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AFRICAN FOOD PRODUCTION: RESEARCH AGAINST TIME

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African food production: research against time

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In Asia the introduction of improved agricultural techniques has effected what is now commonly called the Green Revolution. A similar drive is urgently needed to arrest the current alarming decline of agricultural productivity in Africa. To this end the International Institute of Tropical Agriculture has since 1967 conducted a comprehensive programme of research concentrating on problems peculiar to Africa and, no less important, devising methods of ensuring that the results can be utilized by small and medium farmers familiar only with traditional methods.

The greatest paradox of tropical Africa is the co-existence of abundant natural resources, land, and water and the dismal performance of agriculture. Over the past two decades, self-sufficiency in food for the countries south of the Sahara has steadily been dissipated, in spite of the commitment of the independent national governments to accelerated development. Per capita food production has declined in 30 out of 35 countries.

Many countries have been left with no other option than to divert scarce financial resources for grain imports, which have doubled in volume and increased fivefold in cost in the decade of the 1970s. In 1980, food imports in these countries have liquidated 32 per cent of their export earnings. As a consequence, overall economic development is held in ransom by the threat of famine and malnutrition. The international community has escalated its development assistance to Africa by food aid, concessional food sales, and strengthening national institution building. The long-term solution to the food crisis in Africa must come from the transformation of traditional agriculture into science-based farming. Although it represents a very small part of development assistance, the international community's support to Africa through the Consultative Group for International Agricultural Research constitutes a crucial input, which can elevate Africa from the current food deficit malaise into one of self-sufficiency and overall economic development.

Research institutions responsible for food crops in Africa on the national level are, for the most part, still in the formative stage and are often poorly funded and understaffed. Trained professionals, especially those who conduct research and extend results to farmers, are very scarce. These fledgling institutions are under severe pressure not only from the magnitude of the food crisis but from the complexity of humid zone agriculture itself — basically labour-intensive cultivation of poor soils in an inhospitable environment.

In the 1960s, Asia went through much the same crisis that Africa is experiencing now. But several Asian countries—all of them big importers of food—pulled out by adopting technology from national and international agricultural centres and by making a solid commitment to rural development. Their efforts resulted in what has come to be called the Green Revolution. Now necessity calls Africa to undergo the same sort of revolution.

The International Institute of Tropical Agriculture (IITA), which is one link in a network of 13 agricultural research and training centres around the world, was officially founded in 1967, based on proposals and funding by the Ford and Rockefeller foundations and with a Nigerian Government grant of 1000 hectares of land near Ibadan, and a later gift of 80 hectares for a high-rainfall research site at Onne, near Port Harcourt, to assist in solving food production problems in the humid and subhumid tropics, with special crop responsibilities in Africa.

IITA has a staff of over 130 scientists who come from some 40 different countries. The Institute is now a member of the system of international agricultural research centres for which support is provided by governments, development agencies, and foundations through the Consultative Group on International Agricultural Research, which solicits and distributes funding among research centres. Over the years, more than 30 donors have contributed to the financial support of IITA.

The work of the Institute falls in three general categories—the effort to develop a system of farming that will be more productive than traditional bush fallow methods; the selection and breeding of high yielding crop varieties that are resistant to the major diseases and pests; and the strengthening of national agricultural research systems throughout the humid and subhumid tropics by a comprehensive training programme and collaborative research.

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Regarding as fundamental its responsibility to support and strengthen national research programmes, IITA is involved in cooperative programmes and collaborative research in many parts of the world, and especially in Africa. The benefits of this approach are reflexive and cumulative—allowing each institution to build upon the work of the others.

What follows is a summary of the problems facing IITA scientists, some of the Institute's achievements, and a survey of major research projects now under way.

Farming systems

IITA farming systems research began with two practical questions: Why do most tropical soils become unproductive and useless after only a few years, and what can be done to arrest this deterioration.

The programme thus tackled, on a complementary track with the Institute's crop improvement research, the major problem of tropical agriculture—the inability of the land to sustain annual food crop production for more than a few years at a time.

The results of nearly 15 years of research in pursuit of these two questions are quite clear, even though solutions to the problems in terms of the economic and social capacities of the farming structure are still difficult to design. When tropical forest is cleared and land cultivation begins, the majority of the soils change rapidly in many ways, and most of the changes appear to be negative.

Chemically, the land becomes more acid very rapidly. Essential plant nutrients are lost, even when fertilizer is used. Physically the soil seems to collapse on itself. It becomes denser, less porous. Often erosive forces cause the finer particles to disappear, leaving a sandy or gravelly material. The soil loses its capacity to form stable aggregates because the binding material, the soil organic matter, is gone. The original layer created by forest cover will often disappear in one or two years, leaving little of the original humus.

Once cleared, the land contains fewer and shallower roots, thus breaking the cycle between subsoil and the surface. More seriously, when the forest canopy is gone, surface temperatures, which rarely exceeded 26°C under forest cover, rise as high as 45°C. Biological activity drops, and much of the accumulated material literally burns up. The effect is a rapid downward spiral, where the decline in organic life and residue causes a collapse of the soil structure and a drop in retention of water and nutrients, an increase in acidity, and a decrease in plant growth that, in turn, reduces the supply of organic residues. The soil structure becomes less permeable and more vulnerable to erosion.

The answer for successful clearing and cultivation seems to lie in imitating, as closely as possible, the traditional bush fallow system. The IITA Farming Systems Programme has developed a number of soil and residue management alternatives that prevent or delay the breakdown of soil productivity. One is the no-tillage system, in which the plough and disk-harrow are discarded and the crops are sown directly into the untilled land. IITA crop plots under this system have produced good sustained yields after 3–4 years while land under normal cultivation with modern soil conservation measures has become semi-sterile.

Tillage is an age-old technique to control the weeds and to produce a soft seed bed for germination. In tropical highly fragile soils, it can result in horizontal and vertical displacement of fine soil particles which are rich in plant nutrients. The no-tillage system utilizes herbicides to control the weeds and mulch and to minimize direct impact of rain and replenish organic matter.

While it seems to be a simple solution, the no-till system is very difficult in practice and hard to adopt on a large scale. Weeds and bush regrowth, unchecked by ploughing, compete with crops. The thick layer of plant material on the soil surface makes mechanization difficult. Weed management research, including the use of herbicides, is being carried out at IITA, and the Institute's agricultural engineers have developed a series of small planters and applicators capable of operating under 'trashy' conditions. It is hoped this small-scale mechanization can be perfected for commercial distribution.

The need to develop practices similar to the recycling system of the original forest has led to studies on 'alley cropping', the use of rows of fast-growing trees between broad beds of field crops. The preferred tree species are two leguminous nitrogen-fixing shrubs, Leucaena and Glyricidia, brought in from Asia and South America. The shrubs are pruned at regular intervals during the growing seasons and the clippings are used for organic mulch. The shrubs provide some shade for temperature control and are sufficiently deep-rooted to continue growth during the five months dry season at Ibadan.

Alley cropping fields at IITA and other locations have produced good crops for at least eight consecutive years. It appears that the method can substitute for a bush-fallow cycle. But again, this system has to develop its own management technologies. Many of the shrubs are sensitive to any herbicide that might be used, and inter-row tillage is feasible in alley cropping only if the alleys are properly spaced.

IITA scientists are also conducting research into the production of dead and live mulches. Most of the studies have concentrated on leguminous plants with good nitrogen-fixing ability and vigorous growth. It has been found, however, that many of the leguminous plants decompose rapidly under microbial action because of their high protein content and do not give lasting protection from rain and sun.

One, a vigorous cultivar of the annual Velvet Bean (*Mucuna utilis*), appears to be able to produce up to 20 tons per hectare of mulch a year, leaving a thick carpet of vines and leaves resistant to deterioration. Good maize stands have been achieved when planted through this cover with an IITA rolling injection planter. The use of this cover crop in a food crop production cycle is proving, under proper management, to benefit soil fertility. The thick mulch suppresses weeds for at least one cropping cycle, reducing the farmer's investment in time-consuming weeding. Earthworms appear to favour this dense cover; fields of *Mucuna* are covered with earthworm casts after a year.

Figure 1 Cassava plant with heavy mealybug infestation. When the terminal shoot (the preferred part) is completely destroyed, the cassava mealybug moves to the leaves. Note the development of a fungus on the mealybug honeydew on the stem.

Another approach in producing thick mulches is growing them simultaneously with the crop. This is done by seeding perennial creeping legumes under maize or sorghum and controlling them with chemical growth retardants so that they suppress weeds without competing with the crop.

During the last year and a half, the Farming Systems Programme has collaborated with other institutions to develop better ways of transferring research findings to farmers and to determine in what ways farmers would accept change in their farming systems. A regional programme for West Africa for On-Farm Adaptive Research (OFAR) has been created in which IITA is playing a key role. The OFAR system contains two major elements: a diagnostic socio-economic and agronomic research phase, and a cooperative experimental programme with on-farm involvement in differing ecological areas. The system will define what is needed at the small farmer level and what the expectations of farmers are. It will evaluate research results under actual farm conditions.

Even though IITA's major emphasis is directed toward the small and medium farmer of the humid tropics, some attention is being paid to the application of these same principles to large-scale farming. A number of governments in the humid tropics of Africa and other continents have definite policies for the development of large-scale farming in their countries as a principal device for food security. Large-scale farming under no-tillage and mulch cover conditions presents its own set of difficulties. IITA is testing and looking at various mechanical and biological means to alleviate these problems.

Root and tuber improvement programme

Roots and tubers form an important part of the diet in most tropical areas, being naturally adapted to the soils and climate of the region. Root and tuber crops are capable of producing more calories per hectare than any other food crop. They grow well under diverse climatic conditions and have the ability to recover from disease, or insect attacks, or unusual weather conditions. Nearly 85 million tons of roots and tubers are grown annually in Africa for human consumption. The four root and tuber crops on which research is carried out at IITA are (in order of current priority) cassava, yams, sweet potatoes, and cocoyams.

Africa produces 48 million tons of cassava annually from 7.4 million hectares, providing more than 50 per cent of the caloric requirement for 200 million people on the continent. Production is most extensive in Nigeria and Zaire. However, the average cassava yield in Africa is very low—6 tons per hectare, as compared with a potential of 15–20 tons.

The two most serious problems facing the IITA Root and Tuber Improvement Programme in the early 1970s were disease-related—the endemic cassava mosaic disease and the fast spreading epidemic bacterial blight. The major part of the Institute's early research was directed toward the developing of varieties resistant to these diseases. Fortunately, as work progressed, it became apparent that there was a high correlation between resistance to one and resistance to the other. A recurrent selection system was established for improvement of populations for disease resistance and other agronomic characters while maintaining large genetic variations. Resistance alone was improved in one cycle, taking 1–2 years, but it took 4–5 years to combine it with a high yield potential.

As they are developed, improved cassava varieties are distributed to national programmes, either as true seed for reselection and adaptation programmes or as clonal material produced by the IITA tissue-culture laboratories. Stem cuttings, the customary planting materials, cannot be transmitted across national boundaries because of phytosanitary restrictions.

Improved cultivars developed at IITA over the past eight years have out-yielded local cultivars by a factor of from 2 to 18 times, especially under severe mosaic or bacterial blight exposure. Particularly good progress has been made by national resistance breeding programmes using IITA-supplied seed in Nigeria, Gabon, Zaire, Sierra Leone, Tanzania, Liberia, the Seychelles, and India.

A more recent threat to cassava production in Africa has been the appearance and rapid spread of two exotic insects—the cassava mealybug,

Phenacoccus manihoti (figure 1), and the green spider mite complex, *Mononychellus* spp. (figure 2), believed to have been accidentally introduced from the Americas in the early 1970s. They have now spread over roughly half the cassava-growing areas of the continent. In three-fourths of these areas, they occur together, where they compete for the same part of the plant—the tender growth shoots. Both attack the plants throughout the year with population peaks in the dry season.

IITA has investigated both biological control and resistance breeding as countermeasures and met with some success in both approaches. Natural enemies of the mealybug (*Scymnus* sp. and *Apoanagyrus lopezi*) have been located in Latin America, cleared through the Commonwealth Institute of Biological Control and national quarantine procedures, and released experimentally in Nigeria, where they are establishing themselves successfully. Several species of predatory mites have been identified and are being used in experimental trials at IITA during 1983. At the same time, some qualities of resistance to either, and usually both, of these insect pests have been found within IITA's germplasm collection, and work is under way to incorporate these qualities within the IITA elite cassava varieties.

Since the problems specific to Africa can now be considered as under some degree of control, the IITA Root and Tuber Improvement Programme will give greater attention to breeding aimed at elevating the yield potential of cassava. Two main research areas are likely to be emphasized. The first is resistance to nematodes and the other is anthracnose. Nematode resistance may exist in some related species of cassava, and inter-specific hybridization will be used in the hope of transferring this and other desirable characteristics to cultivated varieties. A screening methodology for anthracnose resistance is now being sought.

Yams (*Dioscorea* spp.) are a traditional crop in West Africa, which accounts for over two-thirds of the world production. Research at IITA has centred on improving genetic variability and propagation materials, as well as developing a plant that will produce well with minimum staking. The major problems associated with yam cultivation are high labour requirements for staking and harvesting, and the necessity of setting aside up to one-fourth of the crop for use as planting material.

Figure 2 A leaf area reduction caused by the green spider mite on a susceptible cassava clone compared to normally developed leaves on a resistant clone.

Initial work at IITA established that yam seeds, which had previously been regarded as an unviable means of propagation, were indeed capable of germination, after a dormancy period. This discovery has made possible the development of breeding lines by hybridization. Although some limitations still need to be overcome, IITA scientists have succeeded in breeding improved families and lines of the white yam (*D. rotundata*) and work has begun using newly-available seeds from water yam (*D. alata*). Major breeding objectives of virus and nematode resistance, high yields with minimum inputs, and good storage ability now seem feasible.

In most yam-producing areas, the cost and availability of planting material are major limiting factors. IITA research has developed two methods of preparing planting material. One is a rooted vine system, useful for rapidly multiplying élite clones that are free of nematodes and other soil pathogens for advanced testing in breeding programmes. The other is the 'Anambra minisett system,' which enables growers to produce yam setts for sale to other farmers on a commercial basis. More than 25 000 seed-yams can be produced from one hectare using this system. A third method, using true seed to produce seed-yams, is now being tested.

In an effort to breed yam varieties that will yield well without staking, good results have been achieved in producing small seed-yams but staking is still required to produce high yields of market yams. Much work also remains to be done both within the breeding programme and in post-harvest management studies to improve yam storability.

The most serious biological constraints to sweet potato production in the tropics are weevils and viruses. The sweet potato virus disease complex consists of two components—one, which appears to be fully latent in all genotypes of sweet potato and is transmitted by aphids, and the other, transmitted by the white fly. Damage occurs only when both are present. Factors of resistance to disease infection and to disease spread have been found among IITA's élite varieties, and some of these varieties show resistance to the weevil as well. In particular, varieties TIS 2498 and TIS 2534 have consistently shown superior and stable performance in Nigeria over several years under widely different and generally poor environmental conditions.

Through the Institute's tissue culture laboratory, disease-free sweet potato and cassava clonal material has been distributed to over 20 countries around the world.

Cocoyams, particularly *Colocasia* sp. and *Xanthosoma* sp., are found in all tropical regions of the world, but are less important in economic terms. IITA scientists have succeeded in promoting flowering through the use of giberellic acid, which has greatly expanded the opportunities for genetic improvement. The long-range objective is to identify clones of *Xanthosoma* showing satisfactory levels of resistance

to root rot blight complex. This work is being carried out in Cameroon, in association with the national research programme. Some resistance has been found, but not of satisfactory levels as yet. One result of the work has been to show that cocoyams are resistant to nematodes, suggesting the possibility of their playing an increasing role in crop rotation.

Cereal improvement programme

The IITA research programme has regional responsibility, within the international research centres system, for work on maize and rice in Africa. Both of these crops are important in the African economy and both still have immense potential in terms of yield improvement as well as area cultivated. Working with breeding materials from the global centres (Centro International de Majoramiento de Maiz y Trigo—CIMMYT, International Rice Research Institute—IRRI) and from African sources, IITA researchers seek solutions to specifically African problems such as maize streak and stem borers and the African forms of rice blast and yellow mottle virus. It collaborates in this work with the Institut de Recherches Agronomiques Tropicales (IRAT), the West Africa Rice Development Association (WARDA), and the Semi-Arid Food Grains and Development Project (SAFGRAD).

Maize, one of the leading crops cultivated in Africa south of the Sahara, is widely used for human consumption and is increasingly in demand for poultry feed as countries seek to reduce dependence on imported supplies.

The major objective of the maize improvement programme at IITA is to develop stable, high-yielding varieties that are adapted to the various ecologies and consumer preferences of Africa. The programme's approach in breeding is to carry out population improvement and international, multilocational progeny and variety trials in cooperation with national programmes. Through this approach, the programme has developed early, medium, and late maturing populations with yellow or white kernels and flint or dent type grain, and is now focusing mainly on achieving varietal stability through resistance breeding for the major diseases and insect pests in Africa.

Early maize work centered on improving resistance to lowland rusts and blight. Two populations developed—TZPB and TZB—were tested in Nigeria through the minikit programme of the National Accelerated Food Production Programme, where they consistently outyielded local varieties. Seeds of these varieties now make up 60 to 70 per cent of maize seed production of the Nigerian Seed Service, enough to plant 200 000 hectares in 1983. TZPB has also been released in Cameroon, where it now covers 150 000 hectares.

Attention in the IITA maize breeding programme was subsequently directed toward resistance to maize streak virus (figure 3), one of the main factors responsible for the low productivity of maize in Africa. Two resistant populations—TZSR-Y-1 and TZSR-W-1—have been developed and tested throughout Nigeria, where their yields have been comparable to the popular, but nonresistant, TZPB and TZB families. They are now being tested in multilocational trials throughout Africa, where they appear to yield well under a wide variety of growing conditions.

Figure 3 Resistant breeding nursery of maize against maize streak virus, showing resistant plants right, and susceptible plants left.

The maize mottle virus also threatens African maize production. It is transmitted by the same leafhopper species as the streak virus, and there is some evidence that streak resistant varieties may also be mottle resistant.

With the completion of additional insect rearing facilities at IITA during 1982, the Institute has stepped up its work on the stem borers, the most serious maize pests in Africa. Work is most advanced on *Sesamia calamistis*, which is found in the lowland humid tropics. A screening methodology for resistance has been established, with encouraging results. Certain basic methodological information is still lacking regarding screening for resistance to *Eldana saccharina*, and work on *Busseola fusca*, a major pest of the savanna regions, is just beginning. Components of integrated pest management of *Sesamia* and *Busseola* are also under study.

A third objective of the maize programme, the development of varieties for semi-arid conditions, is carried out, for the most part, by the IITA/SAFGRAD team in Upper Volta. Crosses between United States and tropical germplasm are showing great promise. The work with simple agronomic practices to conserve soil moisture shows positive results.

A major Nigerian programme for the development of hybrid maize has made it possible for IITA to accelerate and broaden the scope of its work in this area. The first hybrids are now likely to become available at farm level in Nigeria by 1985.

Although the area planted to rice in Africa is still relatively small, demand for this crop has been growing steadily—a reflection of increased urbanization. Sub-Saharan Africa now imports 16.5 per cent of the world's rice trade. The principal objective of IITA's rice improvement programme is to increase production through research on dryland, hydromorphic, and irrigated swamp ecologies. The strategy is first to develop superior adapted varieties

resistant to stresses common in African regions and, second, to develop appropriate cultural practices to improve the performance of these varieties. The development of a translucent, long-grain type is also important for the African consumer.

Most of the rice currently produced in Africa is grown in upland conditions, although researchers see great potential for lowland cropping. Local upland varieties are generally adapted to climatic and disease stresses, but yield poorly, tend to lodge with increased fertility, and do not respond well to improved management. IITA has worked to solve these problems through a hybridization programme of local varieties with high-yielding semi-dwarf varieties developed for the lowlands. A technique for selecting, in the seedling stage, semi-dwarf segregants with deep, thick roots has been developed—the thickness of the root contributing to drought tolerance and the dwarf gene both reducing plant height and improving tillering. IITA varieties have out-yielded the dominant local upland variety, OS-6, by a wide margin in Nigerian national trials and were top performers for drought tolerance and recovery in the IRRI international tests.

IITA has also produced élite germplasm with tolerance to iron toxicity and rice yellow mottle virus, a disease that occurs only in Africa. This resistance is essential in lowland varieties for Africa. Host plant resistance to stem borers, particularly to *Diopsis* spp., the stalk eyed fly, is being sought.

Low yields of African lowland, or irrigated, rice have often been blamed on the climate. However, it is becoming apparent that the problems are more often unadapted varieties, untimely planting, inadequate plant protection, and poor crop husbandry. IITA researchers have found, for instance, that rice planted so that it ripens during periods of ascending solar radiation (that is, in Nigeria, September-October and March) yielded nearly twice as much as those which ripened during periods of unfavourable radiation.

At the same time, a number of subsidiary aims are assuming increasing importance. Improved tolerance of low temperatures is being sought for second-season rice in the savanna areas and for the East African highlands. Work recently begun with the National Cereals Research and Extension Project in Cameroon indicates a primary need to incorporate resistance to sheath rot and blast into these cold tolerant cultivars. Weeds are a serious problem in upland rice cultivation and in lowland areas where water control is erratic. The need to hire bird-scarers to protect the ripening grain is a growing labour expense, particularly as the traditional bird-scarers, the children, are increasingly attending primary schools. This is a problem which requires continuing attention if rice production is to be economically viable, but it is doubtful whether it is amenable to a breeding approach.

Grain legume improvement programme

The Grain Legume Improvement Programme comprises two crops—cowpeas, for which IITA has worldwide responsibility within the international research centres system, and soybeans, for which it has regional responsibility in Africa. Both of these legumes are important sources of plant protein for human consumption; soybeans could, with expanded production, do much to help meet the growing demand for domestically produced vegetable oils and animal protein feed.

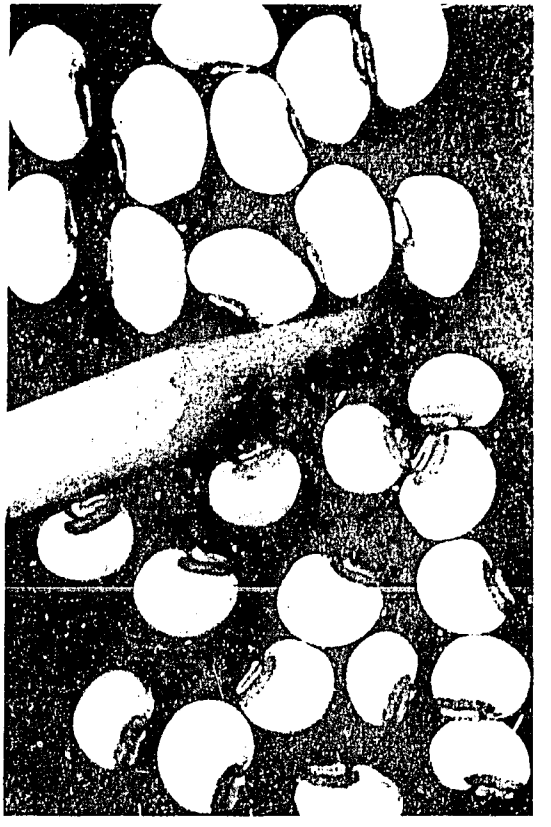

Figure 4 Cowpea seed from backcrosses with VITA-5 are 20–40 per cent larger than the original VITA-5 seed.

Cowpeas originated in West Africa, but are now common in many other parts of the continent. They are also cultivated under marginal moisture and poor soil conditions in Asia and South and Central America. IITA's early work on cowpea improvement was mainly devoted to basic research on crop physiology and to the development of host-plant resistance to insects and diseases. Sources of resistance to most of the important diseases, and many combined sources of resistance, were identified and incorporated in breeding lines. A large portion of the 92 élite cowpea lines distributed in international trials since the mid-1970s have high levels of combined resistance to the principal bacterial, fungal, and virus diseases.

With the 1980s, insect resistance has assumed the highest priority—principally in reference to flower thrips, *Megalurothrips sjostedti*, pod borer, *Maruca testulalis*, and the bruchid, *Callosobruchus* spp. The IITA germplasm has yielded sources of reasonable resistance to bruchids, which do considerable damage to cowpeas in storage, and of moderate resistance to thrips and *Maruca*, both of which cause substantial losses in the field.

Variety TVx 3236, hybridized from a thrip-resistant variety and Ife Brown, the most locally popular improved variety, is moderately resistant to flower thrips and has good grain type and cooking quality. It has been especially successful in northern Nigeria where yield trials were conducted on several farms in Kano State by the farmers themselves in cooperation with local agricultural officials. The average of all reported yields, based on samples from each farm, was above 1000 kilograms per hectare, compared with a national average of 212 kg/ha. In 1983, the Kano Agricultural and Rural Development Authority expects to release 50 000 kilograms of seed to approximately 5,000 farmers, who will grow TVx 3236 on about 5000 hectares. If well managed, this seed should be sufficient for planting 500 000 hectares in 1984. Altogether, IITA-developed varieties have been locally adapted and are out-producing local varieties in West Africa and in several countries around the world—principally Brazil, Nicaragua, Guatemala, South Yemen, and Tanzania.

Another approach to increased cowpea production that has been very successful has been the development of extra-early maturing varieties, popularly referred to as '60-day' cowpeas. Initial research on this type was carried out by IITA researchers in Tanzania, who planned to use it as a catch crop for the short rainy season. The lines they produced have opened up the possibility not only for successful monocropping in a short rainy season, but for double cropping on rice fallows, relay cropping in relatively larger rainfall areas, and parallel multiple cropping with cereals and cassava. At the IITA substation at Onne, Nigeria, 60-day cowpeas were grown in the residual moisture of the rice fallows, with yields ranging from 600 to 1300 kilograms per hectare. At present no crop is grown in this area after the rice harvest, and a successful double-crop of cowpeas could have immense economic importance to the farmers there.

The original extra-early maturing cowpea lines have been further hybridized to develop lines with rough, white seed coats, the preferred type in West Africa. Now work is continuing to breed this early maturing characteristic into the seed types preferred in other parts of the world. Not only do these varieties allow farmers to get one or more extra crops per year, but the plant type matures uniformly, reducing labour requirements for spraying or harvesting, and opening up the possibility of mechanical harvesting (figure 4).

Soybeans, although they are not cultivated as extensively in Africa as cowpeas, have enormous potential on the continent. IITA soybean research has placed primary emphasis on compatibility with indigenous rhizobia, seed storability, and yield capability. Genetic improvement of both soybeans and cowpeas is reinforced by soil microbiology research which so far has focused on biological nitrogen fixation.

IITA scientists have identified several soybean varieties that nodulate consistently with indigenous African rhizobia, with resulting vigorous plant growth. Called 'promiscuous nodulators' because of their indiscriminant characteristic of forming symbiotic relationships with various rhizobia strains, they could provide an opportunity for farmers in Africa to grow soybeans without commerical inoculants.

In 1978 a crossing programme was begun to incorporate this promiscuity characteristic into genetic backgrounds adapted to different tropical environments. The programme has made significant progress. In 1981 advanced breeding lines were tested at six ecologically different locations in Nigeria. The promiscuous lines nodulated well and grew vigorously. Advanced lines have also been sent to 25 locations throughout Africa for additional testing.

Rapid seed deterioration, both before and after harvest, continues to be a constraint to increased soybean production. IITA has made some progress in identifying varieties with resistance to storage losses. A recently developed method for identifying lines with resistance to field weathering will greatly aid this research.

Training

The importance of increasing the number of trained researchers and technicians in African national programmes cannot be over-emphasized. Without this essential link to the farmer-producer, the work of international research is done in a vacuum. The number of university students and national programme staff members that come to IITA for various levels of training has increased every year, but applications are still considerably greater than the Institute can accommodate. Their numbers include post-graduate students who work on the research portion of their degrees under the supervision of a senior scientist; undergraduates receiving some research experience; and staff members of departments or ministries of agriculture, international agencies, and other organizations who gain additional technological knowledge or skills tailored to their individual needs.

Since the programme started in 1970, 144 PhD candidates from 12 countries have engaged in research at IITA. In addition, each year up to 20 undergraduates are chosen from African universities to get research experience at IITA for three to four months during their final long-vacation period. Non-degree training is more flexible, and, since 1970, over 200 government or related agency personnel have participated in individually designed programmes. By far the largest number of training participants, 1859, have been involved in group courses of various lengths of time up to 16 weeks.

Bibliography

More detailed information of the work of the IITA will be found in its *Annual Reports*.

Protein deposition in animals

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The deposition of proteins in tissues of farm animals is a consequence of the balance of the rates of protein synthesis and degradation tissues. This turnover contributes to the energy costs of protein deposition. Protein metabolism is strongly influenced by the hormonal status of the animal and this is being exploited currently by the use of several hormones and hormone-like substances as growth promoters.

Numerous factors control the extent of and rate of protein deposition in animals. This review is limited to a few selected areas which have special relevance to the production of edible protein by farm animals.

Several generalisations can be made concerning protein deposition. The rate of protein accretion falls with increasing body weight and the proportion of fat to protein being deposited increases. Animals with a larger mature body size commence fattening at a relatively higher body weight, hence the longer fattening can be delayed the greater the production of lean tissue. The reduction in the rate of protein deposition is reflected in a drop in the efficiency with which dietary nitrogen is retained in the carcass. In the well fed pig this falls from about 50 per cent at 25 kg to 35 per cent at 100 kg and 22 per cent at 160 kg live-weight. The ability to retain protein can be affected by several factors: for example genetic origin, sex, environment, nutrition, and hormonal status.

The effect of hormones on body composition

The hormonal status of an animal is a major determinant of growth rate and of the relative rates of protein and fat deposition. Manipulation of the hormonal status by castration of the male has been common practice for many hundreds of years. In general this increases the fat content of the carcass: for example, in sheep from 2–28 per cent with a mean value of about 12 per cent. Androgens tend to stimulate protein deposition: bulls have a higher growth rate than steers and are more efficient at converting food to live weight. Exogenously applied oestrogens in ruminants, at least, stimulate growth, especially of the castrate male with some marked increases in the protein content of the carcass. Responses in females are less clear cut. In poultry, oestrogens markedly increase the fat content of the carcass and the growth rate of the animal. Cortisol administration to cattle and sheep reduces live-weight gain, with the fat content of the carcass increasing and the protein content being reduced. The effects of these and other hormones on carcass composition have recently been reviewed by H. Galbraith and J. H. Topps [1]. In many countries the implantation of animals with hormones and hormone-like substances to manipulate growth is a common practice (see below).

Protein turnover and deposition of protein

During the last fifteen years there has been an increasing awareness of the concept that proteins in almost all animal tissues are continually being synthesised and degraded and that the balance between these two processes dictates the rate of protein deposition. Many of the techniques and concepts associated with the significance and measurement of this turnover of protein are discussed in an excellent book by J. C. Waterlow, P. J. Garlick and D. J. Millward [2]. Although this book owes its origins to studies of malnutrition in children, the majority of its contents are applicable to farm animals.

Total body turnover of protein can be assessed from the flux through the plasma pool of an essential amino acid whose metabolism is essentially confined to protein synthetic and catabolic pathways. The best technique is to use a continuous intravenous infusion of [1-^{14}C] -leucine and to correct for leucine oxidation (see [3]). Total body turnover can be calculated if the mean leucine content of body protein is also known, and is found to be inversely related to metabolic body size and hence to basal metabolic rate (see Table 1), especially when only adult or slowly growing animals are considered. There is in general a positive association between heat production and total body protein synthesis, although this is not apparent, for example, in exercising animals and animals recovering from exercise [4].

Protein synthetic rates of mixed proteins in the individual tissues are measured using isotopically labelled amino acids. The amino acid is either continuously infused or given in a single dose. The incorporation of the label into the protein assessed and the fractional synthetic rate are determined from the calculated or determined change in the specific activity of the free amino acid in the intracellular pool (see [2, 5] for details). Protein degradation is much more difficult to determine and is often assessed from the difference between the synthetic rate and the

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