CODEN: IBBRAH (14-86) 1-18 1986

ISSN 0434-6793

I N S T I T U U T   V O O R   B O D E M V R U C H T B A A R H E I D

RAPPORT 14-86

PROGRESS AND FUTURE PLANS OF THE PROJECT "MANAGEMENT OF NITROGEN IN ACID LOW ACTIVITY CLAY SOILS IN THE HUMID TROPICS FOR FOOD CROP PRODUCTION"

Progress report No. 1

by

B.T. KANG, A. VAN DER KRUIJS and J. VAN DER HEIDE

1986

Instituut voor Bodemvruchtbaarheid, Oosterweg 92, Postbus 30003,
9750 RA Haren (Gr.)

Inst. Bodemvruchtbaarheid, Rapp. 14-86 (1986) 18 pp.

CONTENT

A COLLABORATIVE PROJECT BETWEEN THE INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE, IBADAN, NIGERIA

AND

THE INSTITUTE FOR SOIL FERTILITY, HAREN, THE NETHERLANDS

THE PROJECT IS FUNDED BY THE DUTCH MINISTRY OF DEVELOPMENT ASSISTANCE, THE HAGUE

1. ACHIEVEMENTS

Results of field and laboratory investigations conducted during the first phase and part of the second phase of the project have shown that sustained food production can be obtained on manually cleared land in the area with low levels of fertilizer-nitrogen application.

Annual and perennial legume species play a significant role in soil management on the acid and fragile soils. The results also disclosed the importance of proper plant arrangement and population and timely planting under humid and low solar radiation conditions. This observation was supported by lysimeter and root studies.

During the project period major attention was given to training of research associates from developing countries. To further promote the exchange of scientific information, an international conference was organised. Closer contacts with national research institutes and traditional farmers were established and maintained through field days, on farm research and organized visits.

2. FUTURE PLANS

Since the first phase of the project, a research and training cooperation has been established with Nigerian institutes such as the National Root Crops Research Institute in Umudike, The Federal University of Technology in Owerri, the Rivers State University of Science and Technology at Port Harcourt, and the Michael Okpara College of Agriculture at Umuagwo. This cooperation will be intensified.

Similarly, on-farm research to evaluate low input production techniques under farmers' conditions will be given high priority. An important area will be to study the socio-economic aspects of the local farming system in the area and to evaluate adoption of improved technology by traditional farmers. Close contact will be maintained with the University of Brawijaya in Indonesia which carries out part of the experimental work under similar ecological conditions in Lampung, Sumatra. Apart from the regular individual training program, a greater attention will be given in the second phase to short-term group training programs in low input production technology.

Further research will be carried out at the Onne station and at the National Research Institutions in the area, to study the N-contribution of annual and woody shrubs (such as pigeon pea and Flemingia) in low-input production systems. The effect of promising annual cover crops in rotation systems and the performance of leguminous woody species in alley- and inter-cropping systems will be evaluated. The turnover of ^{15}N-labelled organic residues in the soil will be studied in lysimeters and under controlled conditions at IB.

3. STAFFING AND TRAINING

After the initiation of the project by a staff member of IB in late 1981, the field activities at Onne from 1982 to January 1986 were carried out by a Dutch Research Associate-expert, Ir. A.C.B.M. van der Kruijs, supported by three Nigerian field staff. Backstopping was provided by IITA and IB staff. At the termination of his assignment as associate-expert, Ir. van der Kruijs was absorbed in the IITA core program.

An important component of the project is the training of junior scientists from developing countries under the supervision of the project's scientific staff at IITA and IB. In the first phase of the project, a total of nine trainees were involved in the project's field activities.

Three of the nine trainees were in training programs for more than six months. These long-term trainees were involved in the following projects:

1. Crop uptake and leaching loss of nitrogen from ^{15}N-labelled urea using lysimeters in S.E. Nigeria (Wong Ting Fook, Mauritius, Ph.D. thesis research, University of Reading);
2. Factors affecting establishment of selected tree species of potential importance in agroforestry (Bahiru Duguma, Ethopia, Ph.D. thesis research, University of Ibadan);
3. Root studies on an Ultisol in relation to nitrogen management (Kurniatun Hairiah, Indonesia, University of Brawijaya).

Short-term trainees (among which four were from the Rivers State University of Science and Technology at Port Harcourt) were involved in the general field of the project and in the evaluation of farming practices in the Onne area.

4. DISSEMINATION OF RESEARCH FINDINGS

4.1. Workshop

With additional funding from the Netherlands Ministry of Development Assistance, the project organized an international symposium on nitrogen management in farming systems in humid and subhumid tropics. The symposium was held in Ibadan, October 23-26, 1984. About 50 delegates from national and international institutions from the humid and subhumid tropics participated in this very successful symposium. In 1985, the proceedings of this symposium were published as a joint publication by IITA and IB.

4.2. Farmers' field days

With additional funding from the Netherlands Embassy in Lagos, local authorities and farmers from the Port Harcourt/Onne area were invited to the Onne station in order to become acquainted with the project activities. Special emphasis was given to demonstrating improved farming practices to the farmers and discussing these practices with them as a prelude to the initiation of research-managed trials on farmers' fields in the second phase of the project.

Over 200 participants, about 75% of which were farmers, participated in two field days. These first contacts with the local farmers have resulted in regular contacts and in exchanges of views with farmers in the area.

5. APPENDIX

BACKGROUND AND SUMMARY OF RESEARCH RESULTS

A. INTRODUCTION

The traditional upland crop-production system in large parts of the humid tropics including that in West Africa relies on a short cropping period followed by a long bush fallow period for soil regeneration. This production system is characterized by low cropping intensity and low crop yields with little or no input of chemicals. This system has provided traditional farmers for generations with a stable production method. However, during the last few decades the traditional system is undergoing rapid changes, mainly due to increasing population pressure. This has led to an increase in cropping intensity and a shortening or elimination of the much-needed fallow period, resulting in rapid soil degradation and low yield.

For prolonged or continuous cropping, the loss in soil fertility must therefore be compensated for by the use of either organic nutrient sources and/or fertilisers. Since traditional farmers in many parts of the humid tropics cannot afford costly inputs, efforts have to be made to either reduce dependance on chemical fertilisers or to increase efficiency of fertiliser use. For this purpose a nitrogen-utilization project funded by the Netherlands government was undertaken from 1982 to 1984. The projects which focussed on farming systems in the humid tropical region of West Africa was a joint effort of the International Institute of Tropical Agriculture (IITA), the Institute for Soil Fertility (IB), the International Fertilizer Development Centre (IFDC) and the Royal Tropical Institute (KIT). As a follow-up of this project a second phase also funded by the Netherlands government was undertaken by IITA and IB. This second phase began in 1985, and will continue for three years. The following contains a brief account about the progress of the two phases of the project.

B. ECOLOGY AND SOILS OF THE PROJECT AREA

The project is intended to serve the humid and perhumid tropical regions. These are areas with annual rainfall exceeding 1800 mm having little or no water deficit. The vegetation is tropical rainforest, which covers a large part of the coastal region of West Africa (including the IITA sub-station at Onne) and other parts of the tropics.

Although long-term weather information in not yet available for the Onne station, climatic data from Port Harcourt showed, that the area has an annual rainfall of approximately 2400 mm with a pseudo bimodal rain distribution. Pronounced cloudiness associated with the high-rainfall conditions results in significant attenuation of solar radiation. The amount of sunshine hours based on long-term observations averaged 4.2 hours per day, ranging from 2.0 hours per day in September to 6.1 hours per day in February.

The most common upland soils in the region are strongly acidic Ultisols and associated Entisols. Mineralogically, these soils are grouped as low-activity clay soils. Such soils are characterized by a low effective cation-exchange capacity, low base saturation, and high aluminum saturation of the exchange complex. These soils also have severe nutritional constraints. They are fragile soils that rapidly decline in productivity following bush fallow or forest clearing and cropping. With continuous arable farming, soil acidity and deficiencies of nitrogen, phosphorus, potassium, magnesium and zinc become major limitations to crop production. These soils are prone to soil compaction with mechanical cultivation and become subsequently highly erodible.

C. FARMING SYSTEMS

Traditionally, these soils are used for extensive subsistence farming based on long-term bush fallow for soil fertility restoration and weed suppression. With rapid population increases, the fallow period in some areas is becoming progressively shorter and is unable to restore adequately the soil fertility exhausted during the cropping cycle. For the Onne area the length of the cropping and fallow periods are estimated to range between 1-2 and 4-8 years, respectively. In these areas tree crop-based production systems are stable. The dominant cropping system is a root crops-based system consisting of intercrop combinations of maize, yam, cassava and plantains.

D. RESEARCH OBJECTIVES

For sustained crop production, nitrogen is the most limiting and the most costly nutrient in the humid tropics. However, information on the fate and utilization of soil and fertilizer nitrogen by food crops in this region is insufficient. Little quantitative data are available regarding the extent of leaching and total N-balance under different cropping systems. This information is needed for the development of effective food crop production systems under high-rainfall conditions. Field and lysimeter investigations were therefore carried out at Onne station, and soil and plant analyses were done at IB and IFDC. Part of the soil analysis that was supposed to be done at KIT due to the closure of the laboratory was transferred later on to Oosterbeek soils laboratory. The soil and plant analysis done in the Netherlands is financed by IB.

During the course of the investigations, particularly during the second phase of the project, more attention was given to the investigation of the roles and nitrogen contributions of annual cover crops and woody perennials in rotation and in alley cropping systems. A lot more emphasis will be given in the second phase of the project to have more on-farm trials and more collaborative work with National Agricultural Research Institutions in the area.

E. RESEARCH PROGRESS AND RESULTS

E.I. Field trials

E.I.1. Investigations of maize-and-cassava-based cropping systems

Field investigations on the nitrogen requirement of maize-and-cassava-based systems were carried out on land newly cleared from bush fallow over a four-year period. Results of the investigations are summarized below.

Maize performance

Even after a long period of bush fallow (over ten years), the maize crop responded to application of nitrogen on the strongly acidic Ultisol at Onne. Maize yield was highest in the first year following land clearing and gradually declined to very low levels with subsequent cropping with no nitrogen application. However, maize yield can be sustained at reasonable levels in subsequent years if nitrogen is applied (Figure 1). With application of 45 kg N/ha maize yield can be maintained at satisfactory levels with continuous cropping. Maize yield and nitrogen response was lower with the intercropped maize crop. Reducing the maize (and also the cassava) population by half from 40.000 plants (1982 and 1983) to 20.000 plants/ha (1984 and 1985) did not appreciably affect maize yield.

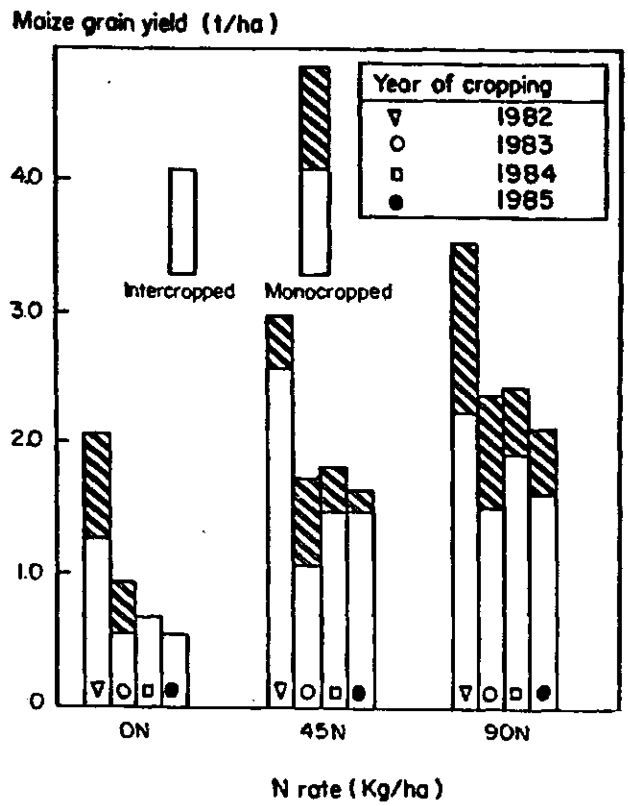

Figure 1. Grain yield of maize grown on land manually cleared from long-term bush fallow at Onne during a four year period as affected by nitrogen application and intercropping.

Inclusion of one second-season legume in the rotation system had no pronounced effect on maize grain yield; although maize yield tended to be higher following a **Mucuna pruriens** cover crop than after a cowpea crop. Inclusion of pigeon pea in a maize-cassava intercrop grown at low plant density tends to increase maize yield. Further research will be carried out to investigate the reason of maize yield improvement when maize is intercropped with pigeon pea.

Cassava performance

The yield of the first cassava crop following bush fallow clearing showed no response to nitrogen applied at the lower rates (Table 1). Tuber yields showed some decline with application of nitrogen at high rates due to vigorous vegetative growth and stronger competition by maize crop. In the second cropping year general tuber yields declined slightly. An application of 45 kg N/ha increased tuber yields, but no benefits were observed at higher rates of nitrogen application.

Halving the maize and cassave populations in the third cropping year (1985) restored cassava tuber yields to about 90% of the first years's level. It therefore appears that solar radiation may be as important a limitation as nutrients in intercrop system in the high-rainfall region.

Table 1. Maize and cassava yield in intercropping system at Onne in the first and third years after land clearing.

	Maize grain yield (kg/ha)				Cassava fresh tuber yield (t/ha)*			
N level (kg/ha)	Cropping system A		Cropping system B		Cropping System A		Cropping System B	
	1982**	1984**	1982***	1984****	1982**	1984**	1982***	1984****
0	1089	552	1417	776	28.5	14.1	27.8	19.4
45	2793	1554	2366	1428	22.3	13.7	25.8	19.3
90	2034	2224	2428	1612	12.1	11.8	27.7	20.3
135	2637	2924	2885	2014	24.3	10.8	22.9	24.2
180	2241	2976	2583	2052	16.8	14.6	19.7	28.2
Mean	2159	2064	2336	1576	22.6	13.0	24.8	22.3

* Harvested 11 months after planting
** Maize: 40,000 pl./ha; cassava: 10,000 pl./ha.
*** Maize: 40,000 pl./ha; cassava: 10,000 pl./ha; pigeonpea: 25,000 pl./ha.
**** Maize: 20,000 pl./ha; cassava: 5,000 pl.ha; pigeonpea: 10,000 pl./ha.

Nitrogen utilization

The efficiency of nitrogen fertilizer utilization declined considerably with increasing nitrogen fertilizer application. The maize crop utilized relatively more nitrogen in monocrop than in intercrop systems. Data from ^{15}N labelled fertilizer showed that the cassava crop can take up more of the applied fertilizer nitrogen than can the maize crop in an intercrop system. ^{15}N recovery data also indicate that three months after fertilizer application, the ^{15}N labelled fertilizer had disappeared from the rooting zone of the food crops.

E.I.2. Evaluation of nitrogen sources

To evaluate the effectiveness of three nitrogen sources (urea supergranules (USG), ordinary urea and calcium ammonium nitrate (CAN) and placement methods for upland crop production in sandy soils under high-rainfall conditions, trials were carried out at Onne for a two-year period using maize as a test crop. In both years maize responded significantly to N application. However, no difference in maize yields could be attributed to N source or placement method. The three N sources appear to be equally effective. There were no differences in maize yields between broadcast and band application of prilled urea. There was no residual effect on a second maize crop in either of the years.

E.I.3. Studies on plant density and root development

Results of the maize-cassava intercropping trials showed that a low level of radiation appears to be a limiting factor for crop production. To improve the efficiency of utilization of solar radiation, a spacing experiment with intercropped maize and cassava was carried out. The results showed that maize plants planted individually in the row had higher yields than those planted in clusters, a planting practice widely used by local farmers. Root studies further confirmed that maize plant have more evenly distributed individually roots than do those planted in clusters (Figure 2).

The root studies also revealed the complementary nature of the root systems of maize and cassava in intercropping systems. The cassava roots grow deeper than those of maize (Figure 2).

Further studies are required to improve depth of root development so that the nutrients leached into the lower soil horizons can be used by the crops.

E.I.4. Investigations on leguminous cover crops

The performance of some annual cover crops (**Centrosema macrocarpum, Desmodium ovalifolium, Pueraria phaseoloides, Psophocarpus palustris, Mucuna pruriens** and **Vigna unguiculata** (= cowpea)) in acid soils was studied in a field experiment at Onne. The objectives were to assess the cover crops for weed control, their biomass production and nitrogen contribution. Studies show large differences in biomass production and root

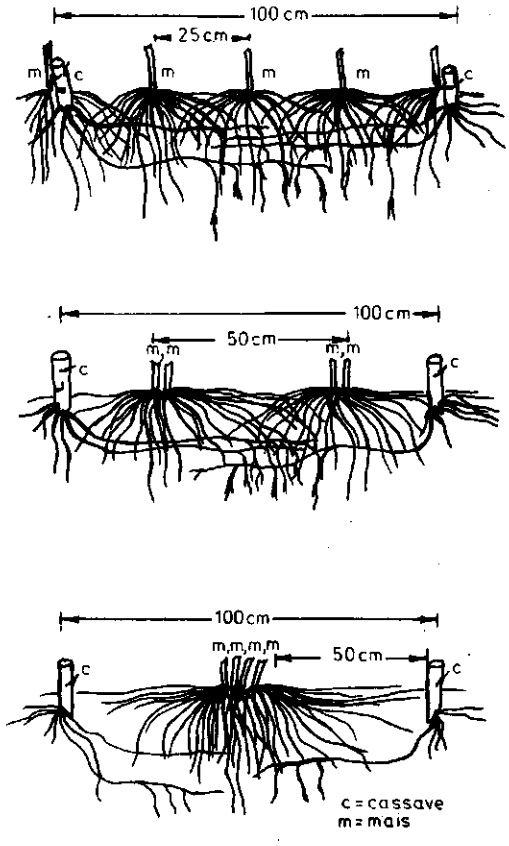

Figure 2. Root distribution of intercropped maize and cassava at Onne (C = cassava; M = maize).

devel mass, a low root/shoot ratio and a relatively high N concentration. However, their root development is rather shallow and poor. Other species have slower growth as seen from measurement of percentage of light interception (Figure 3), these species have more extensive root systems and higher root/shoot ratio, especially **Centrosema.** This species develops a deep root system up to 100 cm depth. **Pueraria** shows good nodulation. **Psophocarpus** and **Desmodium** grew poorly on strongly acidic soils. They establish slowly and require frequent weeding for good establishment.

E.I.5. Alley cropping trial

Alley cropping is an agroforestry system in which food crops are grown in the alleys formed by planted hedgerows of trees and shrubs. Also, periodic prunings of the hedgerows prevents shading of the food crop and provides much-needed green manure and mulch to the crops. This will help in nutrient recycling, and in the case of woody species nitrogen is also contributed to the system.

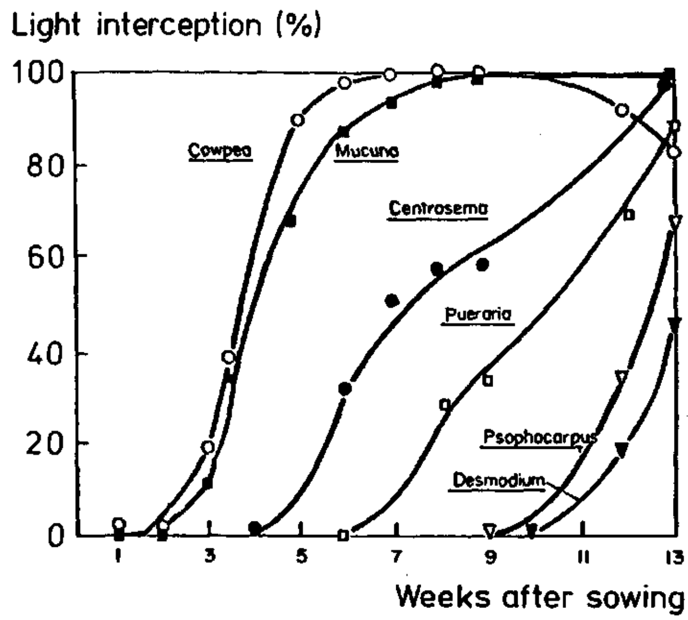

Figure 3. Light interception (%) by leguminous cover crops and cowpea with time.

Earlier studies have shown that some woody species such as **Flemingia congesta, Cassia siamea, Acioa barterii** and **Calliandra calothyrsus** grow well in strongly acid soils. A field trial was therefore initiated in 1983. Preliminary observations show that food crops such as cassava grow well when alley cropped with **Cassia siamea** and that plantain does well when alley cropped with **Flemingia congesta.**

E.II. Lysimeter studies

Nitrogen balance and nitrogen leaching was studied in tension-drained monolith lysimeters over a two-year period using maize as a test crop in the first season and upland rice as a test crop in the minor season.

For both seasons only one nitrate peak was observed suggesting that only the first-season N application was leached beyond 120-cm depth. A substantial amount of the mineralized N, formed at the onset of the rain, leached readily as nitrate (Figure 4). The amount of mineralized N that was leached out also exceeded the total uptake by the maize crop. Therefore, adjusting the time of planting may increase the efficiency of the utilization of soil mineralized N. In the year of application, over 20% of the first-season-applied fertilizer was lost by leaching. Of the nitrogen in fertilizer applied to a second-season rice crop, 20% leached below the 120-cm depth in the next year.

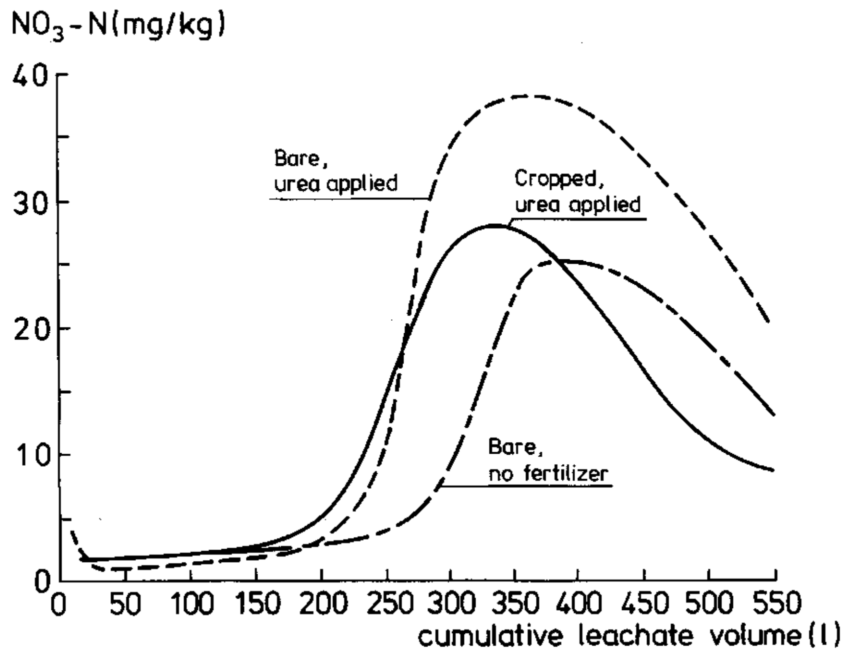

Figure 4. Leaching patterns of nitrate in monolith lysimeters under cropping and bare fallow, Onne, Nigeria.

The leaching loss was higher from the bare soil (49%) than from the cropped (27%) soil. Half of the applied fertilizer is either "stored" in the soil or lost from the profile by denitrification and/or volatilization.

The leaching of nitrate was also accompanied by large losses of calcium, magnesium and potassium.

E.III. Soil organic matter studies

With low-activity clay soils, the management of soil organic matter is important if soil productivity is to be maintained. Data on the analysis of the status of soil organic matter are still processed.

Mineralisation measurements of soil organic matter assessed weekly showed large fluxes in NO_3-N and NH_4-N at the onset of rains. The first results indicate that substantial amounts of soil organic N are being mineralized at the onset of the rainy season, with ammonium N being the prevalent form of mineralized N. Only a small increase in mineral N is observed in the second season.

In the second year following bush clearing, the mineralisation rate of organic matter declines considerably. Early planting in the area should be given much attention in order to utilize the N-flush at the beginning of the rainy season.

A long-term incubation experiment was carried out at IB in 1981. This experiment, which will be conducted over a six-year period, is designed to assess the rate of decomposition of residues of several plants (maize, cassava, cowpea, etc.) under controlled conditions.

F. ON-FARM ACTIVITIES

During 1985, on-farm research was carried out with selected farmers in the Onne-area in order to evaluate acceptance of technology, developed at the IITA substation at Onne. The first results indicate good acceptance by the farmers of the introduction of cowpeas as a second season crop and of woody leguminous fallow species such as **Flemingia congesta** for soil improvement.

As part of these activities, alley cropping plots were also established at Ohaji in the Owerri area. These trials were co-supervised by national institutions in the area.