various inputs and resources. Since agricultural production systems are location-specific, research in cropping systems can only facilitate development of component technologies for a given cropping system that is adapted to a specific environmental situation.

Networking is a collaborative research and development effort in which individuals interact and cooperate in tackling a common problem of mutual concern in such a way as to share information and experiences. On the whole, networking facilitates a synergistic effect in the finding of solutions in an area of common concern. You are all here today launch a Cropping Systems Research Network with emphasis of the root crops based cropping systems which are but components on the often highly complex traditional farming systems in various parts of West Tropical Africa.

Strategies for developing improved cropping systems

In general, designing of improved cropping systems and their agroecosystem management plans may involve any of three main alternatives:

1. Modification of farmers' traditional agroecosystem.

2. Mimicking natural ecosystems.

3. Designing of new agroecosystems.

Of these three strategies, designing of new agroecosystems may be regarded as currently of limited potential because:

(a) We have limited knowledge or understanding of existing complex traditional agroecosystems and interaction among components to facilitate modeling, simulation and manipulation of individual commodities.

(b) Limitations in time for developing totally new systems under pressures of rapid population growth, environmental deterioration and pressures of modernization.

(c) Inability to transfer modern agro-ecosystems of the temperate regions to the tropics and current concern about the high cost of inputs and environmental hazards of pesticides needed to sustain productivity of such systems.

(d) Limited scope and progress of research in tropical food crops and their production systems due to deficiencies in capabilities of tropical countries in personnel, facilities, research management and funding.

(e) Limitations in our production economics capabilities and success in integrating agronomic and socio-economic research until the recent advent of farming systems.

The potentials of mimicking natural ecosystems are limited because, although such natural ecosystems are stable and exhibit high primary productivities, they are all largely closed systems that do not give sustainable yields with constant harvesting. There are, however, a few agroecosystems that resemble natural ones in which good use is made of compatibility among species that complementarily utilize different parts of the biosphere in terms of nutrients, light and space. For example, cocoyams under plantains and cocoa, Yoruba soft cane (*Sarcophrynum* spp.) under cola nuts (*Cola nitida*); pasture, cocoa and coffee under coconuts, etc. The home gardens of the tropics constitute the most complex agroecosystems that mimic nature but the productivity remains low, stable and nutritionally strategic. There are still opportunities for improving and utilizing this approach.

The modification of the farmers' existing agroecosystem is therefore the most promising strategy and has been largely facilitated by recent developments in farming systems research. This holistic approach provides opportunities for understanding of existing systems as a basis for repairing, modifying or changing them, and perhaps eventually designing new ones. The farming systems approach ultimately results in the integration of appropriate traditional component technologies for managing the cropping system or subsystem using compatible elements of "modern" or improved agroecosystems in the development of new and improved crop production subsystems or systems.

Guidelines for priorities in cropping systems research

The traditional and transitional cropping systems which we desire to change were developed for different over-all environmental conditions and objectives. They are, by and large, very complex and sometimes involves species which positively interact with each other to boost yields, while at other times some elements of the interaction have negative effects on total productivity, as a result of competitive interactions above and below the ground. This requires simplification of the cropping systems to ensure that commodities are able to sustain productivity and satisfy subsistence, commercial and environmental conservation objectives. This would require a much better understanding of crop plant interactions above and below the ground than has hitherto obtained. It also requires much better appreciation of the past and present trends in Nigerian agriculture, in the humid and subhumid tropics, and clear identification of target subsystems, commodities and the component technologies used in their management. This entails incorporation into improved systems of more selected indigenous neglected commodities than generally feature in the existing cropping systems. IITA, as an international agricultural research center, gives priority to development of principles and methodologies that apply to major benchmark areas in the improvement of major tropical food crops and development of more efficient farming systems for sustained productivity. A network should be organized in such a way as to minimize duplication, and facilitate delineation and selection of effective minimum major benchmark areas for location of collaborators in such a way that work in them is most beneficial to the whole network, while at the same time facilitating use of extrapolation of results to minor ecological zones within each benchmark area.

Roots and tuber crop based cropping systems are not only cropping systems of interest to IITA, but they involve commodities that are dominant in the humid and subhumid tropics. Based on this brief background, the following guidelines are recommended.

1. In the establishment of a cropping systems network based on progress made at IITA and elsewhere, it is necessary to identify key benchmark areas from which participants will be selected in such a way as to minimize duplication of effort and wastage of resources. Within each benchmark area, commodities of primary, secondary, subsidiary and negligible importance and major cropping systems and technologies should be identified.

2. In the development of more efficient and improved cropping systems there is need for a degree of simplification of the number of commodities grown on a given piece of land at any one time while at the same time maintaining enough diversity to fulfil farmers' over-all subsistence, nutritional, income-generating and environmental conservation objectives. Such improved cropping systems should not consist of only major crops but may include minor crops that can contribute to balancing of the diet, maintenance of soil fertility, minimization of labor and weed, pest and disease damage, fulfilment of certain socio-cultural requirements and preferences, provision of raw materials for smallscale industries or local use, etc.

3. Studies of cropping systems as a basis for designing improved systems have to some extent neglected processes that take place

underground such as alletopathy, competition for water, disease and pest damage, etc. It is necessary to aim at a meaningful balance in the study of processes of crop interaction above and below ground and between basic and applied research.

4. Integrated approaches to pest, disease and weed management are increasingly receiving greater emphasis in various production systems. Priority should be given to designing of improved cropping systems and technologies that increasingly take advantage of development in this area.

5. Specific efforts should be made to evolve efficient management of inter-disciplinary research teams that will be involved in the network in such a way that the potentials of various disciplines are realized, professional capabilities and status enhanced and effective exchange of information and sharing of experiences encouraged. No participant should act like a non-participating observer or just a mere receiver of technologies developed at IITA. There should be at least eventually more symbiotic relationship among all concerned.

6. Root and tuber crops based cropping systems can utilize upland areas and some wetlands. Efforts should be made to realize the potentials of new cropping systems in situations in the landscape where they can be of maximum advantage at reduced inputs.

7. The idea of networking is almost as glamorous and attractive now to some donors as farming systems recently were. Efforts should be made to avoid the usual propensity in Africa to establish institutions, mechanisms or facilities that are based on need and meaningful objectives but which never effectively function and execute the task for which they are founded. In the execution of the research and development activities in the network, the current limitations in funds and resources at IITA should be given due consideration.

The above ideas are by no means exhaustive, but I feel they should give you food for thought and suggestions of issues for discussion during your deliberations. On behalf of the director general of IITA and of the director of the farming systems program, I declare this meeting open and wish you fruitful deliberations.

ANNEX 2

THE ROLE OF AGROECOLOGICAL CHARACTERIZATION IN WEST AND CENTRAL AFRICA[1]

A. Goldman

Role and functions of agroecological characterization

Agricultural environments are inherently diverse and variable. They vary both in time–from one season and from one year to another–and in space–from one location or area to another. Although farmers probably have, in many respects, the best knowledge of the particular environments in which they work, researchers and others often need to understand the range and diversity of environmental factors over a larger region. Agroecological characterization involves the description and analysis of the characteristics of a site or region that are relevant to agricultural potential and output and to the nature of the agricultural systems in the region(s). It frequently involves generalization of point data such as rainfall and other climatic data from recording stations; soils data from site tests; topographic and terrain information; data on land use and crop and livestock systems. This can be done on a variety of different scales and levels of detail and to serve a variety of objectives. At one end of the scale, broad agroecological "zoning" has a long tradition of use in relation to agricultural research. At the other end, detailed collection and analysis of environmental data at specific experimental locations has also often, though not always, been an element of site-based agricultural research.

Recently, new methods have been developed for generating agroecological data, generalizing from them and using them in interpreting the results of agricultural experiments. This has been stimulated primarily by the development of enhanced capabilities to store and analyze this kind of data and to use them in combination with crop and crop system models. A recent conference of the Consultative Group on International Agricultural Research explored many of the

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[1] This paper was presented at the Cassava-Based Cropping Systems Research meeting, 22 July 1986. Some of the material in this paper originally appeared in a longer document prepared for the IITA Strategic Planning Study, titled "Agroecological characterization and its relation to research issues in West and Central Africa."

characterization, particularly as they affect the nature of research and planning at the international and national research centers (Bunting 1987). Although the new approaches have only begun to influence the design and conduct of agricultural research in West and Central Africa, they have the potential to exert a profound impact.

Characterization of agroecosystems has been employed for two main types of functions among international agricultural research centers, as summarized in the following table.

PURPOSES OF ENVIRONMENTAL CHARACTERIZATION

Planning

- Define institutional focus and regional characteristics
- Establish priorities in research agenda
- Determine, target, and assess suitable crops and technologies

Agricultural Experimentation

- Site selection; determination of number of sites
- Interpretation of results (relative to enviroment & genotype-environment interactions)
- Technology recommendation and fine-tuning; recommendation domains.

At the general planning level, the concerned institute needs to define the boundaries and characteristics of the regions in which it works and to determine, in a broad sense, the types of appropriate technologies. Even with a worldwide or regionally defined crop mandate, however, a delineation of the main environmental zones in which the crop is grown is essential. More detailed planning functions such as the setting of priorities among different possible research goals also often require disaggregation by environmental and related parameters.

The same is true for decisions on the siting of experimental trials and subsequent interpretation of results. The sites must be adequately representative of conditions in some larger area, just as the results need to be interpreted in relation with regions of ecological similarity and with respect to the seasonal conditions that marked the time of the experiment. Moreover, the decision of the number of sites required for varietal or other trials–which plays a large role in determining the costs of experimentation–is generally directly related to the definition of the relevant agroecological factors. Finally, the technology that has been developed needs to be recommended and further refined in relation with agroecological conditions in particular areas. The importance of this has become increasingly evident in recent years, with the recognition that the earlier philosophy of "wide-adaptability" of new crops and varieties is not practical for many of the areas with which the CGIAR centers are now concerned.

Agroecological characterization (AEC) can, of course, comprise a considerable range of activities, and the types of data and levels of detail that are appropriate will vary with the objectives involved. Three general categories of research objectives and a corresponding hierarchy of AEC needs might be summarized as follows:

OBJECTIVES	*AEC NEEDS*
Basic research	"Environmental range"(non-locational)
Technology development (suitable for given region)	Biophysical characterization
Adoption of new technology	Socioeconomic and biophysical characterization

While basic scientific research may require only a rudimentary consideration of environmental characteristics in the areas of concern, development of technology that is ecologically suitable for a given type of area usually requires a more location-specific characterization of climatic and edaphic parameters and their variability. Even technology that is quite environmentally suitable has often not been adopted, however. When wide adoption is an important objective, socioeconomic as well as biophysical characterization of areas is often necessary and must be included in most or all stages of the research process. The following sections explore the general approaches and major elements in agroecological characterization of the areas of primary focus for IITA–which include "coastal West Africa" (the countries along the West African coast stretching from Guinea Bissau to Cameroon) and Central Africa.

Agroecological characterization in West and Central Africa

There have been numerous approaches to classifying and characterizing agroecological zones. In West and Central Africa, most classifications are based either on climatic or vegetation variables, or some combination of the two. When Eastern and Southern Africa are included, altitudinal and sometimes latitudinal categories are also usually employed. As this suggests, the appropriateness of any classification scheme depends to a great extent on the nature and size of the region considered and on the questions posed.

Because of the striking ecological differences between the forest, savanna, and Sahelian vegetation zones in West and Central Africa, these are commonly used as the primary basis for agroecological classification (with a "transition zone" or "derived savanna" also sometimes included). Vegetation-based classification is useful largely because it is so readily identifiable by direct observation, particularly in areas with a broad pattern of distinctive vegetational ecosystems such as West and Central Africa. In addition, vegetation is an indicator that synthesizes the influence of climate, soils, and human activity, all of which affect agricultural practices.

Figure 1 shows the main vegetational zones of tropical Africa, with the nomenclature that is still most commonly used for the region (originally derived from work by Keay [1959] and others).[2] Although there may be variations in terminology and in the precise locations of the boundaries between zones, most ecological maps of this large region have a fundamental similarity in general pattern, even when based on different variables.

The main alternative to a vegetation-based classification is one based on climatic parameters, generally relating to moisture availability and balance. The labels most frequently associated with these moisture-related zones include humid, subhumid, semiarid, and arid, with other categories or variants sometimes also added. The simplest moisture variable for defining these zones is total annual precipitation, which can range from over 4,000mm in parts of coastal

[2] Other maps and classifications employ variants of these terms; e.g., "forest-savanna mosaic" or "transition zone" are often used in place of "derived savanna"; and the Guinea savanna and Sudan Savanna are sometimes termed the "moist savanna" and "dry savanna" respectively. In some cases the Guinea savanna is divided into southern and northern sections while in others it is not (cf. Morgan and Pugh [1969]; Kowal and Kassam [1978], among others).

Liberia, Sierra Leone, Guinea, and Cameroon to about 900mm where the dry, or Sudan, savanna begins (see table 2). However, it is more relevant to crop growth to use a measure of moisture balance–ie, the relation between precipitation and potential evapotranspiration [PET]–which determines the actual "humid period" or "growing period" for crops.

The use of this measure has evolved and changed somewhat over the past two decades (Davies and Robinson 1969; Lawson 1979; FAO 1978), although the usage that is still probably most common is derived from Troll (1965) and is based on the total number of "humid months," or those in which rainfall exceeds PET. There are, again, a number of variations in the boundary definitions for humid, subhumid, and semiarid zones.[3] Figure 2 shows the isocontours for the number of humid months for West Africa. A comparison of this with the vegetation zones in Figure 1 suggests that there is a reasonable correspondence between the upper boundaries of the rainforest and the Guinea savanna with the 7-month and 4-month contours respectively (although there are some discrepancies in areas such as northeastern and extreme southwestern Nigeria, due to distributional features of the precipitation). A more recent variation, used in the FAO agroecological zones project (1978), is based on the total annual number of growing period days (which as a more disaggregated variable is better suited to computer-

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[3] The definition of the climate classes by the number of humid months (those in which precipitation is greater than PET [or some proportion of PET]) varies among the original Troll classification (1965) and some more recent works (Lawson 1979; Le Houérou and Popov 1981) as follows:

NUMBER OF HUMID MONTHS

Zone	*Troll*	*Lawson*	*Le Houérou & Popov*
Perhumid	>9	>8	>10
Humid	7 - 9	6 - 8	8 -10
Transition	___	5 - 6	___
Subhumid	4.5 - 7	4 - 5	5 - 7
Dry subhumid	___	___	4 - 5
Semiarid	2 - 4.5	2 - 4	3 - 5
Arid	<2	1 - 2	2 - 3

In some cases (eg, Le Houérou & Popov), rainfall needs only to exceed 0.5 or 0.35 PET to classify a month as humid. In view of the range of criteria, the choice of which classification to use depends on which boundaries are most convenient and relevant to the specific purpose at hand.

based analysis).[4] The contour lines for this measure are shown in figure 3. The 270-day and 180-day contours appear to correspond most closely with the West African vegetation zones of figure 1, though again there are a number of local discrepancies.

A summary of the corresponding values for these moisture variables and the vegetation zones appears in table 2 below. These are based as far as possible on the boundaries shown in figure 1, and it should be remembered that the numerous definitional variations mentioned above imply that any selection is somewhat arbitrary and that the correspondence among different measures is not exact. The degree of discrepancy also increases as one moves away from West Africa, since altitudinal and latitudinal effects have greater influence.

As was mentioned, the main advantages to vegetation-based classification are that it is very amenable to direct observation and that it synthesizes the effects of both soil and climatic conditions as well as of human activity. Among its main disadvantages, however, are that it is fairly specific to West Africa (and to a somewhat lesser extent to Central Africa) and that it is not associated with a quantitative measure and thus is imprecise and subject to interpretation. Conversely, the ease of quantification and the wider areal applicability are among the main advantages of climate-based classifications. Such measures as total annual precipitation, annual excess of precipitation over PET, number of dry (or wet) months, and length of the annual growing period can be used for classification and comparison of diverse regions, and–of growing current importance–for storage in computerized data bases. This latter capability is likely to play a critical role with the spread of computer mapping techniques.

In sum, the following general principles can serve as guidelines for selection of an appropriate basic agroecological classification scheme:

(a) When concerned just with West and Central Africa, a vegetation-based classification is usually appropriate. The actual categories will depend on the specific use intended, but the forest, savanna, and Sahelian zones will be central. In some instances categories for the derived savanna, wetland areas, mid- or high altitudes, and/or other subdivisions of any of the zones may also be included.

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[4] The growing period is defined as beginning when rainfall exceeds 0.5 PET and ending when rainfall falls below 0.5 PET plus stored soil moisture (assumed to be 100mm; FAO 1978).

(b) When East Africa and other areas are also included, the best classification is generally one based on moisture balance plus altitude. The categories would be defined by a matrix with altitude in one dimension (lowland, highland, etc.) and moisture balance In the other (humid, subhumid, etc.). Again, the precise number of categories and boundaries need to be defined in relation to the purpose at hand.

(c) If areas outside the intertropical zone are included, a latitudinal parameter will also be useful (tropical and subtropical categories often being sufficient).

(d) For a computerized data base, continuous quantitative parameters are most useful. Ideally, these should be stored, as far as possible, as disaggregated, non-interpreted point data–eg, mean monthly (or weekly) precipitation, mean high and low temperatures, windspeed, latitude and longitude, altitude, etc. These can then be transformed to find such values as PET and interpolated to provide surface contours. Boundaries of zones can be defined in relation to specific parameters as needed (see Bunting 1987).

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ANNEX 3

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ADDENDA: ANNEX 2

Table 2: Major ecozones and characteristics in West Africa

Zone	Number of humid months	Mean annual rainfall	Growing period (days)	Main Soils
1. Forest	7-9+	1400-4000+ (mostly unimodal)	270-365	Mostly acidic (ultisols and oxisols); some nonacid (inceptisols, entisols, vertisols, alfisols, etc.)
2. Derived Savanna	6-7	1300-1500 (bimodal, some areas)	240-270	Moderately leached soils (alfisols, some ultisols, etc.)
3. Southern Guinea Savanna	5-6	1200-1500 (partially bimodal)	190-240	Mainly alfisols and related soils; acidic ultisols and oxisols in some wetter areas; also entisols and vertisols in some areas.
4. Northern Guinea Savanna	4-5	880-1300 (unimodal)	140-200	As above, with greater proportion of nonacid alfisols, etc., and fewer areas of acidic soils.
5. Sudan Savanna	2-4	500-880 (unimodal)	90-140	Alfisols and some drier aridisols, etc.

Sources: Papadakis (1966); Davies (1973); Harrison Church (1980); FAO (1978); Kowal and Kassam (1978); Lawson (1979); Le Houérou and Popov (1977)

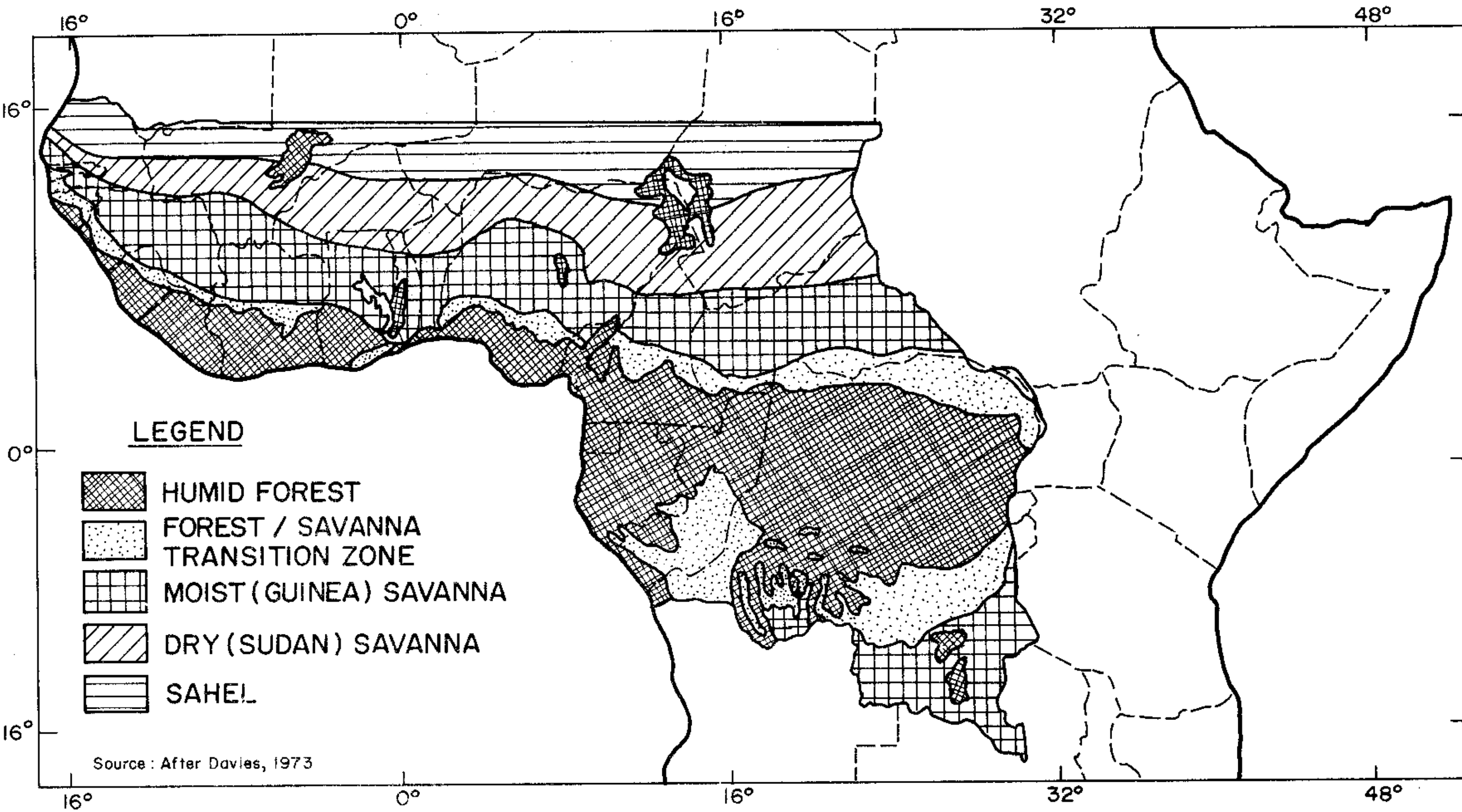

Fig.I. Vegetation Zones in West and Central Africa

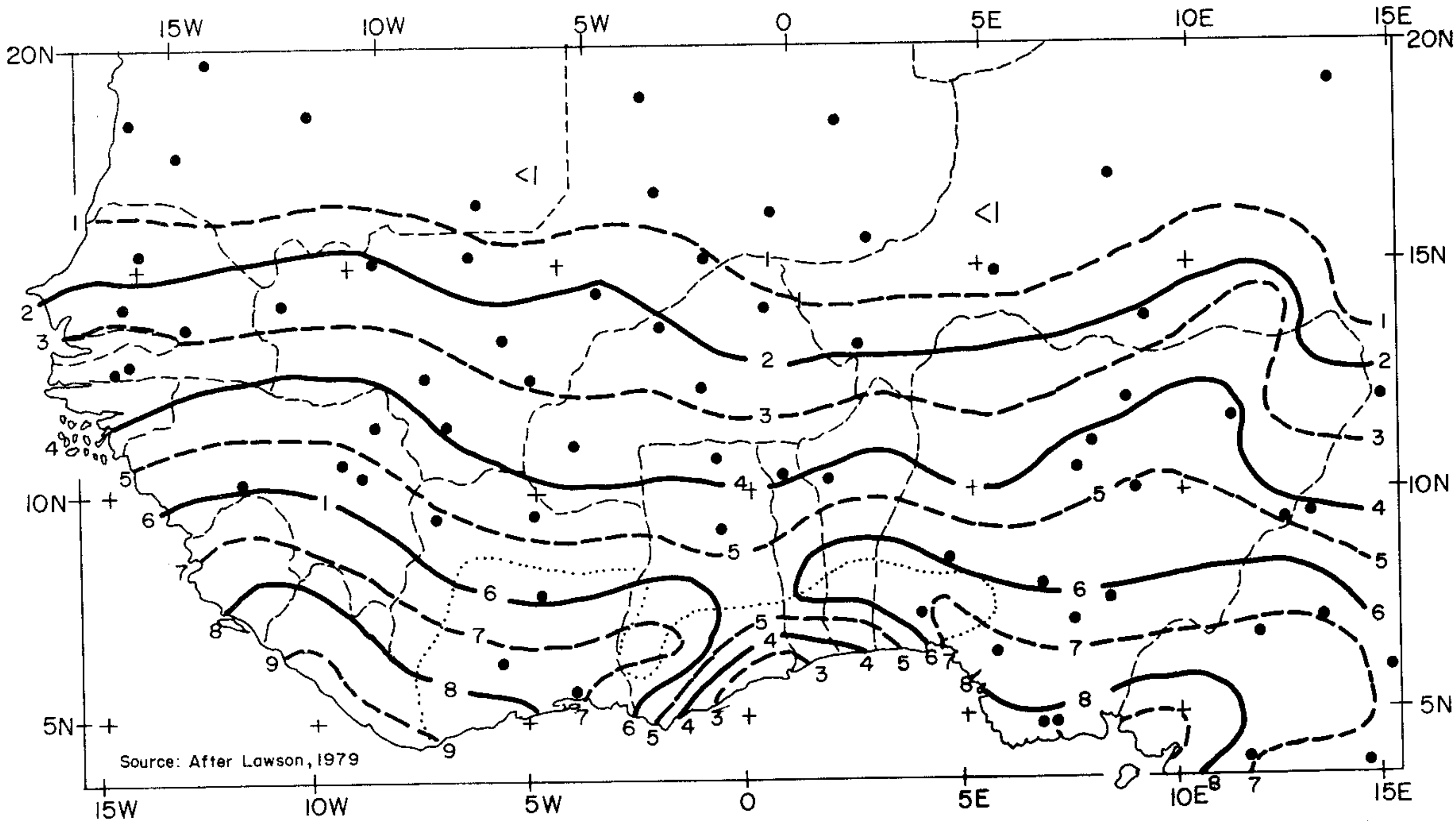

Fig. 2. Numbers of Months with "Positive" Water Balance (Precipitation ≥ Evaporation) in West Africa

.... Bimodal Rainfall Area ● Main Meteorological Station

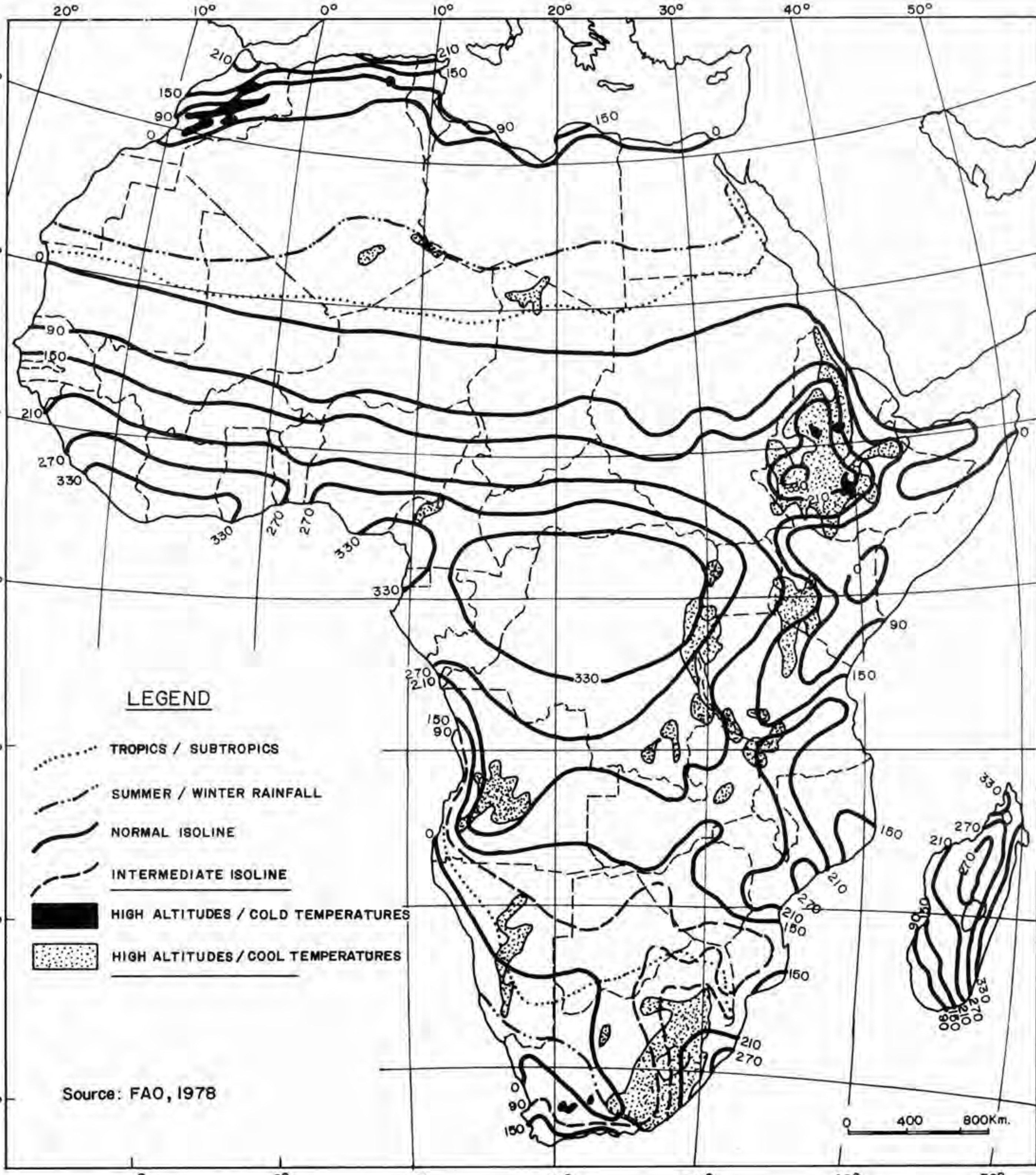

Fig. 3. Lengths of Growing Period