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**Proceedings of the
Nigeria–Australia Seminar
on Collaborative
Agricultural Research**

**Shika, Nigeria
14–15 November, 1983**

Editors: Saka Nuru and J.G. Ryan

**Federal Ministry of Education, Science and Technology, Nigeria
National Animal Production Research Institute, Shika, Nigeria
Institute of Agricultural Research, Samaru, Nigeria
and
Australian Centre for International Agricultural Research**

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Foreword

Australia and Nigeria have a lot in common. Besides their traditional ties as members of the Commonwealth, they have similar agroclimatic regimes in their northern latitudes and a history of quality research on the problems facing farmers in those regions. These semi-arid tropical (SAT) regions have climates that are harsh and risky and, in the case of Nigeria, are amongst the more populous parts of the country. As a result, Nigeria was anxious to meet with ACIAR and Australian scientists familiar with the peculiar problems of SAT agriculture to explore with them how their expertise and experiences could be brought to bear on the concerns of counterpart scientists working in the same regions of northern Nigeria.

We are pleased that Australia was willing and able to respond to our overtures. This publication contains the papers presented by the Australian and Nigerian scientists at the Workshop and we are confident that they will provide the foundation for our future cooperation in agricultural research.

Bukar Shaib
Minister for Agriculture and Water Resources
Government of Nigeria, and
Member, Policy Advisory Council, ACIAR

Preface

The Workshop was a cooperative endeavour of the Federal Ministry of Education, Science and Technology, (FMEST) Nigeria and the Australian Centre for International Agricultural Research (ACIAR). Its objective was to provide a forum for exchange of ideas on agricultural research in Nigeria and Australia around which might be built a collaborative framework facilitated by ACIAR. It was held at the National Animal Production Research Institute (NAPRI) at Shika in Northern Nigeria on 14–15 November 1983.

Scientists attended from the following research institutes: NAPRI; the Institute of Agricultural Research (IAR), Samaru; Ahmadu Bello University (ABU), Zaria; the Institute of Agricultural Research and Training (IAR and T), Ibadan; the Lake Chad Research Institute (LCRI), Maiduguri; the National Veterinary Research Institute (NVRI), Vom; the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Samaru; the International Livestock Centre for Africa (ILCA), Kaduna; the Kainji Lake Research Institute (KLRI), New Bussa; the Nigerian Institute for Trypanosomiasis Research (NITR), Kaduna; and the Agricultural Extension Research Liaison Services (AERLS).

The Workshop was successful and provided ACIAR with a clear perception of where the best scope lies for collaborative agricultural research between the two countries. These are delineated in a concluding section of these Proceedings.

I would like to thank Dr. Bukar Shaib, a member of ACIAR's Policy Advisory Council, for

his guidance and support in arranging the Workshop and to Professor Saka Nuru, the Director of NAPRI at Shika and his colleagues for being such gracious hosts. Mr. Dominic Iyambo, Dr. Patrick Onuorah and their staff of the Federal Ministry of Education, Science and Technology were instrumental in facilitating arrangements with the Australian High Commission in Lagos. We thank them for their assistance. The Vice-Chancellor of Ahmadu Bello University, Zaria, Professor Ango Abdullahi, and the Acting Director of the IAR, Samaru, Mr. John Davies, were most generous in allowing their staff to participate in the Workshop. A special acknowledgement is due to Dr. Victor Adebambo of the Federal Ministry of Education, Science and Technology who facilitated travel, accommodation, banking, and other logistical arrangements without which the group would not have had such a productive visit, and we are most grateful to him.

His Excellency, Mr. Allan Taylor, the Australian High Commissioner to Nigeria, took a special interest in the Workshop and the visit of the Australian team. This was most appreciated, as was the assistance rendered by the staff of the High Commission in Lagos.

J.G. Ryan
Deputy Director
ACIAR
Canberra

Welcoming Address

Professor Saka Nuru*

The Vice Chancellor, Professor Ango Abdullahi, regrettably is unable to be with us this morning to welcome you all on this significant occasion, because of another equally important assignment. Prof. Abdullahi is right now in Lagos attending a meeting of the Committee of Vice Chancellors, which had been previously arranged before he received the notice of this seminar. He has asked me to inform you that had it not been that the topic for the Lagos meeting is crucial, and requires his personal presence, he would have very much liked to personally welcome you to Ahmadu Bello University. As it is, the Vice Chancellor has requested me to represent him and to welcome you all to this campus. On his behalf, I welcome all our guests to Ahmadu Bello University and in particular to the Agricultural Complex of this University. A special welcome to his Excellency, the Australian High Commissioner, and the Permanent Secretary, Federal Ministry of Education, Science and Technology, who, despite their heavy schedule of duty in Lagos, have found time to be with us for this seminar.

Our Chairman on this occasion, Dr. Bukar Shaib, is not new to this campus, as he was one of our Honorary Graduands. We reliably learn that this seminar is Dr. Bukar Shaib's brain-child. As Chairman of the National Committee on the Green Revolution and as a member of the Policy Advisory Council of the Australian Centre for International Agricultural Research (ACIAR), he has worked relentlessly to bring the Australian scientists and their Nigerian counterparts together to review some of the research efforts to date, and how best the scientists concerned can exchange ideas for national progress in agriculture. This is what we are about to witness for the next two days. We salute Dr. Bukar Shaib for his foresight and warmly welcome him to Ahmadu Bello University. Some of our august visitors from Australia are probably here at Zaria for the first time. We welcome you heartily and hope that you have a memorable sojourn. To the

rest of our guests we equally extend our warm and friendly welcome, and appreciate your being with us for this important seminar.

At this point of my address, let me say a few words about this seminar and our agricultural institutions here at Ahmadu Bello University. It is our understanding that the Australian Centre for International Agricultural Research is a statutory body established by the Australian government to encourage and support research in agriculture, with the aim of solving pressing agricultural problems in developing countries, in order to improve agricultural production in all aspects. This is a noble idea to which we fully subscribe. You are no doubt aware of the existence of agricultural research and extension institutions here at Ahmadu Bello University. Our Institute for Agricultural Research, one of the oldest institutions of this University, has established an international reputation in the field of arable crops, while our agricultural extension unit is second to none in this country. The National Animal Production Research Institute (NAPRI), where we are today, is over fifty years old, and has established its reputation in research in food-animal production, through its research in animal breeding and genetics, nutrition, and pastures. Some of NAPRI'S pasture research work has extended beyond the boundaries of Nigeria to South America and some African countries. We are therefore in a position to share our research knowledge with our Australian colleagues, from whom we are sure to pick up new tricks where we are deficient or lack expertise. As you know, this country is all geared for agricultural revolution and the present Federal administration emphasize this daily through its Green Revolution programs. Your idea of bilateral co-operation in research especially to solve urgent production problems, cannot therefore come at a better time. We wholeheartedly support the idea, and assure you and the Federal Ministry of Education, Science and Technology of our full support for the success of this laudable goal. It is indeed gratifying to us to note that the Australian government has taken great interest in sharing

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its agricultural scientific expertise with Nigeria, and it is our hope that this envisaged collaboration will be of mutual benefit to both countries.

No matter how much we try, there are bound to be some shortcomings in our organization of this seminar. We do hope you will overlook some of these and draw our attention to anything you find missing. The Directors, the National Animal Production Research Institute, and the Institute for Agricultural Research will

be very glad to assist you and make your stay comfortable. If you have some time at your disposal, we invite you to visit the main campus at Samaru before you depart. This can easily be arranged.

Once more, on behalf of the Vice Chancellor and the Ahmadu Bello University authority, I welcome you all to Zaria, and Ahmadu Bello University in particular, and wish you a fruitful deliberation. Thank you.

**Soil and Crop Management
in
Nigeria**

Crop Production in the Nigerian Savannah

J. Davies*

Over 75% of Nigeria lies in what has been referred to as the Nigerian Savannah. It extends from between latitude 6° and 7°N in the south to beyond latitude 13°N at Nigeria's northernmost border. It is sub-divided into three major zones, viz. the Southern Guinea Savannah Zone, the Northern Guinea Savannah Zone, and the Sudan Savannah and Sahel Zones.

Southern Guinea Savannah

It stretches from approximately 7° to 10°N with an annual rainfall of 1000-1200 mm. The major crops are yams, cassava, sorghum, maize, millet, with the cereal/root crop mixture also being important. Parts of the area are important for soyabean and benniseed production. Cattle are generally absent due to the presence of tsetse fly and trypanosomiasis.

Northern Guinea Savannah

It extends from approximately 10° to 12°N with an annual rainfall of 800-1100 mm. It is an important zone for growing cereals – sorghum, millet, rice, and increasingly maize, as well as cotton, groundnuts, and cowpea. It is also important for livestock production, being largely free of tsetse fly; there is some integration of cattle with agriculture, the cattle being used for draught and to provide farmyard manure.

Sudan Savannah and Sahel Zones

They extend from 12 to 14°N with rainfall between 800 mm to less than 500 mm in the northern Sahel. The major crops are millet, sorghum, groundnuts, cowpeas and onions. Cattle, sheep, and goats are important.

Major Characteristics of Savannah Agriculture

Large scale (mechanized) farms and irrigation

schemes have been developed in recent years but the agriculture in the Savannah area is still largely subsistence farming, relying on annual rainfall, and based on small farms 1-3 ha in size, operated by farmers with manual labour using simple hand tools or bullocks, and using limited inputs. Mixed cropping is the preferred production system, such as mixed cereals, sometimes with cowpea, cereals/groundnuts, cereals/cotton etc. Although in the past soil fertility was maintained to a certain extent by a system of bush or grass fallow, today large areas are now under continuous cultivation with reliance on inorganic fertilizers.

Some of the important constraints to improving production are:—

1. Climatic: The unreliability of the rainfall – unpredictable as to onset, amount and duration.
2. Soil fertility: Generally the Savannah soils are low in organic matter and fertility levels, particularly in N and P. Certain trace elements are also limiting. The situation is compounded by the removal of nearly all the crop residues, which are used either for livestock feed, fuel or household purposes.
3. Lack or shortage of inputs: Seed of improved varieties, fertilizers, and appropriate machinery for the small farmer, etc.
4. Lack of capital or credit to purchase the inputs.
5. Shortage and high cost of labour, particularly at peak periods: There has been a drift of young people from rural areas to the urban areas. Weeding is a major constraint and nowadays farmers find difficulty in obtaining labour to help.
6. Poor storage facilities, marketing facilities, and pricing structure.

More detailed information on the major crops grown in the Savannah, of the factors limiting their production, and the achievements of research in overcoming them, are presented below. Areas for further work and possible collaboration with ACIAR are also indicated.

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Cereals

Cereal crops produced mainly in the savannah ecological zone are sorghum, millet, and wheat; however in recent years maize hectareage has expanded considerably. Wheat is mainly grown under irrigation and its production is restricted to the few irrigation sites.

Sorghum

Although sorghum ranks fourth among cereals in cultivated area world-wide following wheat, rice and maize it is the most important cereal crop grown in Nigeria, occupying about 46% of the total land area devoted to the growing of cereals. The area of land used for growing sorghum has increased by about 25% over the last two decades, going from about 4.6 million ha in 1959 to an estimated 5.9 million ha in 1981.

Sorghum presently accounts for about 50% of the total cereal production in the country. Just as land area devoted to growing of sorghum has increased over the years, so also has the production, which has gone from a low of 2.5 million tonnes in 1960 to a high of 4.8 million tonnes in 1976 (Table 1). Production within the last 4 years has been around 4.0 million tonnes.

The production for 1983 is expected to be much lower because of the early cessation of rain. The downward trend has been due mainly to migration of people from rural to urban areas in search of higher paying government jobs, the increasing age and consequently less productivity of the few remaining farmers, lack of,

and/or prohibitive cost of inputs, and pricing and marketing systems that farmers complain have not been in their favour.

Cost of Production

The current cost of production of one ha of sorghum is about five hundred naira (N500) and at an average yield of about 2 t/ha, it will cost about two hundred and fifty naira (N250) to produce 1 t of sorghum. This cost is shared between land preparation, fertilizer, weed control, pest control, harvesting and other handling charges. The present Guaranteed Minimum Price approved for the Grains Board is two hundred and twenty naira (N220). This is certainly not much of an incentive to the producer.

A great percentage of people in the savannah and indeed all of Nigeria depend on cereals as the principal source of carbohydrate. The consumption of sorghum is mostly in the form of flour, which is used for preparation of a variety of meals and snacks. These include Tuwo, Fura, Akamu, Danwake and Danbu. Consumption of sorghum and some other cereals by State is shown in Table 2.

The demand for sorghum is increasing, and using the parameters given by the International Bank for Reconstruction and Development for projection, the demand for sorghum will exceed its supply by about 2.3 million tonnes by 1985.

Yield and Yield Limitations

A close look at Table 1 will show that the average yield of sorghum is still less than 2 t/ha. Higher yields of about 2.8 to 3.5 t/ha are achieved at research and government-owned

Table 1. Estimated area sown to sorghum and production obtained during the last 20 years.

Year	Area (M ha)	Production (M t)
1959/60	4.6	2.5
1964/65	5.6	4.2
1969/70	5.8	4.3
1974/75	4.8	3.9
1976/77	6.1	4.8
1980/81	5.9	4.1

Table 2. Consumption in kg per capita per week of cereals in various States of Nigeria.

State	Cereals				
	Sorghum	Millet	Maize	Rice	Wheat
Kaduna	1.93	1.46	0.08	0.01	0.005
Bauchi, Borno and Gongola	1.60	1.78	0.70	0.01	n
Niger and Sokoto	1.74	0.79	0.96	0.05	n
Kano	1.78	1.91	n	0.01	n
Benue and Plateau	0.80	0.67	n	0.005	n
Kwara	1.17	0.03	n	0.27	n
Oyo, Ondo and Ogun	0.01	0.01	0.15	0.05	n
Imo and Anambra	n	n	0.25	0.12	n
Bendel	0.005	0.005	0.28	0.15	n
Rivers	n	0.02	0.06	0.09	n
Cross River	n	n	0.15	0.12	n
Lagos	n	n	0.04	0.06	n

Source: Computed from Federal Office of Statistics Records.

n = negligible.

farms. The limitation of yields in the private farms, which incidentally are responsible for about 80% of the total production of sorghum, is due mainly to management problems such as not using the correct variety, not planting at the appropriate time, sub-optimal plant population, and inadequate control of weeds, pests and diseases.

Solutions to some of these limitations, such as the identification of the appropriate variety for each ecological zone (see Table 3), a general guide-line as to when planting should be done, optimum plant population and spacing for optimum yield, have been found. In the area of crop protection, we have not had very much success in trying to control *Striga*, and this is one area where we can collaborate with ACIAR.

Millet

It is the second most important cereal crop to sorghum in Nigeria. It is produced over a large area in the savannah. An average of 4.4 million ha are devoted to growing this crop, annually. Since production is mainly for home consumption, holdings are small and generally less than 2 ha. This has led to a situation, whereby both total area devoted to millet, and total production, have not changed much over the last two decades (Table 4).

Whatever little change there has been, especially in production, it must have been brought about by differences in rainfall available during the growing season, and is not necessarily due

to increased production per unit area nor an increase in cultivated area. The average annual production over the last 20 years is about 2.4 million tonnes for a national average yield of about 600 kg/ha. Of course much higher yields of 2500 kg/ha are obtained from research and government-owned farms.

Cost of Production

The current cost of production of 1 ha of millet is about five hundred naira (N500) and at an average yield of 1.5 t/ha it will cost about three hundred and forty naira (N340) to produce 1 t of millet. The current Minimum Guaranteed Price is two hundred and thirty one naira (231 N). The producer price has to be increased to give encouragement to producers.

Consumption

The consumption pattern of millet is similar to that of sorghum and there is an increasing demand for it, especially with the increase in population. It is estimated that by 1985 demand for millet will exceed its supply by about 1.2 million tonnes (Table 3).

Yield and Yield Limitations

Yields obtained at research station level and some of the government-owned farms range between 2.4-2.9 t/ha. This is about four times the yields obtained from small privately owned farms. The greater disparity in yield between research farm and small-holder farms is of

Table 3. List of improved pure line varieties of sorghum developed for the four different ecologic zones.

Zone	Variety	Type	Grain yield (t/ha)	Plant* height (m)	Grain** colour
NSS	H.P.3	Adapted exotic	2.5	1.3D	CSC
	H.P.8	" "	2.2	1.4D	CSC
	BES	Selected local	2.6	1.6SD	Y
KSV 11		Adapted exotic	2.8	1.4D	W
KSV 12		" "	2.6	1.9SD	C
SS	KLB	Exotic x Local	1.4	2.0SD	W
	KSV 7	Adapted exotic	1.4	2.1SD	C
	L408	" "	1.3	2.0SD	C
	RZI	Selected local	1.9	1.9SD	Y
	YC5760	" "	1.3	3.6T	Y
	KSV8	Adapted exotic	2.0	3.1T	W
	L187	Exotic x Local	2.9	1.8SD	Y
	L181	" "	2.5	1.9SD	C
	L1499	" "	2.7	2.0SD	W
	SK5912	Selected local	2.8	2.5ST	Y
NGS	FFBL	" "	2.3	4.0VT	W
	SSV9	Exotic x Local x Local	3.0	1.9SD	M
	SSV10	Exotic x Local x Exotic	2.8	1.7SD	C
	-7-4	Selected local	1.2	4.0VT	W
	ML-4	" "	1.1	4.0VT	W
SGS	FCI	" "	1.1	4.0VT	Y

* D = dwarf; SD = semi-dwarf; ST = semi-tall; T = tall; VT = very tall.

** W = white; Y = yellow; C = cream; M = mori; CSC = cream with dark seed coat.

Table 4. Estimated area sown to millet and production obtained within the last 20 years.

Year	Area (M ha)	Production (M t)
1959/60	4.3	2.4
1964/65	4.4	2.7
1969/70	4.2	3.2
1974/75	4.0	2.6
1975/76	4.5	2.8
1980/81	4.5	2.9

course traceable to poor management problems. Other constraints on millet production are inadequate supply of labour, lack of capital inputs, lack of adequate drying and storage facilities, bird damage, lack of adequate weather forecasting, and unfavourable marketing/pricing arrangements.

The Institute's research staff are working hard to resolve the issue of poor management practices and to develop high-yielding and adaptable varieties. The problem of unreliable weather and bird damage however remains largely unsolved. This is an area where we can

collaborate with ACIAR. As far as the unreliability of weather is concerned, the Institute has developed some drought tolerant/early maturing varieties. All of our efforts to find a solution to the bird problem in millet have not been very successful.

Maize

Maize, the third most important cereal crop, is grown on an estimated 1.7 million ha annually; a great portion of this is in the rain-forest zone. However, it is being increasingly grown in the

savannah region and this certainly will have added substantially to the total area grown to this crop.

The estimated annual production is about 2.0 million tonnes with the national average yield at about 1.2 t/ha.

Production, especially in the savannah, has been on the increase. The rate at which maize production has been received and accepted in the savannah ecological zone has meant that millet is losing much ground to it. It is actually being speculated now that in the Northern Guinea and southern fringes of the Sudan Savannah, maize in the next few years will replace millet. Maize is also finding a place under irrigation in some of the large irrigation schemes.

Cost of Production

At present in the savannah region it costs between N450-500 to produce 1 ha and at an average yield of 1.2 t/ha it will cost between N375-400 to produce a tonne. The present producer price approved by the Government is N325/t. A little upward adjustment in producer price will serve as an incentive.

Consumption

Maize is used for three main purposes, viz. as a staple human food, livestock feed, and as industrial raw material. Consumption, because of its many uses, has been on the increase and the Federal Government of Nigeria has at one time or the other imported maize to supplement local production (Table 5). It is projected that by 1985, demand for maize will exceed its supply by about 178 000 t.

Yield and Yield Limitations

Yield in the savannah is currently low (about 1.2 t/ha) compared with 6-10 t/ha obtained in the

United States. The 1.2 t/ha is also low when compared with the 3-5 t/ha obtained from research stations. However, there is every hope that this 1.2 t/ha will rise within the next few years because of the great natural potential for maize production in the savannah. Such potential includes a favourable radiation input and relative freedom from pests and diseases.

Production in the savannah is just gaining ground, and therefore our efforts right now are concentrated on trying to develop adaptable and high-yielding varieties, and determining the optimal management and cultural practices for optimum yield.

Two current areas that are likely to pose problems, and may prevent achieving the yields being sought, are (a) the low natural fertility of the savannah soils in nitrogen and phosphorus (two very important requirements for optimum maize production), and (b) the problem of controlling *Striga* in maize.

We will be willing to collaborate with ACIAR to find a solution to the danger likely to be posed by *Striga* in maize production.

Wheat

Although wheat production is far less than the other cereal crops discussed above, its increasing importance as a source of flour in the daily diet of Nigerians cannot be over-emphasized. The most important food produced from wheat is bread, and apart from its convenience, it is nutritionally superior and cheaper than most other food staples.

Although wheat has been cultivated in Nigeria for some centuries, the present total area of production of 8000 ha is largely concentrated in the major irrigation schemes located in Borno, Kano, Sokoto, and Kaduna States. The current average yield is about 2000 kg/ha for a total production of about 16 000 t/annum.

Cost of Production

For 1 ha it ranges from N700-760, and at an average of 2 t/ha it will cost between N350-380 to produce a tonne of wheat. This cost is shared between land preparation, fertilization, water charges, harvesting, and other handling charges. Compared with the other cereals, wheat is about the only crop where the cost of production matches the market sale price.

Table 5. Importation of unmilled maize into Nigeria.

Year	Quantity (1000 t)	Value (N)
1974	2 440	608 289
1975	2 211	429 999
1976	9 861	1 422 338
1977	20 172	3 490 112

Consumption

The popularity of bread is demonstrated by an increasing demand for wheat. Because the wheat produced in Nigeria is insufficient to meet the demand for flour, it has to be imported. It is estimated that by 1985, the demand for wheat should exceed supply by about 2.0 million tonnes.

Yield and Yield Limitations

Wheat research in Nigeria is very much in its infancy when compared with cereals like sorghum and millet. The present yield of about 2 t/ha is low when compared with 8-10 t/ha obtained in Mexico and America. The Institute is identifying adaptable high-yielding varieties, and defining optimal management and cultural practices for optimal yield.

While the general constraints of poor management to higher yield remain, probably our most immediate need is personnel — a wheat agronomist and a physiologist.

Groundnut

Groundnut, which is important primarily for its oil content (44-56%) and protein (25-34%), is also a valuable crop for both human and livestock consumption. Its production has had profound effects on traditional agricultural practices and rural development. This is evidenced by the leading role it played in its contribution to the agricultural export economy of Nigeria, as well as to farmers' incomes prior to the 1970s. Increased groundnut production can greatly supplement the insufficient protein and also help offset the current shortage of vegetable oil in Nigeria.

Distribution

Groundnut still constitutes one of the most popular cultivated commercial crops in Nigeria with the bulk being grown in the northern states. The southern states produce less than 1% of the total output.

More than 90% of Nigeria's estimated 0.8-1.2 million ha of groundnut is grown annually on small farms (0.25-1 ha), mainly between latitudes 9° and 13°N. The crop is predominantly cultivated by hand and mostly as an inter-

cropping component of various crop mixtures. The major production areas are in the Sudan and Northern Guinea Savannah, and to a lesser extent, in parts of Southern Guinea and derived savannah. The forest ecological zone produces insignificant quantities.

Groundnut distribution is dependent on ecological adaptations and requirements that include well-drained and friable sandy loams, rich in calcium and with moderate amounts of organic matter; high solar radiation; moderate rainfall during growth; and reliable periods of dry weather while the pods mature so as to harvest with rapid drying of the lifted pods.

Production: Trends and Constraints

The average estimated yield obtained by Nigerian farmers is about 650 kg/ha; however, by growing the crop in accordance with recommended practices, yields of over 3000 kg/ha are possible. Groundnut production in Nigeria has, over the past decade, faced a downward trend. This has been due largely to one or a combination of several inter-related factors, notably inadequate fertilizers, seed and pesticide inputs; drought; socio-economic constraints; unattractive producer prices; and pest and disease epidemics. Thus the low guaranteed producer prices, less farm labour due to rural population movements to the cities; drought years in the past decade; unprecedented aphid and rosette virus epidemics in 1975; an increasing incidence of rust; and higher prices for cereal crops and vegetables have all contributed to the fall in groundnut production.

Despite an increase in guaranteed producer price from N68/t of kernels in 1966-67 to N350/t in 1979-80, and now N450, farmers are increasingly shifting to other crops as the main source of revenue. Preliminary investigations have revealed that the high cost of labour and pricing policies, drought, and disease epidemics constitute the major factors affecting the farmers' decision-making process in groundnut production. Although the drought is increasingly pushing the groundnut belt southward in order to meet the edapho-climatic factors suitable for optimum production, the traditional northern belt is potentially the best suited.

These shifts will affect not only the farming systems but also the fertilizer requirements of groundnuts and the mycotoxin (aflatoxin) prob-

lems associated with the wetter Guinea Savannah zones. All these will necessitate renewed research efforts in breeding for pest, disease, and drought resistant varieties with good agronomic characters that are acceptable and adapted to the various ecological zones.

Research Achievements

Over 13 varieties with varying growth cycles and good resistance or tolerance to drought, rosette, and leafspot have recently been developed. Many of these are high-yielding, giving as much as 2000 to over 3000 kg/ha of pod. This is a big improvement over the traditional varieties that yield at best 750 kg/ha.

Weeds, which are estimated to reduce 18-70% and sometimes up to 90% of the pod yield can now (after the Institute's intensive research) be controlled with herbicides. Herbicide usage can save up to 80% of the production labour now being spent on weeding.

Up to 20-40% of the pod yield is lost due to rust and leaf-spot diseases. We now have identified some fungicides that can substantially increase pod and haulm yields by 40%. Haulms are increasingly playing an important role as livestock feed especially in urban areas.

Current research efforts involve (a) the development of varieties that are resistant to drought, pests and diseases; (b) the determination of nutritional, physiological, and agronomic factors affecting groundnut production; (c) the development of effective pest and disease management strategies and (d), the investigation of socio-economic implications of groundnut production as well as researching into postharvest technology.

Possible Areas of Collaboration with AICAR

1. Mycotoxin Management

Aflatoxin contamination constitutes a serious health hazard to humans and livestock, especially in lesser developed countries like Nigeria (where a great majority of the population is ignorant of its danger), due to the unavailability or shortage of monitoring facilities.

Preliminary investigations have suggested that soil pests and high moisture levels not only predispose groundnut to toxicogenic fungi but

directly damage developing pods thereby reducing yield. The severity of attack may possibly depend on cultural practices and the type of variety under cultivation.

However, investigations in this important area have not received the attention the problem deserves because of limitations in staff and research facilities.

This project will involve collaborative investigations by entomologists, pathologists, breeders and bio-chemists/food scientists for 4-5 years.

2. Groundnut Improvement Research:

This project will broadly embrace the breeding for short-season, drought, pest and disease-resistant varieties with desirable agronomic characteristics.

The thrust in this interesting area will be on drought-stress tolerance, early maturity, and high yields. The main objectives will include the identification of the mechanisms of drought tolerance; the determination of the agronomic characteristics of a range of groundnut lines for selection and hybridization; the development of simple assessment selection methods to identify drought-stress tolerant groundnut germplasm; and the determination of the physio-nutritional factors responsible for blindnuts among a range of groundnut cultivars and breeding lines. An important element will include the determination of plant-water relationships in respect of salinity, nutrient availability, nodulation, and rhizobial activities.

This interdisciplinary research, which will take about 5 years, will involve breeders, physiologists, agronomists, and soil microbiologists all working together as a team.

3. Socio-economic Constraints on Groundnut Production and Marketing Policies:

This will entail an intensive survey of selected groundnut producing areas with a view to appreciating the extent of groundnut production and utilization. This will include an interview of samples of family units engaged in groundnut production at all levels, including non-producers, so as to understand the place of groundnuts in the farming systems, socio-demographic and economic factors affecting the decision-making

processes, and a detailed study of the marketing policies as they relate to groundnuts. The ultimate goal of this project is to come up with socio-economic solutions to the declining production of this one-time mainstay of Nigerian economy.

The approach to this research will be strictly inter-disciplinary with socio-anthropologists, economists, breeders, agronomists, nutritionists, and crop protectionists participating.

This project will take 4-5 years.

Grain Legumes

The two grain legume crops grown are soyabean and cowpea.

Soyabean

Soyabean production has been declining since 1967 because of the poor price in relation to other crops, and because of the marketing structure. The annual production fell from over 20 000 tonnes in the 1960s to about 8000 tonnes in the 1970s. It is anticipated that there will be a large internal demand for soyabean consumption as a result of the soyabean popularization campaigns. Soyabean is also an invaluable supplementary feed for the livestock industry and is in demand by the oil-mills for crushing. The latter has now gained further significance because of the acute shortage of cooking oil and the decline in groundnut production.

Soyabean has been grown traditionally in the Southern Guinea Savannah areas, in Benue, Niger, and Kwara States. The farmers' average yield is about 300-500 kg/ha. Yields of over 2 t/ha are easily obtained at the research stations in Yandev, Mokwa, and Samaru.

A key component in the soyabean production package is the availability of high yielding varieties that possess field resistance to major diseases and insect pests. Fortunately, in the major soyabean producing areas of the savannah zones, they are presently considered to be free from serious attacks by pests and diseases. Apart from resistance to natural hazards, it is absolutely important that varieties in our production kits be resistant to lodging and pod-shattering. The commonest and the most important commercial variety in northern Nigeria, the Malayan, is low-yielding in addition to being

very susceptible to lodging and pod-shattering. In fact, it is estimated that an average farmer loses up to 30-50% of grain yield because of pod shattering before and during harvest.

The Institute for Agricultural Research has released two high-yielding varieties, viz. Samsoy 1 and Samsoy 2, which are well adapted to the main soyabean growing areas. They are both tolerant to pests and diseases. Their main feature is their non-shattering quality. Technology for soyabean production has been developed. Research effort has concentrated on the development of promiscuously nodulating varieties, though work on rhizobial inoculation is also being done. Advice on fertilizer and herbicide application is also available. Further work is being done on these aspects and on the agronomy and crop protection problems of growing soyabeans in the Nigerian savannahs.

Cowpea

Cowpea is the most important grain legume food crop in Nigeria. The demand for what is popularly called beans is rapidly increasing. Cowpea constitutes a very important source of vegetable protein in the diet. According to the National Agricultural Development Committee Report on Food Crop and Pastures, cowpeas contribute over 57% of the total protein from legumes, but only about 8% of the total daily protein intake in Nigeria.

Cowpea production in Nigeria is estimated to be about 800 000 tonnes annually. Over 80% of this is grown in the savannah zones, in the northern half of the country. Traditionally the crop is grown as one of the components of a mixed cropping system. Very little is grown as a sole crop because of many production problems, most important of which are the use of low-yielding photosensitive local varieties and poor pest control. About 4 million ha of land are estimated to be under cowpea cultivation annually with an average yield of about 200 kg/ha. Research results have indicated that yields of 1500-2000 kg/ha are obtainable with improved varieties and effective pest control measures.

Significant achievements in cowpea research have been recorded at the Institute in the last decade, the climax of which is the formulation of a complete crop management package for production in the Nigerian savannahs.

Three areas of cowpea research at IAR de-

serve special mention, viz. cowpea breeding, crop protection, and storage:

Cowpea Breeding

In the last decade, research effort towards improvement of cowpea cultivars has enabled the Institute to release six new high-yielding varieties, which have found wide acceptance in the whole of Nigeria.

The major limiting factors in production are insect pests, diseases, and the use of lowly productive, photosensitive and spreading local varieties. In our breeding program we have been able to develop high yielding, daylength neutral varieties with resistance to some of the major diseases.

Crop Protection

Damage by pests and diseases is a major constraint to stable production in Nigeria. In the absence of crop protection measures, a 90% loss of potential yield is not uncommon.

The most significant achievement of entomological and plant pathological research is the development of an effective pest and disease management strategy, that combines minimum pesticide usage with varietal and cultural control.

Storage

Cowpea is heavily attacked by the beetle, *Callosobruchus maculatus* at all stages of its progress from farmers to consumers. The weight loss due to beetle attack may be as high as 50%. A number of different methods for storage suitable for different stages in the movement of the crop has been developed.

The cowpea breeding program will continue to breed both white and brown, rough-seeded, high-yielding varieties with acceptable seed quality. A breeding program has been started to breed cowpea varieties suitable for irrigation cropping. Such varieties should be resistant to virus diseases and nematodes. In addition, they should be cold-tolerant. They will be used in rotation with wheat and tomatoes being produced in the irrigation schemes.

In crop protection, the search for sources of pest and disease resistance will continue. *Striga* is becoming a very serious parasite of cowpea. Screening of a large number of lines for re-

sistance and/or tolerance, which started three years ago, has indicated that there is a possibility of obtaining lines that are resistant to *Striga*. The exact relationship between cowpea and this parasite (*Striga gesnerioides*) needs to be elucidated to provide a basis for studies on integrated control of *Striga*. Work on another important parasitic weed, *Alectra* will also be intensified.

The most serious fungal diseases of cowpea under rain-fed conditions have now been identified as Scab, caused by *Sphaceloma* sp and Brown Blotch caused by *Colletotrichum capsici*. In addition, Septoria leaf spot (*Septoria vignae*) causes premature defoliation that culminates in appreciable crop losses. All three fungal diseases can be effectively controlled by the application of medium volume (400 l/ha) foliar fungicidal sprays. Work will be intensified to determine the optimum time to commence spraying and the optimum number of sprays needed. More importantly, screening of different fungicides will be continued to identify those that can be applied as very low volume sprays (5-10 l/ha). At the same time, screening of different lines/varieties for multiple disease resistance to the three major fungal diseases and to bacterial blight (*Xanthomonas phaseoli* var *vignae*) will continue because of the obvious advantages of disease control by genetic means. Since most of these diseases are seed-borne and seed-transmitted, work has begun to find the most effective method of ensuring that seeds intended for crop production are free of these pathogens.

In entomology, studies will continue on the assessment of damage and the establishment of the economic threshold of major pests to develop an effective integrated pest management program for cowpea. Search for resistant material is an important aspect of our research, and this work is being intensified to develop varieties with resistance to thrips, pod-bugs, aphids, and bruchids.

It is essential at present to use chemicals in cowpea production (and will remain so for some time to come). There are two aspects, viz. (a) the development of an effective and safe pesticide application regime, and in this respect, we are now recommending a minimum application of a combination of a synthetic pyrethroid and a systemic compound; and (b), the development

of appropriate pesticide application technology. In this area, a considerable amount of research has gone into the development of Controlled Droplet Application (CDA) techniques, which are now recommended. Research work will be continued on both aspects. The Institute has a major project on the 'Electrodyn' spraying technique, which has been found to have considerable promise for use under Nigerian conditions.

Agronomic studies of cowpea both as a sole crop and as an inter-crop will be continued in order to produce an efficient package of practices for recommendation to farmers. In particular, optimum plant populations and optimum fertilizer rates for the major producing zones are under active research.

Grain Legume Research

The main aim of the Grain Legume Research Program is the improvement of all grain legumes in the Nigerian savannah through multidisciplinary research. The two priority crops in the program are soyabean (*Glycine max*) and cowpea (*Vigna unguiculata*). Other crops in the Program's mandate are: Bambara nuts (*Voandzeia subterranea*), pigeon pea (*Cajanus cajan*), lima bean (*Phaseolus lunatus*), haricot bean (*Phaseolus vulgaris*), winged bean (*Psophocarpus tetragonolobus*) and African yam bean (*Sphenostylis stenocarpa*).

The objectives of the research program include:

1. Development of high-yielding acceptable, ecologically well adapted varieties with desirable agronomic characters and resistance to major pests and diseases.
2. Determination of the various inputs required (e.g. fertilizers, herbicides, etc.), and the best agronomic practices to achieve a high level of production.
3. Determination of suitable pest and disease management practices to achieve effective and economical control.
4. Determination of current practices and problems associated with the production and testing of the various technological inputs at farmer's level.

Areas of Possible Collaborative Research with ACIAR

1. *Striga* (cowpea) and *Alectra* control in the West African savannahs. This will include breeding for resistance, studies on plant-parasite relationships and possible chemical and cultural control methods.
2. Integrated Pest Management Program for cowpea pest control. Emphasis here would be on non-chemical methods.
3. On-farm testing of a cowpea production package in different ecological zones; identification of major constraints and possible solutions.
4. Development of grain legumes other than cowpea and soyabean, e.g. Bambara nut, haricot bean, winged bean etc.

Cotton

Upland cotton (*Gossypium hirsutum* L.) is one of the major cash crops in Nigeria and has been grown there for centuries. However, 'commercial' cotton production started only in about 1910 under the auspices of the British Cotton Growing Association (BCGA), which was set up primarily to find new sources of cotton lint for the Lancashire Textile Industries in Britain.

Most of the cotton is grown in the northern states by small-scale farmers under almost exclusively rain-fed conditions. An adequate supply of soil moisture derived from rain is therefore necessary if plants with a high-yielding capacity are to be produced.

An important change in the last two decades or so, associated with the expansion of the crop, has been the use of an increasing part of it in Nigeria's own textile mills, which now consume all the cotton lint produced in the country. Although an increased total annual production of cotton lint was experienced over several years, there has been a declining trend in the last few years, resulting in the present output falling far short of the requirements of textile mills. Annual production increased gradually from about 65 000 bales of lint (181.4 kg = 1 bale) in 1949-50 to about 500 000 bales in 1969-70 (a record year), due primarily to the planting of a larger hectareage in response to better prices; thereafter, there has been a decline in production.

Table 6 illustrates the steady decline in lint production from year to year while there has been a steady increase in the consumption of this commodity by our textile mills. Despite the fact that the producer price increased by about 50% in the past 5 years, production declined by about 71% over the period 1976-81, with an increase in consumption by the mills by over 100% in the same period.

Until recently, cotton was the fifth most important export crop of the country but all the total annual production of cotton lint is now consumed internally by the expanding Nigerian textile industry. However, if the requirements of our textile industry are to be met locally, cotton production would have to be raised to 900 000 bales of lint per year by 1990. The average annual production of seed cotton in the last decade was about 128 000 tonnes (1970-82 mean), which declined to about 90 000 tonnes during the last five years (1977-82 mean) with considerable seasonal fluctuations. There is therefore a need to increase production to meet the future requirements of the textile industry and to reduce dependence on imported textiles.

Despite the fact that precise statistics on cotton hectareage and yields are lacking, it has been estimated that the total area put to cotton is about 0.6-0.7 million ha. Since most of the cotton produced in Nigeria is from small-holdings managed by peasant farmers, most of which still grow cotton in the traditional way, an appreciable increase in cotton hectareage is not envisaged at the present time.

The present declining trend in production is partly due to peasant farmers in Nigeria, the main producers of cotton, paying more attention to food crops as opposed to cash crops. Also, cotton is considered as a low-value crop with a

high labour requirement, so that large-scale cultivation is not likely to be profitable. For this to be economic, it is certain that mechanical harvesting would be required. Yield/ha also continues to decline, probably because more and more of the marginal areas are being brought under cultivation, a situation compounded by the fact that farmers usually plant late, apply little or no fertilizer, and do not spray chemicals.

Crop Yields: Levels, Limitations, and Problems

The average yield of farmers' cotton in the main producing areas has been estimated at 300-400 kg seed cotton/ha. These average yields are among the lowest in Africa, and fall far below levels attainable at experimental research stations in Nigeria. In demonstrations applying only moderate inputs of fertilizer and insecticide to June-sown cotton on farmers' plots, seed cotton yields of 800-900 kg/ha have been obtained. Using the same or slightly higher input levels, yields of 2000 kg/ha of seed cotton and above are not unusual. Despite the profitability at these yield levels, and the availability of subsidies on fertilizers, insecticides, and spray machines, farmers have been extremely reluctant to adopt the recommendations for improved cotton production.

The principal reason for these low yields is late planting. It is usual practice in Nigerian agriculture to delay the planting of cash crops, such as cotton and groundnuts, until staple food crops have been planted and established. Farmers usually plant their cotton in the second-half of July and continue until the end of August or even later. Such late planting severely restricts

Table 6. Nigerian Cotton Lint Production Statistics, 1976-77 to 1981-82.

Year	Production (bales)	Export (bales)	Consumption by Mills (bales)	Producer Price (N per tonne)
1976-77	453 126	53 528	277 138	330
1977-78	219 152	52 753	228 153	330
1978-79	206 039	122 783	250 670	330
1979-80	161 620	Nil	284 000	330
1980-81	149 820	Nil	345 000	400
1981-82	130 000	Nil	469 045	465
1982-83	N.A.	Nil	N.S.	510

Source: Nigerian Cotton Board.

the growing period of the crops, so that growth is limited and yields are small. It has been argued that the lower yield potential of later sown cotton will not repay the cost of expensive insecticidal protection, but it is now thought possible that worthwhile yields, in excess of those being obtained by local farmers, might be obtained from July-sown cotton, good management, and efficient crop protection. It is also believed that cotton production can be increased to the extent of 20% through the use of new varieties, and 55% through the adoption of improved practices. Since the evolution of new varieties is a long-term exercise, the additional seed cotton requirement must be met mainly by increasing yields of the existing area through the adoption of improved practices in all the three cotton growing zones.

The problem of pest control is one of the main constraints to profitable cotton production in Nigeria. Estimates of losses due to insects and diseases are not available on this subject. Educated guesses have put the figure of such losses as high as 50% of the total crop. The loss to the farmer and the nation is in reduced yields, reduced fibre and seed quality, and increased production costs. Amongst the great diversity of insects there are only a few that seriously reduce the quantity or quality of seed cotton harvested from a crop. Fortunately, there is, however, only one serious disease of cotton in northern Nigeria, and this is bacterial blight (*Xanthomonas malvacearum*).

The problems facing cotton production in Nigeria are in factors that can be categorized into socio-economic, technological, agronomic, and even political areas. The labour intensive-ness of, and to some extent, capital investments associated with cotton production renders it a disadvantaged crop amongst the competing crops like cereals. Other problems include difficulty in persuading farmers to adopt recommended practices; the poor availability of inputs; an inefficient marketing system for cotton producers, and so forth. These series of problems interact to work against the development of the cotton industry in Nigeria.

Solutions to date and IAR's Current Activities

There are available improved cotton growing recommendations for use by small-scale cotton

farmers on aspects of fertilizer application, planting date, variety, and insecticide spraying. All these emanated from the results of many years of research work at the Institute for Agricultural Research, (IAR), Samaru. Even though farmers do not widely adopt these recommendations, it has been amply demonstrated that they are technically feasible and can be economically worthwhile, except in seasons where the growing period was considerably reduced.

Recent research work at IAR has established that early planting of dressed cotton seed (in June), the use of fertilizers at the rates of 200 kg of calcium ammonium nitrate and 125 kg boronated superphosphate/ha, 3-4 sprayings with cypermethrin (u.l.v.) to control insects, and timely weedings would bring about 6-8 fold increases under the peasant farmers' conditions. The varieties issued to the northern and eastern cotton zones meet the present quality requirements of the bulk of the textile industry, but breeding work at IAR continues to obtain further improvement in yield, disease resistance, and spinning quality. The production of foundation seeds of recommended varieties and their multiplication are undertaken by IAR before they are further increased at State levels, and are finally distributed free to farmers as dressed planting seed by the Nigerian Cotton Board.

The adoption of a 3 or 4 month closed season for cotton helps to keep pests reasonably in check but the full expression of yield of well-grown cotton requires direct pest control by means of insecticides within the crop. Entomological work on cotton did not begin at Samaru until 1948. Since then it has greatly expanded, along with continued plant breeding and seed multiplication, and has had an important impact on the cotton industry.

There is still a lot to be done in the area of extension services to help promote the cotton industry. The main problems undoubtedly lie in the field of extension, persuading farmers to sow at the correct time, to use more fertilizers and insecticides, and to use them properly. There needs to be a well-organized propaganda campaign highlighting the economic advantages in using improved methods.

One aspect of the crop that also deserves some attention is quality. Cotton lint is classified into five categories ranging from A⁺ to D,

depending mainly on staple length. Only a proportion of the crop, mainly from the eastern zone, falls into the A⁺ and A categories. Even though there is a considerable variation in quality between areas and between seasons, there are very few data on this.

A progressive increase in production will require a higher yield from individual cotton farms and it is therefore the aim of cotton research at IAR to show how this may be achieved. We have recommendations for sowing date, spraying and fertilizers for the main crop zones and research is now concentrating on refining these recommendations and investigating the problems of the later-sown crop.

Breeding work to develop more new high-yielding, disease and pest resistant varieties, with good lint quality is continuing at IAR. Work is also in progress to update existing agronomic and pest control recommendations. The annual multiplication of foundation seed of recommended commercial varieties is undertaken by IAR. There is also ongoing on-farm testing of socio-economic implications of improved cotton technology adoption.

Areas of Possible Collaborative Research with ACIAR

A very important segment of cotton research that is relatively untouched at present is that of plant-soil-water relations. Research facilities (equipment, personnel, infrastructures, etc.) to undertake research work in this very vital area are grossly inadequate, if not completely lacking. Recent experiences have shown us that moisture relations of cotton may be just the life-line of the cotton industry in Nigeria, and that success in the task of meeting the lint requirements of our textile mills may depend on this vital information.

While we intend to propose new research projects in this area of cotton work in the near future, any assistance that could be rendered by ACIAR toward the attainment of this objective will be very welcome.

Horticultural Crops

Horticulture is a very important aspect of agriculture within the Nigerian savannah with emphasis on growing fresh fruits and vegetables, with vegetables having the upper hand.

Some of the tree crops cultivated in the savannah region include mango, citrus (of various types), guava, cashew, etc. The main vegetables cultivated in this region are onion, tomato, and pepper while vegetables as okra, garden egg, amaranthus, etc., are also important. One other horticultural crop that is growing in importance is ginger.

Onion, tomato, and pepper, the most important horticultural crops in the savannah region, command the highest priority in the research work of the IAR. They are important because scarcely any meal is prepared in Nigeria without the use of one, two or even all of these vegetables. The demand for them is, therefore, very high and farmers cultivate large hectares. However, statistics on the demand, consumption, and number of ha cultivated are unfortunately hard to obtain. For one thing, the crops are mainly grown by small-scale farmers who cultivate several small and scattered pieces of land; poor distribution and lack of storage facilities also compel the farmers to vary their hectare from year to year. In addition, the size of the terrain and inadequate financing make it extremely difficult to monitor the actual demand that these crops enjoy in Nigeria. What is obvious, however, is that millions of Nigerians consume tomato, pepper, and onion daily, and that several thousand ha are used for their cultivation.

Tomato, onion and pepper (as well as other vegetable crops) are cultivated both under rain-fed conditions, and under irrigation during the dry season.

The rate of production and increase in demand of these crops is rising. There are several reasons for this:

1. More and more Nigerians are beginning to realize that vegetables and fruits are rich sources of vitamins and minerals, and consequently are essential for the maintenance of good health.
2. In the past, farmers depended entirely on rains and a few fadamas (flood plains) for the cultivation of these crops. Today, with the establishment of several dams, farmers can now turn to quite a number of artificial lakes for the irrigation of their crops. In fact, vegetable production during the dry season is now gaining the upper hand over cultivation in the rainy season and this trend

will continue as more and more irrigation schemes are established.

The main areas of the savannah where onion, tomato, and pepper are grown are Sokoto, Kano, and Kano States, which are also the areas where irrigation facilities are most developed.

The savannah region has a number of factors that limit increased vegetable production. These include:

1. Pests, Diseases, and Weeds

Weed infestation control is mainly by manual labour and this is time-consuming and expensive, and partly explains the high cost of production and therefore the high cost of vegetables in our markets. Diseases caused by fungi, bacteria, nematodes, and viruses are very important in the savannah region, particularly in the rain-fed crop.

Diseases incited by *Septoria*, *Alternaria*, *Xanthomonas* and *Cladosporium*, for example, lead to serious yield losses in tomato. Onion twister caused by *Colletotrichum gloeosporioides* as well as purple blotch disease caused by *Alternaria porri* pose serious problems to onion cultivation, with onion twister being by far the most important. Virus diseases are the main problem faced by pepper. Under irrigation, and even in the rain-fed crop, root-knot nematodes cause serious havoc in tomato. Thrips and other insects are also important.

Because of the problem of diseases, the ideal way for growing vegetables in this country is under irrigation during the dry season.

2. Farmer Education

Another constraint in vegetable production in the savannah region (and this applies to the rest of the country) is that most farmers have insufficient education to properly apply recommended practices (agronomic, crop protectional, etc.). The ultimate result of this is poor yields, despite effective research at the IAR and the provision of valuable recommendations.

3. Storage and Distribution

One other problem that not only works against increased production of vegetables, but also causes unpredictable fluctuation in the quantities produced relates to the near total absence of storage facilities, and very inefficient distribution

machinery. It is not uncommon to see farmers making good use of the various irrigation schemes to produce tonnes and tonnes of tomato, onion and other vegetables only to find that they cannot dispose of them or store them. Farmers that face this problem in one year may abandon the crop in the following year or cut down on the hectareage allocated to its cultivation.

The IAR is situated in the heart of the savannah region and *inter alia*, conducts serious research on vegetable crops. Objectives of this research include determining means to improve the production of fresh fruits and vegetables for the local trade as well as the production of vegetables and fruits for canning enterprises, both for local consumption and for export. Research in this direction centres around variety improvement (through introduction, selection, and hybridization); cultural practices (planting methods, weed control, crop nutrition, etc.); crop protection; postharvest technology; socio-economics of production. It has already yielded many useful results.

Improved vegetable varieties suitable for cultivation in the various sub-ecological zones have been produced and released; ways of controlling several pests and diseases have been determined, weed control methods and the right type of nutrients for the various vegetable types have been investigated with a number of positive results, and so on. However, there is still a lot to be done, and research into these and other crops is continuing at the IAR.

Areas of possible collaboration with ACIAR lie within the sub-projects already listed, namely, variety improvement, cultural practices/management, crop protection, and postharvest technology. Specific research areas can be worked out if the need arises. One area where aid is badly needed is the provision of research equipment, chemicals, etc.

Irrigation

The area under traditional irrigation schemes increased from 120 000 ha in 1958 to about 800 000 ha in 1978 (Nigerian Agric. Sector Review, Vol. III, Paper 6). With the creation of irrigation facilities, mainly through the River Basin Development Authorities, it was projected that nearly 990 000 ha would come under irrigation by 1985. Around 90% of this irrigated

area falls in the savannah zones.

High priority has been given to the development of major irrigation schemes in an effort to solve the food problem of the nation. Eleven River Basin Development Authorities have been created in the country to date. Six River Basin Development Authorities (R.B.D.A.) located in the savannah zones are the Sokoto Rima River Basin Development Authority, the Hadejia Jama'are River Basin Development Authority, the Lake Chad Basin Development Authority, the Upper Benue River Basin Development Authority, the Lower Benue River Basin Development Authority, and the Niger River Basin Development Authority.

They are all charged with a range of responsibilities including the harnessing, management, and exploitation of the country's water resources for agricultural and other activities. It is believed that assured irrigation with an efficient water distribution system and optimum water use is the key to increased agricultural production, by realization of yield potential of improved varieties.

The Irrigation Research Program of the IAR initiated research to develop suitable farming systems for irrigated areas, with emphasis on proper utilization of water resources as well as the efficient management of soil and water, and its environment.

Currently the program is organized into three sub-programs and many project and sub-projects under each of these units. The important sub-projects are listed below:

1. Water Resources Development and Management Sub-Program

- (1) Inventory
 - a. Watershed characteristics
 - b. Groundwater resources
 - c. Meteorological parameters
- (2) Water Requirements of Crops
 - a. Evapotranspiration studies
 - b. Water budgeting
 - c. Irrigation frequency
 - d. Irrigation scheduling
- (3) Application Methods
 - a. Border irrigation
 - b. Furrow irrigation
 - c. Basin irrigation
 - d. Overhead irrigation
 - e. Traditional methods

- f. Irrigation efficiencies
- g. Method design and development

2. Irrigated Cropping Systems Sub-Program

- (1) Soil Management
 - a. Tillage & residue management
 - b. Nutrient balance studies
 - c. Fertilizer requirement
 - d. Drainage design and efficiency
 - e. Other soil amendments
- (2) Rotations and Sequences
 - a. Rotation
 - b. Sequences
 - c. New introductions
- (3) Socio-Economics of Irrigation
 - a. Various crops & cropping systems
 - b. Various irrigation systems
 - c. Managerial infrastructure of irrigation project
 - d. Support and subsidies

3. Environmental Implication of Irrigation Sub-Program

- (1) Irrigation Hazards
 - a. Monitoring salt buildup and ground water fluctuations
 - b. Leaching requirement
 - c. Reclamation of salt-affected soils
 - d. Aeration and crop growth
- (2) Ecology
 - a. Pest build-up
 - b. Weed relationships
 - c. Animal diseases
 - d. Human ecology

Facilities Available

Limited facilities in respect of soil-plant-water relation studies equipment, lysimetry, water measurement and a meteorological unit are available at our irrigation research stations at Kadawa (35 ha research farm in Kano Project), Bakura (10 ha — proposed 200 ha — research farm at Bakolori Project), and the IAR farm, Samaru, 2-3 ha.

Eight full time senior research staff and about 12 part time senior researchers are engaged in studies relating to various subject areas listed earlier.

Progress Made

Large scale irrigated agriculture is new to this country. No systematic information of any practical value was available prior to the initiation of the irrigation research project at the IAR in 1975. Information for most efficient cropping systems, irrigation requirement of crops, proper scheduling of irrigation input, design and suitability of various irrigation systems, socio-economics, ecological and the environmental impact of irrigation was urgently required. Some progress has been made in many of these areas.

A tentative recommendation in respect of cropping patterns has been determined for the Bakolori Project. Experimentations on irrigation scheduling for wheat have been almost completed and recommendations are expected to be released shortly. The development of management techniques for conditions of high-water table is in progress. Irrigation scheduling for the sprinkler system has been made for the Bakolori Project.

Standards of various types of sprinklers have been studied in detail and standard units of various components such as riser length, hours of operation, operation pressure, and irrigation water depth have been established. Drainage specifications and design criteria have been determined for the Kano River Project Area.

Work in Progress

Currently the following major projects/experiments are in progress, covering various aspects of irrigated agriculture and taking into account recognized constraints that limit crop production in the savannah zones of Nigeria:

Run-off hydrographs from ungauged watersheds. Synthetic hydrographs for N, Nigeria.

Measurement of evapotranspiration (ET) of irrigated crops by various methods. (Not fully started).

Wheat crop growth-and-yield model.

Effect of groundwater table depth on irrigation water requirement of wheat.

Frequency and amount of irrigation for wheat and onion.

Irrigation schedule and growth stages of various crops.

Irrigation scheduling based on replacement of actual consumptive use of wheat.

Irrigation frequency and nitrogen requirements of wheat under sprinkler irrigation.

Time of nitrogen application and irrigation of wheat.

Nutrient losses under different N levels and irrigation intervals

Effect of irrigation frequency and P and Zn levels on onion.

Monitoring the critical level of Zn at different levels of P under intensive cropping in irrigated areas.

Effect of irrigation levels on the fertilizer P requirement of crops.

Lining irrigation channels for seepage control at Kadawa.

Water measuring devices for experiments.

Weed control in field irrigation channels.

Water conveyance and distribution efficiencies at Kadawa.

Effect of field levelling quality on irrigation efficiency and crop yield.

Vegetative cover for drainage channels.

Water-use management under large-scale irrigation projects.

Wheat-based cropping patterns with legumes as green manure on irrigated soils.

Rotation and sequences identification for irrigated areas.

Monitoring salinity status of irrigated soils.

Movement and annual build-up of salts, under conditions of different depths and fluctuating groundwater table and irrigation frequencies during dry season, in a wheat- maize rotation system.

Effect of crop residue management practices, minimum tillage, and irrigation frequency on soil properties and crop growth.

Effects of deep tillage and irrigation frequency on wheat at Kadawa.

Changes in soil properties resulting from long-term cropping and irrigation.

Proposed Areas of Collaboration

Development of evapotranspiration models for various irrigated crops in Nigeria, to facilitate optimum irrigation scheduling for high water-use efficiency of the project area, is urgently needed. Nutrient and water budgeting in the intensive irrigated crop rotations and sequences need to be studied for various irrigated areas in the savannah zones. Testing of minimum tillage and residue management techniques for irrigated

agriculture under double cropping (wheat-maize) on various soil types and ecological zones is needed, since this technique holds promise under experimental conditions. This would call for collaboration in the following areas.

1. Manpower Training: Short-term training in Nigeria and abroad for the personnel of various cadres.
2. Strengthening of Field and Laboratory Facilities:
 - (1) Lysimeter facilities at three locations.
 - (2) Establishment of Rhizotron facilities.
 - (3) Laboratory equipment such as Neutron-probe, leaf area meters, diffusion porometers, conventional soil and plant analysis equipment, and on-farm water measuring equipment.
 - (4) Green-house facilities.
3. Personnel: Short-term exchange of senior personnel for higher training and study of the on-going experiments in the subject area.

Soil and Crop Environment

Present Position and Constraints Limiting Increased Production

One of the most important factors in agricultural production is land. The proper utilization of our land resources is therefore paramount to increased food production.

1. Soil Survey

The key to good land-use planning is a detailed soil and land survey. The Institute has been carrying out soil surveys since 1957. About 48 surveys have been documented in soil survey reports with accompanying soil maps. At present, approximately 95% of the savannah has been covered by soil survey. However, most of these surveys are at the reconnaissance level. For better planning, detailed surveys are urgently needed.

2. Soil Fertility, Fertilizer Use, and Crop Nutrition

Fertilizer consumption has been increasing ever since farmers were introduced to fertilizers. This is not surprising since farmers realize that the application of fertilizers and proper agronomic

practices (e.g. timely planting, weeding etc.) can increase yield by 50% or more. The problem now is to procure enough fertilizer for both rainfed and irrigated agriculture and their timely distribution so that farmers can apply them when they will be most effective.

Most of the fertilizers consumed in the country are imported. In 1981 about 30% of all imported fertilizer was in the form of compounds. Compound fertilizers are generally excellent for the farmer to use since they save time in application, provide major nutrients, and they cost about the same as single nutrient fertilizers. But sometimes some imported compounds are totally inappropriate to either our soil or crop needs. Soil fertility levels regarding the major elements (N, P, & K) have been documented. Soil test levels of N and P are generally so low that crop responses to the application of these nutrients are usually positive (except on long-fallowed land where N may be high). Responses to potassium tend to be restricted to the riverine areas and the very sandy soils of the Sudan and Sahelian zones. Nevertheless for proper nutrient balance, all major nutrients should be applied, especially where high-yielding crop varieties are used.

Much less work has been done on secondary and trace elements. The determination of the critical levels of these require to be investigated. Cases in zinc and molybdenum deficiency in many parts of the savannah, and manganese toxicity in the Southern Guinea zone, have been observed. Boron is necessary for high yields of cotton and is recommended for routine application as boronated superphosphate.

Under continuous cultivation, low amounts of ammonium sulphate (22 kg N/ha) have been found to lead to serious acidification in savannah soils. Calcium ammonium nitrate (nitrochalk) and urea are preferred N sources in upland soils. While the use of compounds may be as good as straight fertilizers in the short run, continuous use of these compounds may cause secondary and trace element deficiencies in the long run. Bulk blending of straight fertilizers is the answer to the dilemma.

3. Tillage and Residue Management

A major problem in the management of savannah soils is the low level of organic matter. This is compounded by the removal of

all residues by the farmer. Organic matter constitutes about 60% of the cation exchange capacity of the soils. It is also important in the maintenance of soil structure. Tillage methods that can best conserve the organic matter of the soil are highly desirable. The maintenance of organic matter is important to all categories of farmer (hoe, bullock, or tractor). In addition, tillage methods that can give adequate weed control at least cost and lessen soil degradation would go a long way in increasing productivity.

4. Agroclimatology

An agroclimatological atlas of the northern states was published in 1972. This provides a quantitative description of climatic variables and their distribution over the savannah. The atlas could be a basis for crops and varieties to be selected for efficient and optimal utilization of climate. Greater productivity of crop would be obtained if photosynthetic response to temperature regimes, light intensity, and efficiency of water utilization in addition to the traditional length of growing period, are carefully considered.

The collection of meteorological data from stations scattered all over the savannah has been going on for over 40 years in some cases. However, out of the 160 met stations that were operative in the early 70s, only 17 have up-to-date records as of 1982. The need for meteorological records can hardly be over-emphasized as they permit us to observe and predict trends in climatic changes. Hopefully future drought years can be anticipated and care taken to buffer their effects.

Solutions Attained, Problems being Investigated and Possible Areas of Cooperation with ACIAR

The types of fertilizer best suited to savannah soils have been identified and the responses of major savannah crops (groundnut, maize, wheat, sorghum, millet, cotton) to these fertilizer sources have been worked out. Nevertheless new or potential sources are being investigated. Also there are many horticultural, fibre, cereal, and legume crops that have received little or no attention. The investigation of the secondary and micronutrient element in the nutrition of savannah crops is needed.

Biological nitrogen fixation studies are still in their infancy at the Institute. It has been shown that the high yielding soyabean varieties have a marked response to *Rhizobium* inoculation. On the other hand, cowpeas have not responded to inoculation. Other legumes need to be investigated. The isolation of effective rhizobia strains, types of carriers best suited to savannah conditions, and the possible manufacture of inoculants are areas where ACIAR could be involved.

Tillage research (zero, hoe, bullock, and various tractors) is in progress at Samaru. There is a need to expand the study to different soil types. Soil and water conservation research is another area where ACIAR could be involved.

Agricultural Mechanization

Background

As an Institute policy, the program focuses on small-scale farmer conditions without necessarily disregarding the problems of large-scale farmers.

Present Position

There does not appear to be a clear national policy on agricultural mechanization, as is reflected by sporadic importation of farm equipment without a clear assessment of its suitability and relevance to farming systems. Also there appears to be a lack of concerted effort for developing equipment locally for different farm-size operations.

IAR Input and Present State of Achievement

The Agricultural Mechanization Program is operating under three sub-programs, viz. (a) Equipment/Technique Evaluation, (b) Equipment Development (Locally), and (c) Equipment Management.

1. Equipment Evaluation

Practically all equipment is imported and comes from a vast majority of different agroclimatic countries. The Institute assists in evaluating such equipment under local conditions. Based on detailed Technical Reports (numbering over 26), a document No. IAR/AM/83-1 'TEST

REPORT SUMMARIES' was compiled and released. From the feedback received, the Institute evaluation did assist in focusing attention on pre-evaluation and as a consequence, many machines were either modified or withdrawn from sale in the country.

2. Equipment Development

As a long term solution and to enhance the development of local industry, the Institute has designed and produced prototypes of several small-scale items of equipment. Some of these are:

(1) Multicrop Thresher

A thresher suitable for about a 2.5 kW power source and threshing/cleaning three important cereals (wheat, sorghum, and millet) has been perfected. Outputs of 80 kg/hr for wheat; 50 kg/hr for millet and 60 kg/hr for sorghum have been obtained using a 2 man crew, thereby giving a large advantage over traditional methods.

(2) Groundnut Decorticator

A machine giving an output of 200 kg/hr (with 2 operators and 2.5 kW engine) has been developed, giving a tremendous advantage over hand shelling (1 kg/hour).

(3) Sorghum Thresher

The prototype gives a 100 kg/hr output, which is comparable to 25 people working per hour.

(4) Others include (a) a groundnut thresher, (b) a straddle row weeder (oxen), (c) ground metered sprayers, and (d) a weeding attachment (Emcot).

The Institute is setting up a small prototype production unit to duplicate many of the promising machines for wide distribution to farmers.

3. Equipment Management

The program has contributed by quantifying the losses occurring in crop handling and processing, and ways to reduce the losses.

Problems Currently Being Investigated

The program is focusing attention on the development of harvesting aids, especially for cereals and cotton. Effort is also directed

towards developing equipment for tillage, combining several operations in order to minimize the energy input and reduce compaction. Preliminary studies have been initiated on crop drying, especially using solar energy. The idea is to accelerate removing the crop from the ground (once physiologically mature), dry it where needed for storage, and then make room for the next crop.

Areas of ACIAR Support:

1. Strengthening equipment evaluation techniques by providing and/or developing precision instrumentation.
2. Collaborating on developing harvesting equipment for cereal and cotton, suitable for the small-scale sector.
3. Collaborating on developing minimum tillage equipment suitable for the ecological area and farming system.

Farming Systems

Cropping Systems Studies

In former years, these included conventional rotation studies with sole crops that were primarily designed to examine the possibility of using fertilizers and crop sequences to maintain fertility in permanently cropped land. The results have been reported in detail, but have had little impact because farmers continue to resist conventional rotations and their ability to obtain fertilizer tends to be sporadic.

More recently, the emphasis has been on mixed cropping studies, resulting in part of the observation that mixed cropping continued to be the preferred production system in the Zaria area, and also in part from repeated failures to intensify through double-cropping on the IAR farm. Studies have focused on the three categories of mixtures identified in the Zaria area, namely (a) mixed cereals, sometimes including cowpea as well, (b) cereal-groundnut mixtures, and (c), cereal-cotton mixtures.

Most of the common mixtures have been repeatedly shown to be capable of yields valued at 5-35% more than the mean of their sole crops, and sometimes more than the most valuable sole crop. Experimental variables in these mixtures have included variety, population, proportion, arrangement, and time of

sowing of the component crops. More recently, fertilizer, herbicide and insecticide inputs have been studied and the mixed cropping studies have been extended to Kano and Mokwa substations representing the Sudan and Southern Guinea Savannas.

Some general principles emerging from this work are as follows:

1. Mixtures, which do not include legumes, usually have a yield advantage in proportion to the difference between the two component crops in the time of maximum growth.
2. Mixtures with legumes (except soyabean) usually have a yield advantage with zero N fertilizer, but this may disappear if high N levels are used, unless the legume and non-legume also differ in the time of maximum growth.
3. Most new varieties, though selected for their performance in sole crops, perform very well in mixtures.
4. Alternate row mixtures have usually been as good as or sometimes more productive than similar mixtures formed by mixing species in the same row or ridge. The alternate row mixtures lend themselves to improvement, especially insecticide application to the lower crop.
5. For mixtures that do not include a legume, the fertilizer response in monetarized terms is usually comparable to the mean of the component crops, but the harvested proportions at different fertilizer inputs can be very different. Some mixtures of legumes (except soyabean) with millet or sorghum do not give economic returns to N fertilizer, but their yields without N fertilizer can be fairly high. Mixtures with maize invariably respond to N fertilizer, although the legume yield may be reduced. Circumstantial evidence suggests that there is little or no transfer of N from the legume to the non-legume in the same season and the residual benefits of legumes in mixture have usually been disappointing compared with sole crops of the legumes.
6. Suitable selective herbicides have been identified for season-long weed control in some of the common mixtures of the savannah and for partial weed control in most of the other mixtures.

Outstanding problems that remain include:

1. Persistent evidence of detrimental residual effects of mixing crops, which appear to be unpredictable in their occurrence, not corrected by high inputs of N and P as fertilizer, and for which no explanation can be offered at present.
2. Difficulties of applying insecticides to cowpea and to a lesser extent cotton when grown in mixtures with cereals, and the related problem of maintaining adequate cowpea yields in high-yielding crops of the more vigorous cereals.
3. The reduced effectiveness of pre-emergence herbicides when used in the minimum hand tillage systems (gicci) common in the mixed crop culture of the savannah.

In 1983 the first on-farm testing of a package of practices designed to give high yields of the productive and popular maize-cotton mixture was initiated. This included variety, herbicide, fertilizer and insecticide.

Farm Management Studies

At present, the studies are concentrating on the impact on the small-scale farmers' system of adopting a selection of sole crop packages as recommended by the Institute. Farmers who agree to grow these packages in return for the inputs supplied by the Institute are carefully monitored throughout and are interviewed at the end of the season. About 50 farmers are presently involved. Some preliminary findings are:

1. The maize package is generally acceptable to farmers.
2. The main limitation on the adoption of the sorghum package appears to be the unacceptable seed quality of the currently available high yielding varieties.
3. Weed constraint was a major constraint among participating farmers in 1982 and, therefore in 1983, an attempt has been made to include a herbicide component into the packages. Some did not work very well but where the herbicide did work, the farmers were very pleased with the result.
4. It has not been easy to persuade farmers to sow early; often they have sown the experimental fields later than fields farmed by

traditional methods with consequent disappointing yields.

5. Farmers are concerned about marketing constraints if they increase their production.

Institutional Studies

A comparative study of extension and input delivery systems in five contrasting states has shown the policy diversity that currently exists within northern Nigeria and the lack of co-ordination between different Ministries or organizations, which in all states share the responsibility for technology delivery. Further studies, especially of constraints on input delivery, are planned.

Social Structures

Data now collected are designed to quantify the degree of diversity existing among farmers in their resource endowment, and should serve to develop criteria for defining recommendation domains among groups of farmers.

On-farm Testing of IAR Technologies

This program serves as a common forum for the on-farm testing studies listed in each of the Commodity Research Programs. These studies are designed to ensure that recommendations coming from the Institute are appropriate to small farmers' needs and circumstances.

Miscellaneous

The 'Identification and Description of Important Cropping Systems' project, begun in 1982, has the aim of collecting existing information on the farming systems of northern Nigeria, and making field studies of areas where no adequate description of the farming systems already exists. The field studies have used the rapid diagnostic survey methods (sondeo) developed in South America, modified by having a series of short (3 or 4 day) visits at different times in the cropping season. A multidisciplinary team visits farms, observes cropping patterns, and holds informal interviews with farmers as they are encountered in the field. In 1982, field studies were carried out in NE Kano State, an area where millet is the most important crop. The report is expected shortly. In 1983, we are

studying an area in Western Plateau State where yam is important.

The primary aim is to feed the information on practices and production constraints back into the Institute's research program and especially into the Cropping Systems Sub-program. However, it is also hoped to follow up the field studies by involving participating researchers in the planning of on-farm and adaptive research being mounted by other organizations, especially the Agricultural Development Projects.

Food Science and Technology

Identified Constraints

Limiting factors to crop production in any environment are several and generally include physiographic, edaphic, and agroclimatological factors. These actually either prevent cultivation or cause losses of already cultivated crops. However, in developing economies, other crop losses have been identified that are mostly postharvest, including storage. In such developing economies like Nigeria, where the development of agro-allied industries are in their infancy, aspects of processing and utilization are far from being developed. It is in this aspect, that the Food Science and Technology Research Program of the IAR (Samaru, Nigeria) becomes pertinent.

This program has identified broad areas of constraints to increasing the production of Nigeria's savannah crops. These include utilizable information on (a), the biological quality of the savannah crops including cereals, oil crops, grain legumes, fibre crops, and horticultural crops; basic information on their qualities would help to determine which crop could be used for what and where in the agro-industry, (b) the processing of these crops, both by local and industrial methods, and (c) the monitoring and evaluation of contaminants of these crops in foods derivable from the processing methodologies.

Solutions of these three identified major constraints would greatly enhance increased production of the savannah crops in larger hectares for more agro-allied industrial uses (including ready human foods, flours, animal feed, drinks, drug, ropes etc.), which would be in addition to normal present usage in human food and clothing.

Problems Currently Being Investigated

Within the Food Science and Technology Research Program, four sub-programs of biological quality, local and industrial processing, and monitoring of contaminants serve as broad research areas. In each of these, solutions to problems are being investigated in five crop-based projects of cereals, oilseeds, fibres, grain legumes, and horticultural crops.

Specific investigations presently are on:

1. Determination of quantity and quality of proteins, amino acids, and tannins in sorghum, millet, wheat, and cowpea, including their nutritive values.
2. Determination of the industrial uses of cereals, specifically baking quality studies of wheat towards making acceptable bread from locally grown wheat, and malting studies in sorghum for making acceptable malt drinks, foods, and lager beers from indigenous sorghum, respectively.
3. Composite flour research towards developing acceptable and usable blends of cereal flours (wheat, sorghum, millet, and maize) for making bread, pastries etc.
4. Crop residue studies in sorghum, millet, and

maize towards obtaining information on their differential utilization as animal feed supplements for cattle, sheep, and goats.

5. Studies on local processing and acceptability of the different foods made from sorghum and more horticultural crops.
6. Studies on industrial processing and monitoring of resultant toxic contaminants in groundnut and wheat.

It is expected that as this relatively new program becomes well established with complete components of analytical and technological equipment, the already identified areas of research will be broadened in scope and depth. Other areas to be researched include mainly the technological aspects of developing new foods and associated new processing methods and equipment.

Role of ACIAR

ACIAR could collaborate in the areas described. Of special concern is the need for a collaborative and interdisciplinary research approach in (a) crop residue studies for animal feed, and (b) bread technology involving wheat flours from indigenously cultivated wheat, and composite flour from all indigenous cereals.

Soil Fertility and Management in Nigeria

R.A. Sobulo*

Nigeria is largely within the tropics. It is generally believed that tropical soils are poor in nutrient status and that fertility can be maintained only by using bush fallow cropping systems. Research to date indicates that this is an over-generalization. In Nigeria, soil fertility is influenced by climate, vegetation, and parent rock from which the soil is formed.

Soil management is very essential in current agricultural development in Nigeria. The notion that soils can be productive when fertilizers are added is erroneous. Fertilizers can in fact ruin the soil if the dynamics of the nutrient and the chemical characteristics of the soil are not well understood. The various agricultural programs of the Federal Government, which includes a minimum of 4000 ha in the Agricultural Development Project (ADP) in each of the 20 States (including the Federal Capital), the crop production programs in the 11 River Basin Development Authorities as well as cooperative farmers food production program will bring at least an additional 1 000 000 ha of land under crop production by 1985. There is, therefore, need to understand the fertility and management of the soils if high crop yields are to be maintained, especially under intensive cultivation.

Nigerian soils can be broadly grouped into the following four major categories for management purposes:

1. Soils with a high base saturation under savannah vegetation – Alfisols, Inceptisols, Vertisols, Cambisols.
2. Soils with a high saturation under forest vegetation – Alfisols, Inceptisols, Gleysols, and Cambisols.
3. Soils with a low base saturation – Oxisols and Ultisols under forest vegetation.
4. Soils in the semi-arid region – Inceptisols, Entisols, and Andosols.

Soils with a High Base Saturation in Savannah Grassland (subhumid region and semi-arid soils)

These soils are formed from metamorphic, igneous rocks, volcanic, and sedimentary parent materials. These parent rocks in turn influence the chemical characteristics. This area has high potential for grain production when water is not limiting and could be termed the Grain Belt.

The soils in the savannah grassland are generally low in organic matter, total nitrogen, and available phosphorus. The organic matter is about 1-2%, total N is 0.03-0.08%, and Bray 1 P, 2-10ppm (Table 1). These values are generally not adequate for yields of 2-3 t/ha of maize. N and P fertilizers are needed even in the first year. While N requirements of 100-120 kg N/ha may be required, a P rate of 10-20 kg P/ha is adequate due to the low phosphorus sorption capacity of a high proportion of these soils resulting from low Fe and Al responsible for fixation of P (Kang and Osiname 1979; Mokunye 1979).

Potassium deficiency is observed on the sand soils (Inceptisols, Contisols) in this zone. Under continuous cultivation 50 kg K/ha (100 kg of muriate of potash) is needed (Amon and Adetunji 1973). Recent results show a more pronounced K response (Heathcote 1973; Sobulo 1980) on sandstone than on soils from basement complex. Linear K requirement is obtained 30-120 kg K/ha when soil K is less than 0.2 m equiv. K/100g in a recently completed study (Sobulo 1983).

Magnesium is low in this zone, often between 0.3-1.0 m equiv./100g depending on soil organic matter. High K application could induce magnesium deficiency on crops like maize; 20-30 kg Mg/ha is adequate for maize.

Sulphur deficiency is common and it occurs in the first year of clearing grass savannah, but

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Table 1. Chemical characteristics of some typical soils in the Southern Guinea savannah zone of Nigeria.

		Soil No.	pH	C (%)	Silt (%)	Clay (%)	Trace elements (ppm)				
							Fe	B	Zn	Cu	Mn
1	A	1	6.2	0.20	18	5	1.0	0.51	1.6	2.0	13.9
	B	2	6.1	0.10	6	5	2.0	0.38	0.5	2.0	7.5
2	A	3	5.9	0.49	14	5	1.0	0.58	2.4	5.0	10.7
	B	4	6.0	0.29	12	15	5.0	0.32	1.2	5.0	11.0
3	A	5	5.8	0.52	8	5	3.0	0.64	2.1	2.0	12.7
	B	6	6.0	0.24	10	6	1.5	0.45	0.5	2.0	12.2
4	A	7	6.2	6.55	8	3	1.3	0.12	1.2	0.5	—
	B	8	6.0	0.23	9	7	2.5	0.04	1.6	0.5	—
5	A	9	6.1	0.47	7	6	2.5	0.10	1.3	1.0	—
	B	10	6.1	0.31	8	7	1.3	0.05	1.2	1.0	—

A = 0-15 cm

B = 15-30 cm

Critical levels for arable crops

Fe = 5 ppm

B = 0.25 ppm

Zn = 2 ppm

Cu = 1 ppm

Mn = 5 ppm

immobilised sulphur becomes available in the second season and then declines with a fall in organic matter (Bromfield 1972). The use of single super as the source of P, or a small dose of ammonium sulphate at 50 kg/ha is adequate to provide 10 kg S/ha required for maize. Bush burning tends to aggravate S and N deficiencies in the savannah.

Zinc deficiency is pronounced in the Southern Guinea and derived savannah zone of Nigeria (Osiname *et al.* 1973a). Extractable zinc in 0.1N HCl (1:10 soil to solution) is suitable for assessing zinc on a pH less than 6.5 (Osiname *et al.* 1973b). When soil-available zinc is less than 1 ppm (Osiname *et al.* 1973b) a pro-

nounced response to 1-2 kg Zn/ha is observed (Table 2). There is need to incorporate Zn in the recommended compound sources such as 15-15-15 for this zone.

Boron deficiency is reported in this zone for cotton (Heathcote and Smithson 1974) and tomatoes (Sobulo 1980b). The use of boronated phosphate or the foliar application of 0.05% borax at 0.5-1 kg B/ha is adequate for these crops. Boron deficiency is observed when hot water boron is less than 0.15 ppm. A range of 0.10-0.40 ppm is common in this zone (Sobulo 1980b). Cu and Fe deficiencies are common but little information is available on their problems and solutions (Kang *et al.* 1977).

Table 2. Grain yield response of IITA maize composite B to Zn fertilization* (after Osiname *et al.* 1973a).

Kg Zn/ha	Site					
	Ikenne	Iwo	Ilora	Ogbomosho	Kishi	Sepeteri
0	6853	4067	3680	4693 a	5839 a	3333 a
1	7053	3693	3973	4933 a	6653 b	5080 b
2	6573	3799	4333	5533 b	6358 ab	4733 b
3	6560	3907	4013	5667 b	6507 b	4907 b
8	6880	3733	3573	5667 b	6493 b	5253 b

* Values within columns followed by the same letter or no letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

Soil Management

In this zone, intensive cultivation is possible provided suitable crop rotation or intercropping is practised.

Maize-cowpea intercrop will use fertilizer more efficiently than would separate crops. A maize and cassava rotation is also suitable in this zone. Rotation involving legume in the system will increase soil fertility and reduce high N requirements for the succeeding crop. Other rainfed crops that will do well include sorghum, millet, yam (Southern Guinea) and cotton.

Soils with a High Base Saturation Under Forest Vegetation (semi-arid tropics)

The soils in this area have similar parent rock to the above, except that rainfall is higher – a range of 1000-1500 mm rainfall and therefore a higher organic matter. Organic matter is about 2-5% in this zone, depending on the age of the forest. Consequently the nutrient status is often higher, viz. about twice or more. The length of cropping can be increased to two years before N and P fertilizer can be limiting. On soils from basement complex, K may not be required until after 3 or 4 years of continuous cropping. Trace elements are often not limiting on the soils from basement complex in this zone, except on very acid soils.

Management

The soils can be easily eroded and therefore nutrient losses through soil and water erosion are common. Maize, yam, cassava, cowpea (late crop), melon, and cotton can grow in this zone. A rotation of 1st year maize (late cowpea), 2nd year (upland rice or yams), 3rd year (cassava) is

recommended for this zone under continuous cultivation. As much as possible, the soil should be under crop cover to reduce soil erosion.

Mulching with rice or maize straw can control erosion. Table 3 shows that 4-6 t/ha will effectively control soil loss on 1-10% slope (Lal 1976). No tillage soil-management can produce a similar effect as mulching at 4-6 tonnes. Total annual nutrient losses (N, P, K, Ca, Mg) from bare fallow was 65 kg/ha from a 1% slope and above 600 kg/ha from 10 and 15% slopes; corresponding values on maize – maize (conventional ploughing) were 9 kg/ha from a 1% slope, and 140 kg/ha and 5.6 and 210 kg/ha respectively for 1% and 15% slopes for cowpea – maize plots (Lal 1976). These data indicated that soil nutrient losses can also be reduced by cropping systems.

Soils with a Low Base Status in the Humid Tropical Region

Soil acidity, high exchangeable Al, very low exchangeable bases, and available micro-nutrients are multiple nutrient problems in this zone. Table 4 shows the chemical properties of some Ultisols in southern Nigeria.

Potassium, magnesium, and phosphorus are often needed to maintain yields but the soils have to be moderately limed to reduce Al toxicity. Frequent low liming at 0.5-1.0 t/ha every 3 years may suffice on this soil. Higher rates often induce nutrient imbalance, particularly K and Mg problems and some essential trace elements such as Zinc and Cu. Exchangeable Al should be reduced to 10-15% of the saturation percentage of effective cation exchange capacity (ECEC) for crops to do well.

Soil Management

Crops adapted to low base saturation and low

Table 3. Mulching effect on runoff and soil loss (mm), first season 1974 (Lal 1976).

Slope %	Mulch Rate (t/ha)				No-tillage	Mean
	0	2	4	6		
1	283.2	6.0	4.2	0.0	6.4	60.0
5	345.9	61.2	10.1	6.7	8.9	86.6
10	218.5	45.5	20.9	12.3	15.2	62.5
15	294.3	46.9	20.0	12.1	14.1	71.6
Mean	285.5	39.9	13.8	7.8	11.2	

Table 4. Analytical data Paleudult at the NIFOR Main Station.

Horizon	Depth cm	Gravel %	V.C. Sand %	C. Sand %	F. Sand %	Silt % .05-.002 mm	Clay % <.002 mm	pH (H ₂ O)
A1	0-11	—	19.5	15.6	13.0	2.7	14.2	4.90
A2	11-36	—	15.2	40.2	15.7	1.7	27.2	4.40
A3	36-68	—	16.0	41.7	13.4	1.2	27.7	4.30
B21+A	68-103	—	17.0	43.0	12.6	0.7	26.7	4.40
B1 +B	68-103	—	14.7	42.8	9.1	0.7	32.7	4.30
B22+	103-156	—	16.2	39.5	8.4	0.7	35.2	4.40
B23+	156-200	—	19.3	33.9	7.4	0.7	38.7	4.55

Org. C %	Total N %	Avail. P ppm	Exch. Cations				Exch. Acidity m.e/100 g Soil	ECEC m.e/ 100 g Soil	CEC m.e/ 100 g Soil	B.S. %
			Ca	Mg	K	Na				
			m.e/100 g Soil							
1.36	.140	1.58	2.50	1.00	0.08	0.04	1.10	4.72	33.24	76.69
0.76	.070	2.18	1.00	1.00	0.08	0.04	2.10	4.22	15.51	50.24
0.52	.084	0.80	0.75	0.25	0.08	0.07	2.10	3.25	11.73	35.39
0.46	.070	1.54	1.25	0.25	0.03	0.07	2.10	3.70	13.86	43.24
0.46	.070	1.68	1.00	0.25	0.05	0.04	1.90	3.24	19.91	41.36
0.34	.056	1.47	0.50	1.25	0.06	0.04	2.00	3.85	10.94	48.05
0.20	.042	0.70	0.75	0.50	0.05	0.04	2.00	3.34	8.63	40.12

Source: Field Tour Report, National Soil Correlation/Soil Science Society Conference, 27th November–3rd December, 1980.

solar radiation should be grown in this area. These are upland rice, cassava, sweet potato, cowpeas (late crop), and some grass and pasture legumes. In such a case, better utilization of the soil and inputs such as fertilizer will be achieved. An inter-crop system as in other cases will reduce soil erosion that can result from greater rainfall and intensity, than in other regions.

The use of rock phosphate or basic slag will provide lime and P, and reduce fixation of the soluble P sources such as single super. Legume sources of N will also reduce soil acidification.

Soils in the Semi-Arid Zone (200-500 mm Rainfall)

Soils in this area are often derived from aeolian sand. They are often young soils (Entisols). Vertisols are sometimes found in this area. The soils generally have a high base status and when saline, they have to be reclaimed before use. Good crop yields are achievable when

irrigation is possible. In the case of Vertisols, cultivation is often difficult when it is too dry. Land preparation under rainfed conditions must be timed to periods when it is neither too wet nor too dry.

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Weed Control and Crop Production in the Arid Zones of Nigeria

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Agricultural crop production is difficult in the arid zones because of insufficient rainfall. In the Nigerian context, the arid zones may be divided into two main vegetational zones, namely the Sahel savannah and the Sudan savannah, with the latter being referred to as the semi-arid zone.

The Sahel savannah is a small belt in the north-eastern part of Nigeria bordering the Niger Republic and generally located north of the 500 mm isohyet. Scrub grassland vegetation characterizes this area; the grass cover is generally sparse, short and poor. Rain falls for only about 3-4 months of the year, and during the long dry season most of the grasses vanish rapidly leaving behind a bare soil. The whole zone then develops a desert-like appearance.

The Sudan savannah is a large dry zone generally located between the 500 mm and 750 mm isohyets and covers a large portion of the northern-most part of Nigeria from Sokoto to Borno. The woody vegetation in this zone is a mixture of thorny and spineless species that are found in some dense patches of woodland or scattered throughout the grazing and cultivated areas. The Sudan savannah unlike the Sahel is an important crop production area with a sizeable population, which has been engaged for centuries in crop farming and livestock grazing. These areas are always under the threat of drought, which seems to affect the area from time to time. Both the arid (Sahel) and semi-arid (Sudan savannah) are recognized bio-climatic regions, the common factor being inadequate rainfall. The real arid areas are incapable of a sustained and established form of agriculture but they can be used for cattle grazing.

In this paper, focus is directed on the problem of weeds and their control as it affects crop productivity, especially in the arid zone but with some references also to the semi-arid zone that borders it.

The problem of crop production in arid conditions is difficult. Inadequate rainfall coupled with a short rainy season and erratic rain distribution restricts the productive period to only a few months of the year.

Table 1 shows the annual rainfall and climatic conditions of some selected stations located in the arid zone in Borno State for the period 1979-83.

The crops that can be grown in the arid areas must be those that can be harvested within a short growing season and it is an advantage if they are also drought resistant or drought tolerant. Weed competition with such crops reduces the yield capacity further, especially as the naturally occurring weeds are more adapted to the arid conditions than the introduced cultivated crops. The problem of weeds is therefore potentially more serious in the arid zone in its effect on crop productivity than elsewhere where there is adequate rainfall. The introduction of irrigation changes the ecological balance and it may even favour the weeds; therefore weed control is of paramount importance for crop productivity in the arid zone.

General Problems Associated with Weeds in Agricultural Production

1. Many nematode, fungal, and bacterial diseases, as well as insects, are harboured by weeds. They thus aid the propagation of crop enemies and render them more destructive and difficult to control. Mention could be made of nematodes of tomatoes and rice, bacterial blight of cowpea and maize, downy mildew of lettuce, and blast of rice caused by fungi, all of which have weeds as the alternate hosts. The pink bollworm of cotton, stemborers of rice, and the sweet potato weevil all infest field weeds, live and multiply in them. In the Lake Chad area the wild

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Table 1. Total annual rainfall (mm) for some arid areas of Borno State (1979-1983).

Year	Yau	Kukawa	Monguno	Ngala
1979	615.7	398.6	526.4	394.0 (1972)
1980	190.3	288.1	299.6	373.0 (1973)
1981	163.2	223.3	302.8	542.0
1982	149.4	169.1	194.4	262.8
1983	118.9	224.5	93.7	302.5
Mean	247.5	260.7	283.4	374.9

The data from Ngala (Table 2) contain rainfall records of 1972-73, which were years of drought. It can be seen that even in an arid area, drought reduces the already meagre annual rainfall.

Table 2. Agrometeorological data for Ngala in the arid zone (1972-1975).

Year	Rainfall (mm)	Mean Temperature (°C)		Total Evaporation (mm) (Class 'A' Pan)	Humidity (%)	
		Max.	Min.		0900	1500
1972	394.0	35.7	20.3	4338	47	37
1973	373.0	37.1	21.0	4999	47	37
1974	481.0	35.2	19.8	4439	46	37
1975	510.8	34.3	19.5	4251	45	40

sorghum harbours the insect pest *Ailopus* sp thus providing its food in the absence of the cultivated crops.

2. Weeds impair the quality of farm products when they contaminate crop produce. Weed seeds, even in small quantities impart objectionable odours and flavours to wheat flour if ground with wheat.
3. Weeds reduce the quantity and quality of livestock products as some such as wild garlic impart an undesirable flavour to cow's milk after grazing. Many poisonous weeds have been responsible for annual losses of livestock. Severe weed infestation reduces the carrying capacity of grasslands and pastures.
4. Weeds impair the health of farmers who accidentally eat poisonous ones. Farmers who suffer from hay fever trace their affliction to pollens of weeds. Farmers' skins often itch due to contact with certain weeds, e.g. *Karangia*.
5. Removal of weeds increases labour cost, and the cost of equipment for weed control.
6. Weeds compete with crops for light, moisture, and nutrients thereby reducing their yields. Heavy yield losses occur yearly from weed infestation during the production of various crops.

Problem of Aquatic Weeds and Irrigation Water Supply from Lake Chad

Aquatic weeds obstruct water flow, increase evaporation, cause large losses of water through transpiration, and prevent proper drainage of land. Dense populations of aquatic weeds as found in Lake Chad use up considerable amounts of the valuable irrigation water. Sikes (1972) reported that transpiration from the vegetation is thought to account for 17% of the water lost from Lake Chad. Roots of weeds in irrigation canals also increase seepage losses.

Weed Species in the Arid Zone and their Characteristics

Climatic conditions in the arid zone favour the growth of weeds early in the rainy season. The arable weed flora dominated by annual grasses consisting of *Pennisetum* sp, *Digitaria* sp, and *Dactyloctenium aegyptium* are ecologically more adapted to arid conditions than the arable crops. They therefore compete very favourably with the food crops for available moisture, light, and nutrients. Their ability to germinate and grow faster than crops with minimum moisture

gives them an advantage. In view of the low mean annual rainfall (less than 500 mm), lasting around 120 days or less, the arid zone is well suited for irrigated agriculture.

Weeds of Irrigated Fields

Conditions in irrigated-crop fields favour the growth of aquatic and semi-aquatic weeds. *Sorghum aethiopicum*, *Cyperus esculentus*, and *Cyperus rotundus* are probably the major weeds found in the irrigated farms around the Chad Basin in the heavy clayey soils. *Sorghum aethiopicum* is an annual grass weed that grows very tall thereby quickly shading the crop, especially the semi-dwarf rice varieties. Both *C. esculentus* and *C. rotundus* are perennial sedges that constitute the greatest menace to irrigated crops. These perennial sedges are complex plant systems comprised of roots, rhizomes, tubers, and basal bulbs below ground, and above ground they have rosettes of leaves and umbel-bearing scapes. In addition to seeds, these sedges reproduce vegetatively by tubers. The basal bulbs and tubers are the principal means of propagation.

Vegetative propagation of the two nutsedges is both rapid and vigorous. It is known that dormant buds of young or mature tubers resume growth in acropetal succession. Tillage operations cut the sedges into smaller pieces, thereby enhancing increased vegetative propagation. These sedges are also formidable because of their excessive rhizomes and apical dominance system.

Wild rice (*Oryza longistaminata*) is widely distributed in the irrigated areas of the arid zone, which are particularly suitable for the development and spread of this weed. Wild luffa (*Luffa echinata*) constitutes a minor problem. This broadleaved weed has long, creeping stems that tend to foul the reel of the combine harvester and hinder combine harvesting. In large scale farming, such as practised by the Chad Basin Development Authority (CBDA), the use of combine harvesters is the standard method for harvesting wheat.

Weeds of the Arid Zone

The annual arable weed flora is dominated by annual grasses of which *Dactyloctenium aegyptium*, *Pennisetum* and *Digitaria* species

are the most important. Although the early weed flora is dominated by annual grasses, a considerable proportion of non-grassy annuals occur, notably *Commelina* spp, *Ipomea* spp, Cucurbitaceae spp, Convolvulaceae spp particularly *Convolvulus arvensis* (Shepherd's Purse), *Ageratum conyzoides* and many annual and perennial sedges. If this flora is controlled, the regrowth weed flora is usually dominated by *Luffa echinata*, a very vigorous broadleaved weed. The most common shrubs are *Acacia* spp.

The troublesome weeds like *Cyperus esculentus*, *Cyperus rotundus* and *Sorghum aethiopicum* normally occur in patches of poor drainage or valley bottoms, and in irrigated fields and less drained areas and fields with a previous history of irrigation.

Effect of Weeds on Crop Production

Weed problems in cropping systems in the arid zone consist of annual, perennial, and parasitic weeds. Tillage methods used in the various cropping systems affect the severity of the problems and often dictate the weed control method. Although some cropping systems are known to reduce weeding frequencies (IITA 1979) none of the commonly used cropping patterns in the arid zone can protect the crop from the effect of early weed interference, which is a problem common to all crops.

Most probably the most important effect of weeds on crop production is the yield losses caused by early weed interference with crops, resulting in competition for the essential requirements – nutrients, moisture and light.

In the arid zone, substantial yield losses occur annually from weed infestation during the production of various crops. For example, under rainfed conditions, yield losses of 32-41% in sorghum, 55% in millet, and 53% in cowpea were reported by Okafor (1982c). Comparatively, Lagoke *et al* (1980) reported a yield loss of 28-65% in cowpea in the semi-arid zone. Under irrigation culture, yield losses of 40-75% were reported in direct-seeded rice by Okafor (1978, 1979, 1980, 1981, 1982a,b). Similar yield losses of 33-100% were reported by Williams (1975) and Fagade (1976) in the semi-arid zone. In maize a yield loss of 63% was reported

by Okafor (1983). However, Okeleye (1980) and Olunuga (1980) reported yield losses of 30-100% in maize grown in the rain forest zone under rainfed conditions. Yield losses of 47-89% were reported in irrigated cotton in the arid zone (Okafor 1982b,d, 1983). Chaudhary (1978) reported a yield loss of 10-95% in cotton in the semi-arid zone. These data show that weeds are one of the major constraints to crop production in the arid zone.

Peculiar Problems of the Arid Zone

The mean annual rainfall in the arid zone is less than 500 mm (Table 1) falling during a rainy period of around 120 days. In traditional cropping systems, one of the reasons for allowing cultivated lands to revert to bush fallows was to reduce weed infestation (Emerson 1953; Conklin 1957). When the fallow period was long (over 5 years) many annual and perennial grass weeds were suppressed by the forest vegetation. While the increasing human population in the humid and semi-arid zones has put such a pressure on available land that fallow periods have now been shortened to the point that perennial weeds, especially grasses, have become serious problems in newly cleared land, it is the lack of rainfall and consequent low rate of afforestation that has helped the ecologically well adapted perennial grasses and sedges to become serious problems in the arid zone. The scanty vegetation cannot suppress the annual and perennial grasses and sedges, however long the fallow may be. This problem is therefore peculiar to the arid zone.

The traditional farming practice in the sandy soils of the arid zone is akin to zero tillage, in that the farmer does not till the soil before sowing the seeds. Just before, or immediately following the first rain of the year, the farmer opens up the soil with a long-handled hoe, while his wife drops in the seed and then covers it. It is common to find that the weed seeds, very much adapted to the ecology, germinate with minimum soil moisture, emerge and grow very vigorously to smother the crops, if left uncontrolled. This is therefore another peculiar weed problem, since in the forest and semi-arid zones most farmers cultivate the soil before sowing the seeds in order to control weeds.

Weed Control Measures

Weed control practices can be broadly classified into cultural, chemical, and biocontrol methods (Akobundu 1980).

1. Cultural control

Cultural control of weeds includes all the aspects of good crop husbandry that are used to minimize weed interference in crops, e.g. crop rotations and cropping systems, burning, hoe weeding, mechanical weeding, and mulching involving either plant residue or synthetic material.

(i) Hoe Weeding (Hand Weeding):

At present the hand hoe is certainly the most widely used cultivation tool for both seed-bed preparation and post-emergence weed control. Weed control operations by hand hoe are slow, tedious, and expensive since a single hoe-weeding may require up to 500 man hours/ha depending on the crop. Ogborn (1977) reported 300-500 man hours/ha for cotton in the semi-arid zone of Zaria.

In areas of low human population density, this method could become a limiting factor. Also the arid areas are sparsely populated and the hand hoeing in large-scale crop production is impracticable.

(ii) Mechanical Control:

Weed control with machines such as tractors requires high capital inputs, skilled operators, and good management in order to realize its potential. Unfortunately there are not many arid areas where all these desiderata are fulfilled. Tractors are most widely used in semi-mechanized systems of weed control, in which the seed-bed is prepared by tractor cultivation, but in which the tractor is not used for post-emergence weed control operations. Where tractors are mainly operated by hire units, it is understandably difficult to arrange timely inter-row cultivations. For pre-plant incorporated and pre-emergence herbicides, the tractor has great operational advantages, since the tractor operations can begin well ahead of sowing, and seed-beds can be made 'weed proof' and left ready for timely sowing. These advantages are not sufficiently exploited by mechanized farm managers in the arid zone.

Tractors, which permit rapid and deep seed-bed preparation, are not always exploited for optimum weed control. Primary post-harvest cultivations should be emphasized. Using the dry season for control of perennial weeds by cultivation and desiccation is routine in developed countries and should be emulated for weed control in the heavy clay soils of the arid zone.

Weed control with animal powered cultivations is essentially a mechanized system. The power unit (the draught animal) has many advantages over the tractor: it requires no spares and it uses renewable fuel (crop residues). The main disadvantages seem to be low draught and susceptibility to trypanosomiasis, which is absent in the arid zone. At present there appears to be no satisfactory equipment for applying herbicides that has been specifically designed for animal-drawn equipment. Surprisingly the number of draught animals for farm cultivation is rather limited in the arid zone of Nigeria.

(iii) In-situ Mulch:

Recent studies by Lal (1975) and Lal *et al.* (1978) show that the use of in-situ mulch for weed control has potential as a long-term method of reducing weed-seed population in soils, reducing soil erosion, and increasing cropping frequency in tropical soils without irreversible loss in soil structure and fertility. This particular system could be very suitable for the sandy and clayey soils of the arid zone but not much of this is practised in the zone.

(iv) Crop Rotations:

Every crop has its characteristic weeds and by growing the same crop in the same piece of land every year, these weeds tend to increase in number. Crop rotation will result in reduced infestation in any one crop due to a shift in weed species, e.g. the CBDA anticipates a rotation involving rice, wheat, and cotton.

2. Chemical weed control

Chemical weed control is suitable for large-scale crop production. It is also the most effective weed control method for dealing with the problem of early weed interference in crops. Its advantages in reducing labour costs and

increasing crop yields in the tropics have been demonstrated by Parker (1972), Okafor (1979, 1981a), and Akobundu (1980a).

Lageman (1977) reported that 90% of hired labour was used during the early rains for weeding, failing which the planted crops will be abandoned. Newell (1977) reported that 25% of the rice crop was abandoned to weeds at the Chad Basin Development Authority (CBDA), probably due to the unavailability of enough hand labour. A pre-emergence herbicide would be ideal, both for reducing labour requirements at the peak period and minimizing early weed interference in crops, which is often taken for granted.

Some factors limiting herbicide use in Nigeria today include:- an acute shortage of trained professional manpower, poor timing of herbicide applications, inadequate knowledge of herbicide recommendations, lack of a reliable extension service, and scarcity of consumer-usable small packs. However the increasing labour shortage, which has become more acute with the departure of aliens, and the high cost of available labour, will make chemical weed control more attractive, if not the best option open to large-scale farmers of the zone.

The small-scale producer is unlikely to use volatile herbicides, which have to be incorporated, because of the extra effort required at a time when the soil is rather hard. Such herbicides should have a wide range of crop tolerances to permit their use in crop mixtures. A typical example is linuron, which has been used as a selective herbicide for the millet-sorghum mixture in the semi-arid zone, when applied pre-plant broadcast. It is also tolerated by cowpeas, groundnuts, cotton, and maize. The quantitative reduction in hoeing effort and in increased crop yields will make this a profitable herbicide, and particularly suitable for the arid zone.

Farmers who presently use the hand hoe for weed control have potentially much to gain from the use of herbicides. Comparatively little use of herbicides has yet developed within the Nigerian arid zone. This is a matter requiring urgent attention by extension workers.

There has been a marked increase in the area under irrigated culture at the South Chad Irrigation Project (SCIP), which is managed by the CBDA. The use of herbicides may yet be one

of the fastest, cheapest, and most effective means of controlling weeds in this large scheme, since hand and hoe weeding cannot be adequate in such situations. For rice crops, chemical weed control has gained ground in the basin.

In the sandy soils of the arid zone around Lake Chad, rainfed crop culture depends entirely on the scarce and sporadic rainfall. Crops grown there under rainfed conditions included sorghum, millet, cowpea, and groundnut. Table 3 shows the herbicides, application rates, and application times on these crops at Baga.

3. Biocontrol of weeds

Biocontrol of weeds is defined as the control or suppression of weeds by the action of one or more organisms, accomplished either naturally or by the manipulation of the weed control organism environment (Anon 1979). Weed control by the biocontrol method has been reported by IITA (1979, 1980, 1981) and Akobundu (1980b) using low-growing crops such as Egusi (*Colocynthes vulgaris*) and sweet potato (*Ipomoea batatas*) and legumes such as *Centrosema pubescens* as live mulches to suppress weeds.

The classical biological control method of using insects for selective weed control in non-crop situations, has not been successful in cropping systems. The application of live mulches and other biocontrol methods for weed control has not been widely practised in the arid zone of Nigeria, but the potential exists for its successful application in this zone.

Peculiar Problems of Weed Control in Large-Scale Agriculture

The need for weed control early in the growing season in order to minimize early weed interference is obvious, especially where large-scale crop production is practised. Research results confirm that the full impact of weed competition occurs early in the growing season. The exact length of the critical period of weed/crop competition varies with crops.

Keeping the crop relatively weed free becomes more difficult in large-scale production. In the Chad Basin area, post-emergence application of herbicides cannot be done by tractor-mounted equipment, because the heavy clay soils, once wet, will not allow the passage of tractors. Similarly, the use of tractors for mechanical control of weeds in the clay soil will be almost impossible. Also, the use of the conventional high-volume, pump-operated sprayers, e.g. the knapsack type in the irrigated heavy clay soils is very tedious, inaccurate, and an exhausting operation. Like hand-weeding, manual weed control with hoes is not feasible in large-scale crop production since it takes about 300-500 man-hours/ha to hoe-weed crops of various kinds.

Aerial application is an alternative for weed control in large-scale agriculture. This method however, will require large areas of uniform crop growth and development. In clay soils that will not allow the passage of mechanical equipment

Table 3. Herbicide treatments for irrigated and rainfed crops at Ngala and Baga in the arid zone (Okafor 1982d, 1983).

		Application Rate (kg ai/ha)	Application Time
Crop	Herbicide		
Irrigated (Ngala)			
Rice	Propanil + bentazon	3.4 + 1.5	21 days after crop emergence
Cotton	Fluridone	1.0	One day after sowing
	Flumeturon	3.0	One day after sowing
Maize	Atrazine + metolachlor (Primetra)	1.5	One to two days after sowing
Rainfed (Baga)			
Sorghum	Terbuthylazine + terbutryn (Sorgoprim)	1.0 – 1.5	One day after sowing
Millet	Terbuthylazine + terbutryn (Sorgoprim)	1.0	One day after sowing
Groundnut	Metolachlor + terbutryn (Igran)	1.6 – 2.0	One day after sowing
Cowpea	Metolachlor + metobromuron (Galex)	1.25	One day after sowing

after irrigation, the use of pre-plant or pre-emergence herbicides will be the best solution for controlling weeds over large areas.

General Comments

The concept of integrated weed management (IWM) involves the art of combining two or more weed control practices to obtain effective weed control and a cost-benefit ratio superior to any of the weed control methods used singly. Absolute reliance on any one method of weed control is difficult in view of the high rainfall over a very short period, fragile or heavy clay soils, the shortage and high cost of labour, the wide range of cropping systems, and the hard-to-kill weeds. Also, a weed control method like manual hoe weeding is unattractive and laborious and in some mixed crops, e.g. millet and cowpea, herbicides used at rates that are safe for the crop may fail to provide effective weed control throughout the crop season. With herbicides giving only a partial weed control, resistant weeds may be expected to build up unless residual weed growth is eliminated by supplementary hand hoeing.

Summary and Conclusions

1. The arid zones are regions of scanty and irregular rainfall and weeds in the region are more adapted to the ecology than cultivated crops. Hence the weed problems of the zone are potentially more serious than in other zones that have higher rainfall.
2. Problems associated with weeds in agricultural production include: their ability to harbour pests and diseases of cultivated crops, impairment of the quality of farm and livestock products through contamination, impairment of the health of farmers, increase in the cost of farming operations, and reduction of crop yield by weed competition.
3. Aquatic weeds pose special problems in irrigation by obstructing water flow in irrigation canals, increasing water losses through evapotranspiration, and increasing seepage through canal walls.
4. The annual grasses and perennial sedges, which are some of the weed species in the arid zone around Lake Chad, are favoured by the climatic conditions. They are more efficient in utilizing minimum available

moisture and can germinate quicker and grow faster than introduced crops such as rice.

Under irrigation the greater availability of water favours the weed even more than the crops, hence the weed problems are exacerbated.

5. The most significant effect of weeds on crop production is loss in yield; up to 32-41% in sorghum, 55% in millet, and 53% in cowpea have been reported in the Lake Chad Basin arid zone. These losses are, however, comparable with those observed from other climatic zones.
6. Bush fallow-farming system has no effect on weed suppression in the arid zone in the absence of forest vegetation to cover the weeds.

The traditional no-tillage farming practice adopted by local farmers in the arid zone favours the weeds since the weeds sprout before the crop and smother it.

7. A variety of weed control methods have been discussed in the paper. They include cultural control, hoe weeding or hand weeding, mechanical control, mulching, crop rotation, chemical control, and biocontrol.

It is concluded that in large-scale cultivation under rainfed or under irrigation in the arid zone, pre-emergent and post-emergent herbicides are the best feasible control procedures, and the combination of two or more methods of weed control is recommended for efficient weed control.

Suggested Projects for Collaborative Research with ACIAR:

Weed Control Research Projects in the Arid Zones:

1. A general survey of weeds in the arid zone with special reference to the Sahel:
The Project would survey weeds found in the Zone and their association with various crops and non-crop situations, and find suitable methods for controlling them.
2. Herbicide residue studies in the Lake Chad Basin (LCB):

With the growth of large-scale farming, especially under irrigation, continuous appli-

cation of herbicides will be on the increase in the LCB. The project would monitor the amount and types of herbicide residues in soil, water, and crops products in the Chad Basin.

3. Crop production and large-scale herbicide application in farms of the LCB:

The problem of timely and large-scale applications of herbicides would be investigated, especially the use of aircraft for aerial application; the use of equipment carried by draught-animals for herbicide application etc. would also be investigated.

Collaborative Research on Barley and Wheat Production in the Lake Chad Basin:

The project would examine the problems of barley production, including development of varieties that have highly stable yields and with malting qualities suitable for animal feeds and beer brewing.

The project would also look into problems of wheat production for bread wheat and the testing of wheat flour produced from wheat grown in the Lake Chad Basin area of Nigeria.

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Management of the Vertisols of the Lake Chad Basin: Possible Areas for Collaborative Research

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Work on crop water-requirement and irrigation frequency in the Lake Chad Basin dates back to the 60s but qualitative research work did not start until 1975 when the Institute of Agricultural Research (IAR), Samaru established a sub-station at Ngala to cater for the South Chad Irrigation Pilot Project (SCIPP). The work of IAR concentrated mainly on wheat and cotton but this was expanded to include other crops like rice, sorghum, barley, and vegetables when the Lake Chad Research Institute took over the substation towards the end of 1976.

The Characteristics of Vertisols

The problems of irrigating Vertisols are directly related to the characteristics of these soils. They contain between 60-75% clay, which consists mainly of montmorillonite and kaolinite that occur in approximately equal amounts.

The soils absorb water very rapidly but they also swell very quickly after taking water, thereby limiting the infiltration time. On drying, they shrink and crack widely, the result of which improves the water entry into the soil. Under natural fallow conditions, the Vertisols can develop cracks that are as wide as 5 cm and 36-50 cm deep. Under cultivation the cracks are wider averaging 5.5 cm, but are shallower (0-35 cm). The maximum depth of cracking is equal to or slightly greater than the maximum depth of root penetration by most crops. For example, the maximum depth of cracking under wheat is about 67 cm while under cotton it is about 90 cm.

Problems Associated with the Management of Vertisols

Collaborative research in the following areas

with the Australian group would be greatly appreciated:

1. Land Preparation

Two aspects that are critical in the water management of the Vertisols are (a) land preparation, and (b) irrigation water applications to the soil. Because of the nature of the Vertisols they are best cultivated when dry and cracked. Then, they crush easily and respond to mechanical cultivation. Unless the prismatic and angular blocky structures of the surface layers are well crushed, water application will be a major problem. This is easily attained by the use of a rotavator. However the operation is very costly and requires heavy duty tractors. A satisfactory job can be done with a disc harrow if operations are repeated two or three times. The general ploughing, which produces a cloddy seed bed, is not conducive to field water-management of Vertisols.

To avoid the creation of a plough pan when heavy duty tractors are used on these soils, care must be taken to ensure that the soils are completely dry and cracked before cultivation.

2. Soil-Water Management

While the characteristics of the Vertisols render them impermeable to water, cracking is an important device for water penetration. Without cracking very little water will penetrate more than 15 cm to the underground layer due to the low hydraulic conductivity of these soils. When irrigation water is applied to dry cracked soil it is absorbed very rapidly. In this respect the cracked soils behave like the lightest and most permeable soils comparable to a sandy soil. However, if the water application is not carried out with sufficient speed, the soil swells quickly and closes all the pores to full moisture capacity, thus becoming impermeable. Any additional water added beyond this point will either pond on the surface soil and evaporate, or

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drain away through artificial drains. Consequently when the irrigation drains are not functioning effectively, waterlogging becomes a major problem.

Because of the nature of Vertisols, very little or no water is brought to the surface by capillary action because at full moisture capacity the surface layer has more water than the subsoil. In fact, the ground water is always several metres below the soil surface.

The guiding principles for irrigating Vertisols is that they must not be over-irrigated nor under-irrigated if optimum conditions for plant growth are to be provided. To this extent, the amount of water to apply must be the amount required to bring Vertisols to full moisture capacity. When the soil is at full capacity, any additional water will pond on the surface and cause more damage to crops like wheat, cotton, and vegetables.

Experience so far has indicated that for the cultivation of wheat in border strips between 100-150 metres long and 60 metres wide, the time for bringing the soil to full field capacity is between 2-4 hours and should not exceed 6 hours, if over-irrigation is to be avoided. To be able to manage a volume of water being applied properly, the water stream should have a discharge of 7-13 litres per second. For a rice crop, a larger volume of water with a longer irrigation time could be allowed.

3. Finding Adaptable Crop Varieties

The range of crops presently grown on the Vertisols is limited. It includes rice, cotton, wheat, barley, and some vegetables. There is a great need to expand the range that can be grown in Vertisols to allow for better cropping systems and efficient water utilization.

Constraints to Food Production in Semi-Arid Nigeria

J.H. MacFarlane*

The problems of crop production in the semi-arid tropics (SAT) can be related to two components of the physical environment, viz. (a) unpredictable periodic rains followed by a long dry season, and (b) poor soil of low fertility; and also to the socio-economic environment of the farmer, viz. (a) small acreage under cultivation by hand, (b) mixed cropping with low plant populations, (c) labour shortages, (d) low resource base, (e) inadequate marketing, and (f) transportation of produce to market at the right time.

Now, let us look at each component to see where changes might be made to help the farmer increase his food production, and, concurrently, his resource base.

The unpredictable rains of short duration cannot be altered but perhaps better use can be made of the rain that is available. For example, at ICRISAT Headquarters in India a technique of watershed management was developed where runoff water from fields is collected in a tank and later used for supplementary irrigation at the end of the season if required, say, when the rains cut-off early. This technique is now being investigated at on-farm studies in India. The major difficulty in this concept is the initial outlay of capital and it requires the co-operation of all farmers in a particular run-off area. This probably is currently beyond the means of most small-scale farmers but may be of importance in the future if and when their resource base has been improved. Another ICRISAT approach is to develop crop cultivars that are drought tolerant and flower well before the cessation of rains.

The other major component of the small-scale farmers' physical environment, i.e. soil fertility, also requires the investment of capital to buy the right fertilizer to be applied at the correct time. In this regard, more effort is needed by the Federal Government, of the countries involved, but I might add the situation

in Nigeria is very much better than exists in many neighbouring countries.

We will now look into the areas where ICRISAT, as an International Agricultural Research Centre in co-operation with the IAR and other regional institutions, could have some impact on the small-scale farmer. ICRISAT's mandate, generally stated is, to increase food production of the small-scale farmer and concurrently his resource base. The typical small-scale farmer in the area has only 1-3 ha of land under cultivation from which he has to produce food for his family, and also grow other crops to generate extra income to purchase goods that he cannot produce. He, therefore, uses a system of mixed cropping that has been developed over centuries as the best farming system to provide his basic needs. Granted, there may have been poor years but generally he can produce enough for himself. But in recent years, the problem of food supply has become more acute because of increases in population and urbanization.

One problem encountered is that the farmer grows his crops under low plant-population – lower than the carrying capacity of the land in most years and lower than what is possible to achieve maximum returns. The sorghum grown by the farmer is tall, long-season photosensitive material maturing after the rains have stopped. IAR over the years has developed sorghum and millet that are higher yielding but they have not been accepted by the farmer. Why? It is possible that the farmer wants to grow something which he knew, which he has grown for years, and has been passed from one generation to another. He knows how this material will respond under most conditions and he knows what the returns will be even if they are small. The new materials are unknown to him and he has to be convinced that these materials are better than his. The food quality may also be another factor why these materials are not acceptable; this is especially evident in some short-season

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materials, which mature before the rains stop, because they are attacked by head bugs and later by grain moulds. The new materials are also shorter, and are not suitable for the many uses that the farmer had for his tall stalk material. The farmer uses a low plant-population because if rains stop early, he will still have enough residual moisture, in most years, to produce some grain. This is where the management of available water resources could be useful as mentioned earlier, to have supplementary irrigation at the end of season to overcome the early cessation of the rains, and then under these conditions he could increase the plant population and still produce a good crop.

The mixed cropping system as used by the farmer, especially where legumes are mixed with cereals, has many advantages. The main one that economists talk about is avoidance of risk, but it also has the added advantage of adding nitrogen to the soil for the cereal crop.

Sole cropping has always been considered the best way to increase food production, and food production techniques in North America are used as an example. The situation of the small-scale farmer is much different – he has limited land for cultivation and consequently attempts to make best use of what is available.

In North America, land was always in excess and the farmer could sole crop but still have a mixed farm, which was the most common farm in North America until after World War II. North American farming was also mechanized, firstly oxen, then horses, followed by the tractor. The North American farmer also had a large acreage to cover in a short period. For years he also resisted change, which was then brought about by the younger farmers. Mixed farming is still common in many areas of Canada and the USA today. Sole cropping will be possible only on the large farms that are mechanized.

This also brings us to another problem, i.e. labour shortage. The supply of labour for the small-scale farmer, what he can afford and what is available, is limited. In fact, in many cases he is the source of this labour for the large-scale farmer, to help supplement his income and, consequently, his own crops may be neglected. Mixed cropping, relay cropping, etc., also help the farmer spread his labour requirements over the whole season. The acreage that the small-

scale farmer can cultivate by hand is also limited by labour shortages at peak times. This problem can only be overcome by mechanization, and by this I do not necessarily mean tractors, which are currently far beyond the means of the small-scale farmer. He requires mechanization to help him prepare his land for planting and weeding. This could be with oxen, donkeys, or some other kind of draft animal and, initially, limited mechanization. Later other equipment for weeding needs to be developed and manufactured here for use in the mixed-cropping system of the small-scale farmer. Herbicide use can also alleviate labour constraints. There is a need for a small tractor, say 15-20 HP, which would be more useful in the small farms and irregular fields that are common in most of the SAT. The majority of tractors on today's market are much too large for efficient use on small farms. The labour shortage problem will most likely become more serious with time because of the movement of young people from the rural areas to the urban areas. The problem was experienced in North America after World War II and as a result, the average farm size today is about three times larger than what it was 30 years ago. This movement of labour to the cities also led to a more rapid move to tractors and other forms of mechanization.

The problems of farming systems have been investigated for a number of years and recommendations have been made but most are not accepted by the small-scale farmer. Why? Basically the farmer over the whole world is conservative and requires re-education into the newer and better methods of farming. More extension and direct contact with the farmer needs to be done to show him the advantages of the new higher-yielding genotypes, higher-plant populations, and new improved farming systems. The farmer is not going to accept new cropping systems unless he has an assurance that these systems will provide a higher income. It must be remembered that it took years for hybrid corn to be accepted in the USA and then it was the younger, more aggressive, more willing to take a chance farmers that initiated this change. Most changes in farming practices have been brought about by the younger farmers.

The next three categories, i.e. low resource base, inadequate marketing, and transportation,

are related. The current market facilities available for the farmer to sell his excess grain are very unreliable and unpredictable because of large difference in grain prices. Many countries have a grain marketing board but this still does not really help the small-scale farmer because he still sells his grain to a middle man, at less than marketing board price, who then transports it to the marketing board and sells it at the set price. The farmer usually sells his grain when there is a glut on the market and consequently receives a very low price. If he could store the grain and wait for a while, he would receive a higher price but since his resource base is low he cannot afford to wait. The availability of adequate credit for the small-scale farmer is limited; he can obtain credit, but at a very high interest rate which most likely, has to be paid when the grain is harvested and the farmer is forced to sell grain at a low price.

The transportation of produce to market is also very hard for the small-scale farmer and sometimes, as mentioned earlier, he is forced to sell to the middle man, who makes most of the profit.

The problem of increasing food production in the semi-arid regions of Nigeria and West Africa are many and complex. What is ICRISAT's approach to this problem?

The ICRISAT team in Nigeria comprises a millet breeder, sorghum breeder (currently vacant, to be filled in 1984), and an agronomist and entomologist.

The overall functions of ICRISAT work as it relates to the Nigeria National Program and other national and international institutions in the West African Region are:

1. Conducting research that is supportive to the ICRISAT mandate and objectives. Unnecessary duplication of research efforts is avoided.

2. Conducting research that is supplementary to that of the national program; this includes areas where needed research may be lacking due to the lack of trained manpower; competition with the national and regional programs is avoided.
3. Facilitating the exchange of information and germplasm.
4. Assisting the national program in the training of research personnel.

Although there are some variations in specific research objectives and research approaches, the overall objective of the ICRISAT program is to develop new genotypes/cultivars that have a potential for high and stable yield. This necessitates resistance/tolerance to the prevalent stress factors, such as crop diseases, insect pests, drought, low soil fertility, and parasitic weeds. Plant types, which differ from the local material, that are earlier maturing, shorter, and responsive to fertilizer levels, are particularly being sought in millet and sorghum breeding programs. The Agronomy Program is investigating the usefulness of adapting these new genotypes/cultivars into the current farmer mixed-cropping system. The response of the cultivars at low and high-crop density and fertility is also being investigated in both sole cropping and mixed-cropping systems. The Entomology Program investigates new genotypes/cultivars for better tolerance/resistance to various insect pests.

The ICRISAT program in Nigeria works in close collaboration with ICRISAT programs in other West African countries to help facilitate the exchange of germplasm and other technologies developed there. ICRISAT has scientists based in Niger, Upper Volta, Mali, and Senegal where they work closely with national programs and other international institutions.

Livestock Management in Nigeria

An Overview of the Livestock Industry in Nigeria

E.N. Agwuna*

The livestock industry in Nigeria consists of cattle, sheep, goats, poultry, and pigs. The population in 1982 was estimate-projected at 9.35 million cattle, 24.4 million goats, 8.7 million sheep, 172 million poultry (20 million of which are commercial), and 0.916 million pigs. The industry's worth in 1980 was estimated at N1.80 billion.

The productive capacity of the national herd is very low and therefore the demand for meat, dairy, poultry, and pork products outstrips the supply. Table 1 shows the projected demand and supply of products based on a human population estimate of 80 million in 1980.

Importation of products has been the means of supplementing the national supply. Recently however, in order to allow for the orderly growth of domestic production, beef and poultry imports have been banned.

Imports of live animals have not been restricted. The domestic off-take of beef animals is supplemented by imports which run to about 30% from neighbouring countries. Table 2 gives the local and imported cattle between 1980-1982.

Production methods are still predominantly traditional and nomadic. The force of habit, the menace of the tsetse fly infestation in most of the country, and the absence of land tenure and credit for the graziers are the operating forces that hamper modernization of the technology in the large and small ruminants. Therefore animals bloom during the rainy half of year and depreciate towards the other half as the fodder depreciates in quality and quantity with the dry season. The avian and swine species have benefited greatly from growing commercial practices. But being sensitive to both quality and quantity of feed supplies, the latter two have also been affected by depressions and recovery in growth over the years.

Current Development Programs

Programs aimed at developing the livestock industry can be grouped for ease of reference into the major areas of animal production, animal feeds, animal health, and veterinary public health.

1. Animal Production

With beef being the dominant species, greater resources have been allocated towards problem-solving activities for the species.

(i) Development of Grazing Reserves

Under a 1965 northern Nigeria Law, certain gazetted areas were set aside exclusively for the use of graziers as a measure to encourage production and to alleviate conflicts between arable farmers and graziers. The Federal Government through the 3rd National Development Plan selected a number of these gazetted areas and designated them as Cattle Settlement Areas from each of the 10 northern States. The aim was to have an overall total of 5 million ha by 1980. These cattle settlement centres are to be demarcated, surveyed, and fire traced. Further infrastructures will be guest houses, labour-line, bore holes and dams, pasture seed multiplication plots, a livestock service centre consisting of a veterinary clinic and store complex, and veterinary dips. From the services centres, graziers can obtain simple treatments and supplementary feeds for their stock.

Problems such as lack of funds not being gazetted have hampered progress. The target reached so far is about 2.0 million ha. Twenty three livestock service centres have been established to serve the areas.

An extension to the cattle settlement program is found in the Relocation of the National Herd, which included putting in the same infrastructures as above in areas outside the

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Table 1. Projected estimate of supply and demand of animal products 1981-1985 (Thousand tonnes).

Year		Beef	Mutton	Poultry Meat	Eggs	Milk
1981	Demand	272.65	79.44	102.91	286.92	938.14
	Supply	165.24	45.89	73.04	270.80	714.64
1982	Demand	294.41	84.29	106.75	296.65	1040.57
	Supply	171.60	47.49	74.49	275.31	771.31
1983	Demand	317.90	89.43	110.74	307.77	1152.85
	Supply	176.88	48.69	75.99	279.96	802.16
1984	Demand	343.28	94.89	114.90	319.36	1277.43
	Supply	182.16	50.15	77.56	284.78	834.25
1985	Demand	370.67	100.67	119.23	331.42	1415.43
	Supply	187.44	51.65	79.75	287.75	667.72

Source: Federal Livestock Department (Cost of production and guaranteed minimum prices for selected livestock products in Nigeria, 1981).

Table 2. Cattle trade (1980-1982).

Year	Local Cattle	Imported Cattle	Total
1980	662 719	355 806	1 012 525
1981	926 143	414 573	1 340 716
1982	1 015 700	516 707	1 532 407

Source: Federal Livestock Department, 1982 Annual Report.

cattle settlement centres to serve those stock and graziers outside the centres. An additional 22 livestock service centres were also established. The main aim of the rehabilitation of the national herd program, designed as a drought fighting measure, was to induce graziers to use the better rain-fed and therefore better vegetation covered areas south of latitude 12 degrees. The zones covered are wider and the 22 livestock service centres are to be found in 17 states. Tsetse fly infestation is anticipated and there is provision for anti-trypanosomiasis prophylactic measures.

The major problems in the two programs are bush fires, tsetse fly infestation, difficulties with acquisition and gazetting, and difficulty in providing cultured and higher-carrying capacity pasture covers in place of the bush grazing that is currently available.

(ii) Regional Pasture Improvement Centres

Ancillary to the foregoing programs is the pasture improvement program aimed at pasture research and adaptation in selected zones. Besides adaptation, these centres also serve as

foci for extending pasture improvement to both the surrounding States and nearby farmers. The *Stylosanthes* genus is used and various species are investigated. Pasture seeds are multiplied for distribution to the States. The research includes the evaluation of pasture species, fertilizer requirements etc.

Two fully developed centres have been established in Haipang, Plateau State and in Kofari, Gongola State. A third centre has been started in Benue State. Five centres have been programmed. Because of the importance of pastures in the development of livestock, the Department is collaborating with other centres also involved in pasture research. The major ones are the National Animal Production Research Institute (NAPRI), Zaria and the International Livestock Centre for Africa (ILCA).

(iii) The World Bank Assisted Livestock Development Project

The World Bank Assisted Program is another beef production program. It was initiated in 1976 and has the major aim of improving commercial beef cattle enterprises. The project, which covers seven States, namely Bauchi,

Borno, Gongola, Kaduna, Ogun, Oyo, and Ondo, is being administered by the Livestock Project Unit under the supervision of the Department. The main components of the project include:

a. **PUBLIC BREEDING RANCHES** at Bornu, Bauchi, Gongola, Ogun, Oyo, and Ondo States. The problems have been disease outbreaks, lack of finance, and difficulty in procuring breeding animals. In the public ranches in Ogun, Ondo, and Oyo States, about 5000 head of trypano-tolerant N'dama have been imported to support the breeding activities to feed other related programs.

b. **PRIVATE BREEDING RANCHES**, which spread through the participating States. The problems have been difficulty in securing title to land and lack of credit. There are now eight private ranches with loans disbursed, although 53 applications have been prepared.

c. **SMALL-HOLDER FATTENING SCHEMES**, which are an extension and credit supported program to fatten off-takes from the breeding ranches over 4-6 months at about 4-6 head per participating farmer. This has been a success and about 2887 small loans of N2000 each have been disbursed.

d. **DEVELOPMENT OF GRAZING RESERVES** under the project is aimed at providing improved grazing conditions for participating farmers as a means of inducing them into commercial practice. Developed and laid-out areas are to be leased to farmers and supported with credit. About seven reserves have been developed amounting to 75 000 ha.

e. A **TECHNICAL SUPPORTING HEAVY EQUIPMENT UNIT** assists participants clear and prepare their land, design and construct dams, and help in grazing reserves demarcation, and development work at hire.

The major problem in this program has been the procurement of titles to land, which banks insist are essential for credit, for private ranches. In the public ranches, the same land problems retarded pace of development. States matching funds have also hampered the latter, as well as the insufficiency of improved pasture.

The first phase program is expected to end in 1983. Negotiations are proceeding for the second stage project, which is to commence in 1984. It will cover all States of the Federation and will include all species of animals.

(iv) Tsetse Clearance Program

Tsetse control and eradication is a major program being handled by the Department of Pest Control Services. Clearance and eradication is moving southwards from the tsetse free area in the north. Pesticide spraying techniques are used.

It is expected that the cleared area will be utilized extensively for livestock production as well as mixed farming during the second phase of the World Bank Assisted Livestock Development Project.

(v) Cattle Breeding Program

Three cattle multiplication centres established at Jibiro, Gongola State (1000 ha) and Funa-Funa, Niger State (2000 ha) are proceeding with improved and cultivated pastures, water supply and reticulation, and fencing for maintaining and supporting elite breeding Zebu herds. The off-take is intended to supply essential breeding stock to neighbouring farmers. A third centre in Ohaozara, Imo State (1955 ha) is to support the trypano-tolerant N'dama and Muturu species.

The major problems include difficulty in land acquisition and the lack of a ready source of suitable foundation stock. Among the private producers, acquisition of more cattle into the breeding herd is practised, while sales are unheard of.

(vi) Dairy Development Program

There are few surviving modern dairy herds although there are about six commercial dairy processing factories in both the private and public sectors, and about another seven small public processing units. The commercial factories use mostly imported powdered milk. Most dairy produce consumed in the country is imported from Europe.

Among the traditional producers, the severity of nomadism, poor milking ability, and the need to reserve a good part of the milk produced for calves constrain dairy output. Imported Friesian milking herds have declined in population owing to poor management and maintenance.

Public development programs aimed at supporting maintenance of the imported milking herds and attached processing facilities were initially undertaken by the Department. Recently a major effort was commenced to extend

innovative packages to settle private co-operative producers located around Jos, Plateau State and to help them improve their milk output. In the package, plots of 1-25 ha pasture sown to *Stylosanthes* species are developed for individual participating farmers; supplementary feeds are also provided. Animal health care is provided and later it is intended to provide artificial insemination.

The major problem in this program includes difficulties in procuring good breeding animals, availability of supplementary feed, overgrazing, and in some cases destruction of developed pasture plots. However, the results are encouraging. Milk output has changed from the usual half a litre/animal/day to about 1.5-2.0 litres. Calving rates are estimated to have improved by 10%.

(vii) Sheep and Goat Development Program

A dryland sheep breeding and multiplication centre that was established in Katsina, Kaduna State now has an elite 3000 flock. Local breeds Uda and Balami are being used so that improved stock can be passed on to neighbouring farmers. This project, which started with Australian technical assistance in 1977, has reached full development on about 3000 ha, a good part of which has been sown to improved pastures and reticulated and supplied with water.

A goat multiplication centre for the Red Sokoto goats is coming up at Zugu in Sokoto State. Improved pastures have been developed on over 200 ha and the centre when at full development will stock a flock of 3000.

The major problems in the two centres have been difficulties in establishing and maintaining pastures at Katsina, water supply, and supplementary feeds. Overall, a major problem in the sheep and goat area is the high lamb and ewe mortality. Investigations into this as well as the fundamental issues of increasing productivity among the local producers are being investigated at ILCA.

(viii) Pig Pedigree Progeny Program

One major constraint to the swine industry is the lack of an adequate supply of weaner and fatterer pigs. The Pedigree Progeny Centre located at Nsukka, Anambra State is designed

to produce breeding parents to be sold to farmers. At completion, the centre will house 50 sow-units. The project is in the construction stage.

(ix) Poultry Development Program

The poultry industry has two components, viz. the predominant traditional poultry with about a 152 million bird population and the smaller commercial section with 20 million. The latter has grown tremendously under favourable government and private sector support in regulating the import of poultry products, and with the assistance of credit. The major constraints however, are the shortage of day-old chicks, poor quality feeds, and sometimes scarcity of the latter or its generating raw materials, especially feed grains.

Development programs are therefore aimed at solving these identified needs. A hatchery expansion program is being developed in three centres at Usefon in Cross River State, Dawakin-Tofa in Kano State, and Ajure in Ondo State. The combined capacity of the three centres will be 5 million day-old chicks annually. Apart from researching feed standards for improving feed quality, there are also programs for the procurement of raw materials like maize and concentrates, which will be described in a subsequent section. Collaborative research is being conducted to test recommended standards before the next phase of the feed standardization, which is regulation of accepted standards.

2. Animal Feeds Program

During the dry spells of the year, the national herd goes through a period of declining growth, weight loss, and high mortality particularly in young stock. A supplementary feeds program aimed at procuring and distributing (at 50 percent subsidy) agricultural by-products like groundnut, cottonseed cake and wheat offals is implemented annually. About 5000 tonnes of the cakes are distributed annually according to the States livestock population.

To support feed milling, bulk importation and distribution at cost of feed grains and concentrates was implemented until recently. Presently, the Grains Board is being authorized to purchase locally grown maize for re-sale to feed millers, at subsidy. The latter program has

the other advantage of helping local production of the maize.

The major problems with the Animal Feeds Program have been the scarcity of by-product cakes and the distribution of either imported or locally purchased maize.

3. Animal Health Program

Major epizootic diseases afflict the national herd from time to time. The country is currently carrying out a nation-wide major campaign to control recent rinderpest outbreaks. Following this in intensity, and also the subject of the national vaccination campaign, is contagious bovine pleuropneumonia (CBPP). About 6 million cattle are vaccinated annually against CBPP. Other prevalent diseases are trypanosomiasis, tick-born diseases, streptothricosis foot and mouth disease, brucellosis, tuberculosis, anthrax, black leg, and haemorrhagic septicaemia. In poultry, the major epizootics are Newcastle disease, salmonellosis, fowl pox, chronic respiratory disease, gumbo and avian leucosis. Sheep and goats are plagued by kata or pneumonia-gastroenteritis. Preventive measures taken are to vaccinate stock annually against these diseases.

The prevalence and spread of some of the above diseases in 1982 is shown in Table 3.

To maintain surveillance over our international and interstate borders, quarantine and control posts are established and manned on a

24 hour basis. The quarantine posts monitor the movement of stock from outside Nigeria while the control posts monitor the interstate movement within the country.

Monitoring the extensive national borders across which people and stock move is a major problem. The recent outbreak of rinderpest was traced to an outbreak in Upper Volta and Mali. Even within the country, the evasive action of stock traders over some control posts present gaps for spread of disease.

4. Veterinary Public Health

Veterinary Public Health provides meat inspection services for the slaughtered food animals. Prior to the 1970s, meat inspection was still a function of the Ministry of Health.

This function has been successfully transferred to the veterinary authorities. Meat inspection also monitors the prevalence of diseases amongst slaughtered stock as in Table 4.

The major problems in administering the meat inspection service are the inadequately designed slaughter slabs and force of habit, which tends to set butchers against inspection.

Abattoir By-Products Utilization

Along with meat inspection is the program to recover and use abattoir by-products like blood, bones, hooves, horns and rumen ingesta. An

Table 3. Major disease outbreaks reported in 1982.

Disease	Number of outbreaks	Disease	Number of outbreaks
Rinderpest	20	Gumboro	13
CBPP	17	Fowl pox	2 (to June)
Kata (Small ruminants)	34	Avian	
		Salmonellosis	2
Sheep pox	1	Newcastle disease	12 (to June)
Rabies	4		

Table 4. Prevalence of diseases in slaughtered cattle, 1982.

Disease	Prevalence %	Disease	Prevalence %
Fascioliasis	1.5	Oesophagostomiasis	0.28
Cysticercosis	0.08	Hydatidosis	0.01
Onchocerciasis	0.17	Foetuses observed	1.0

FAO consultant in the area is helping the Department to determine the details of how to recover, preserve, and use the by-products for feeds in particular, and as fertilizer.

Before the present time, hides and skins had been recovered cured, dried, and exported. A small portion was tanned locally especially to produce the famous morocco leather from the Red Sokoto goats and to produce other leather goods. With the ban on exports of hides and skins, recovery and preservation of these commodities have declined. Some of the by-products are consumed as food.

Livestock Marketing

Marketing of animals is done predominantly live from the producing areas in the north to the consuming areas in the south. A chain of middle

men mediate between the producers and consumers. Rail and motor trucks are used while some traders prefer to trek their animals. Some attempts have been made at slaughtering stock at the producing areas before shipping them to the consumers but this has not been very successful.

At the butchering markets, some of the objections that butchers have against using slaughter slabs come from the lack of water and the congestion due to bad designing. The Department has tried to streamline abattoir and slaughter slab designs for various volumes of slaughter with the assistance of FAO. Construction of a model is proceeding at Port Harcourt at the present. It is hoped that the standard designs will be adopted by more States to further improve the standard of meat hygiene in the interest of consumers.

Collaborative Research Projects in Livestock Disease

A.G. Lamorde*

Nigeria is blessed with vast natural resources such as 71 million ha of arable land and an almost equal area that could be developed either for fodder cultivation or for rangelands. Livestock production is one of the major occupations of the people in the northern parts of the country where over 12 million cattle are kept under traditional systems of management. There are also over 24 million goats, 8 million sheep and nearly 180 million poultry spread throughout the country, thereby constituting the largest animal population in any country in Africa. Animals are efficient converters of plant materials into valuable animal protein for human consumption. The Federal Government is committed to bring back the glory of agriculture in the country's economy through its various schemes such as the National Accelerated Food Production Programs and the Green Revolution. In the recent past, there have been large-scale investments in agriculture both in the private and public sectors. The boom in the poultry production and self sufficiency in maize production are the best examples of achievements. However, there are still many problems and obstacles to be overcome before the enormous potentials of agriculture can be fully realized in order to provide an adequate food supply for the rising human population, at reasonable costs.

Two major constraints have been recognized in animal production, viz. (a) nutrition and (b) disease. Problems of grassland management and the extensive system of cattle rearing under drought and semi-drought conditions continuously precipitate malnutrition and starvation problems. Those few animals that are kept under intensive production systems require heavy animal feed inputs due to the higher costs of ingredients.

Animal diseases *per se* in Nigeria are responsible for 30-40% of the economic losses,

which are twice the losses in developed countries. Unfortunately diseases prevalent in the neighbouring countries enter through porous borders along with the trade cattle movement, and are difficult to control.

The recent panzootic of rinderpest has shown that the country can remain free from a disease only if its neighbours are also free. Table 1 lists diseases in order of economic significance; most of these diseases have been eradicated from the developed countries where productivity of animals has become four to five times greater than in any other developing country, including Nigeria.

Problems Encountered

Problems affecting animal production are very many but only those pertaining to animal diseases of economic as well as public health significance will be reviewed hereunder.

Rinderpest was largely responsible for the establishment of the Veterinary Department and the laboratory at Vom by the then colonial government. The disease was not controlled despite the development of successive vaccines and sera until an internationally organized campaign was launched in Africa during 1962-76. Nigeria was free from the disease for six years only (1974-80) after which its recurrence in 1980 and recrudescence in 1983 precipitated into a catastrophe. The most recent outbreak on the Mambilla Plateau was also due to the import of cheap cattle from Cameroon. Between 1980-83 about 1000 outbreaks were recorded involving half the national herd with 1.6 million infected and 0.38 million deaths. Direct losses due to this disease to date have been estimated to be half a billion naira and total losses to be over 1.5 billion naira. The economic significance of rinderpest demands its complete elimination from the world along the lines of the eradication of smallpox.

Trypanosomiasis, anaplasmosis, babesiosis, heart water and theileriosis, which are insect

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Table 1. Economically significant diseases of Nigerian livestock.

Cattle	Sheep	Goats	Poultry	Horses
Rinderpest	Blue tongue	PPR	Newcastle disease	African Horse
Cont. Bov. Pleuropneumonia	(in exotic breeds)	Pox	Gumboro disease	Sickness
Foot-and-Mouth disease	PPR	Mange	Fowl typhoid	(in exotic breeds)
Trypanosomiasis	Pox	Orf	Salmonellosis	Eq. Influenza
Babesiosis	Mange	Trypanosomiasis	Chronic Resp. Disease	
			Marek's disease	Anthrax
Anaplasmosis	Orf	Anaplasmosis	Lymphoid leucosis	
Heart water	Trypanosomiasis	Babesiosis	Fowlpox	
Dermatophilosis	Anaplasmosis	Salmonellosis	Egg drop syndrome	
Black quarter	Babesiosis	Brucellosis	Inf. Bronchitis	
Parasitic gastroenteritis	Salmonellosis	Coccidiosis	Av. Encephalitis	
Anthrax	Brucellosis	Foot rot	Inf. Laryn. Tracheitis	
Theileriosis	Coccidiosis	CCPP	Colibacillosis	
Malignant catarrhal fever	Toxoplasmosis			
Inf. Bov. Rhinotracheitis	Rift Valley Fever			
Lumpy skin diseases				
Rabies				
Liver fluke				
Enz. Bov. Leucosis				
Brucellosis				
Tuberculosis				
Coccidiosis				

borne protozoon fevers, are endemic in Nigeria. They cause severe economic losses each year and the problem connected with their control and prevention is linked with vector control and chemotherapy. So far it has not been possible to produce satisfactory vaccines against them.

Since the eradication of rinderpest in the year 1974, attention was paid to another equally important disease of cattle, the contagious bovine pleuropneumonia (CBPP) by launching a Joint Project (JP 28) against CBPP throughout tropical Africa. The incidence of the disease was drastically reduced though it was not eradicated. This year, as an aftermath of rinderpest, there are reports indicating an upsurge of CBPP in at least six States in the Federation.

Foot-and-mouth disease does not cause any serious mortality in zebu cattle but its incidence causes concern because lame cattle are unable to go out for grazing. Studies conducted so far indicate that constantly changing antigenic variants of types A, SAT₁, and SAT₂ occur in Nigeria. Commercial vaccines do not afford protection, therefore a polyvalent homologous vaccine is produced by the Wellcome Company but it also requires multiple doses to be given for solid immunity to be produced against the

disease.

Dermatophilosis is a chronic skin infection of cattle especially during the wet season, introduced by the bite of ticks and insects. The infection at times spreads to other species of livestock but its high incidence leads to the culling of many high-grade cattle. There is no satisfactory treatment nor any vaccine for its prevention. Research however, continues to search for a suitable antibiotic or a vaccine.

Black quarter, anthrax, and haemorrhagic septicaemia are enzootic for which vaccines are available. Incidence of tuberculosis, salmonellosis, brucellosis and lumpy skin disease are on the increase according to serological surveys but there are no control programs for them as yet. Only diagnostic services are provided to cattle owners and brucella vaccine is used for voluntary calfhood vaccination. Similarly, sporadic incidence of clinical pseudo-rinderpest (virus diarrhoea, infectious bovine rhinotracheitis, and malignant catarrhal fever) have been recorded but mostly these infections are subclinical in the local cattle. Surprisingly, a high incidence (15%) of enzootic bovine leucosis in some local (Wadara) nomadic cattle is inexplicable.

Peste des petits ruminants (PPR), pox, and

mange are important diseases of goats and sheep in Nigeria. PPR is a rinderpest-like highly endemic disease in the humid zone of West Africa. Rinderpest vaccine has been found to be effective against PPR but it causes the problem of recrudescence in goats incubating disease. Like the rinderpest control program, unless there is one for PPR, the effect of mass vaccination may not be felt.

Sheep and goat pox viruses are species specific, unlike those in East Africa where they are the same and share a common antigen with the lumpy skin disease virus. This poses a problem in vaccine development since each one will need a separate one. Blue tongue and pseudo-rinderpests cause subclinical infection in the local sheep and goats but show clinical disease in the exotic breeds brought in for the improvement of local ones.

Newcastle disease, fowl pox, fowl typhoid, chronic respiratory disease, colibacillosis, Marek's disease, and lymphoid leucosis are endemic throughout the country. Since the last decade, Gumboro disease has been causing concern in most commercial establishments. Besides causing some early chick mortality, it produces immunosuppression that is responsible for a serious upsurge of Newcastle disease in the duly vaccinated growers and layers.

Canine rabies is a very important disease since it is of both veterinary and public health importance. Low and high egg passage Flury vaccines are supplied by the Institute for field use.

The population of turkeys, ducks, pigs, horses, asses, and camels is comparatively small. They do not suffer from major epizootics except in imported exotic breeds, whose number is again insignificant.

The news that an African swine fever outbreak occurred in Cameroon last year, is disturbing because border control is not very effective and there is no vaccine against it. The only recourse left for control is depopulation, which may turn out to be disastrous both for the farmers and the veterinarians.

Efforts Made to Date

The Institute is engaged in providing diagnostic and investigatory services as well as providing vaccines against some important diseases. Tables 2 and 3 give up-to-date figures of

specimens processed and the vaccines produced by the Institute. In order to meet the challenge of a rinderpest panzootic, vaccine production is doubled and two new industrial freeze-dryers with a 10 000 vial capacity are installed. The Institute has conducted preliminary studies with local architects and the Institut Merieux of France on commercialization of a vaccine production facility at Vom. The housing program for the staff has been completed while waiting for the construction of building and installation of equipment. The Federal Government is committed to finance the project during the current National Development Plan period (1981-85).

In recent years, new serological tests such as the immuno-electro-osmophoresis test, the passive haemagglutination test and the radial immunodiffusion test have been developed, and new vaccines such as the freeze-dried CBPP T₁ vaccine, Gumboro vaccine, and cell culture rabies vaccine have been developed and introduced.

Collaborative Research Projects

1. Epidemiology

Nowadays epidemiological reports are filled in by the field veterinarians on the basis of the clinical and postmortem picture and laboratory confirmation is sought. It is obligatory that such reports be backed by laboratory findings and be followed by subsequent ones that detail the category of animals finally affected, became sick, died, or recovered. For economic evaluation of the damage caused, it is essential that vital statistics are collected and appropriately fed to the computer for suitable cost-benefit analysis.

Development of sensitive laboratory tests like the ELISA test or immuno-electronmicroscopy are essential for quick and efficient diagnosis, serological surveys of infectious diseases, and to monitor the immunity level of the national herd after mass vaccination programs. Diagnostic techniques, which can be conveniently employed in tropical conditions, need to be developed and mastered. While computerized automation is the nature of work in developed countries, such techniques often

Table 2. Vaccine production in Nigeria.

Vaccine	1976	1977	1978	1979	1980	1981	1982
Bacterial Vaccines:							
Anthrax Spore	2 039 700	3 380 400	2 653 800	2 110 850	2 256 000	2 308 800	2 038 300
Haemorrhagic Septicaemia	329 300	291 200	253 100	286 700	309 000	112 300	115 700
Fowl Typhoid (Wet)	264 800	396 900	306 750	515 000	688 250	986 300	1 000 000
Fowl Typhoid (Dry)	3 256 850	1 553 350	2 185 850	1 631 830	856 870	947 680	567 900
Fowl Cholera	500 500	352 500	1 113 300	547 750	86 000	63 250	181 200
Contagious Bovine Pleuropneumonia	8 295 520	10 544 600	7 992 250	10 794 190	10 886 020	5 928 900	8 543 230
Blackquarter	5 530 500	2 735 000	5 206 600	2 724 500	1 844 750	1 573 950	1 934 200
Sub-Total	20 217 170	19 253 950	19 711 650	18 610 820	16 926 890	11 921 180	14 380 530
Viral Vaccines:							
Tissue Culture Rinderpest	7 272 850	5 618 800	3 566 700	8 527 600	5 407 100	5 947 400	8 306 700
Newcastle Disease (i/o)	9 044 800	10 202 400	15 260 000	17 550 000	16 474 400	26 613 000	23 337 400
Newcastle Disease (K)	8 306 400	8 779 600	8 995 600	18 768 200	12 869 800	15 363 400	16 481 600
Newcastle Disease (L)	3 082 200	1 251 600	3 614 700	8 683 200	6 165 400	10 014 400	8 807 200
Fowl Pox	6 375 700	8 441 600	5 955 200	12 996 600	9 494 600	13 928 400	14 604 800
Rabies (L.E.P.)	94 242	88 155	98 201	70 067	120 793	134 328	151 022
Rabies (H.E.P.)	9 043	5 070	3 370	19 022	8 253	35 756	10 443
Gumboro Disease	—	—	3 288 000	1 588 800	336 400	7 358 400	12 750 800
Sub-Total	34 185 235	34 387 225	40 781 771	68 203 489	50 876 746	79 522 084	84 449 965
Grand Total	54 402 405	53 641 175	60 493 421	86 814 309	67 803 636	91 343 264	98 850 495

Table 3. Specimens processed at the NVRI Laboratories at Vom and at its outstations.

Year	Avian	Bovine	Canine	Caprine	Equine	Feline	Ovine	Por- cine	Zoo	Human	Others	Total
1978	1 365	3 409	413	729	263	13	238	25	94	235	207	6 991
1979	744	2 648	641	213	10	6	107	51	18	435	189	5 062
1980	819	2 893	346	178	41	8	136	34	17	507	114	5 093
1981	4 079	3 084	1 104	164	366	7	159	80	57	836	150	10 086
1982	8 853	2 603	1 252	838	82	8	161	17	—	1 598	211	15 623

fail in this part of the world due to lack of supportive services.

2. Vaccine Production

Australia has successfully eradicated CBPP by mass vaccination with the V4 vaccine coupled with quarantine measures. This experience could be made use of profitably in suitable vaccine development and disease control procedures. Despite JP 28 against CBPP, the disease incidence is on the increase as an aftermath of the recent panzootic of rinderpest. Experimentally, V4 vaccine or inactivated oil-based vaccine could be produced and used in a controlled area as a pilot project. Results obtained will determine the use of such vaccines in the field in future.

Oil-based vaccines are significantly becoming important in the poultry industry, especially for breeder-vaccination programs. Preparation of a stable oil-in-water emulsion is still considered as a trade secret by commercial vaccine manufacturers.

Currently batches of vaccines produced at Vom are small in size compared with those by laboratories in the developed countries. Large-sized batches of vaccines can be produced in fermenters called biogenerators. Newcastle disease, fowl typhoid, Gumboro disease, rabies, rinderpest, and CBPP vaccines could be produced in large-sized batches to cope with the growing demands for them. The Institute produces 15 different kinds of vaccines (see Table 2) but there are still others yet to be developed like, sheep pox, goat pox, Marek's disease, infectious coryza, and brucellosis vaccines etc. Collaborative projects on the development of these and others can be worked out for the development of each of them.

3. Transfer Funds

Besides the financial constraints introduced by

the Federal Government's austerity measures, the Institute faces serious problems in obtaining certain chemicals, reagents, equipment, spare parts etc. from overseas. Due to foreign exchange problems, local suppliers find it too difficult to procure the goods. The Institute may consider, subject to Government approval, "transfer funds" so that payment could be made for the goods supplied in local currency.

4. Equipment Maintenance and Repair

Another most important area of co-operation is the posting of service engineers to service, maintain, and repair equipment already installed in the laboratories, like the electron microscope, immunofluorescence microscope, ultra centrifuge, freeze dryers, spectrophotometers, and computers.

Technical Co-operaiton in the Fields of Veterinary Research and Vaccine Production between Australia and Nigeria

Australia, a developed country, has become well known for its established laboratories as well as its eminent scientists, who have contributed immensely to the control of animal diseases and veterinary science in general. Geographically, large areas of Australia lie within the tropics, and the resultant climatic conditions are in many ways similar to those prevalent in Nigeria. There can, therefore, be no doubt that Nigeria stands to benefit greatly from any co-operation with Australia, in scientific research, in the areas of veterinary science and disease control.

The Situation in Nigeria

In Nigeria, the responsibility for conducting

research into all aspects of animal diseases, their treatment and control is vested in The National Veterinary Research Institute (NVRI) at Vom. In pursuance of these objectives, this establishment produces bacterial and viral vaccines such as contagious bovine pleuropneumonia vaccine (CBPPV), anthrax spore vaccine (ASV), *Brucella abortus* S19 vaccine, fowl typhoid vaccine (FTV), fowl cholera vaccine (FCV), haemorrhagic septicaemia vaccine (HSV), black quarter vaccine (BQV), tissue culture rinderpest vaccine (TCRV), Newcastle disease vaccine (NDV), rabies vaccine, fowl pox vaccine (FPV) and infectious bursal disease (Gumboro) vaccine.

Research is also carried out into these and such other diseases as anaplasmosis, babesiosis, heartwater, peste des petits ruminants (PPR), foot-and-mouth disease, sheep pox, African horse sickness, Blue tongue, Marek's disease, and diseases of breeding including leptospirosis, campylobacteriosis and trichomoniasis. Other disease conditions, e.g. foot rot, mycoplasmosis of poultry, etc. are also attracting the Institute's attention. There is also a diagnostic division which, apart from diagnosis, conducts research into various other contagious diseases.

The NVRI would therefore be most interested in the following areas of co-operation:

1. Epidemiology.
2. Economic significance of major epizootics.

3. Diagnostic procedures particularly newer and improved methods that are capable of practical application.
4. Vaccine production.
5. Collaborative research into diseases that are common to both countries, and the development of new techniques as well as the utilization of the more recent techniques in disease control.
6. Interchange of research scientists on short study visits to various research and production laboratories.
7. Training of young research scientists with a view to obtaining experience in methodology and various other areas of veterinary research and vaccine production. It might be necessary to enter into a bilateral agreement that will facilitate entry of scientists from Australia into Nigeria and vice-versa.
8. Provision of equipment and training of personnel for the maintenance of such equipment.
9. Provision of materials and reagents as well as facilities and training for the production of such materials and reagents.

The above list is not all-inclusive; it includes the most important priorities of the NVRI at the present time. It is hoped that a more exhaustive report, which will look into the details of the various aspects highlighted above as well as others, will be presented in due course.

Containment of Livestock Parasites with Emphasis on Ticks

J.P. Fabiyi*

Parasites constitute a major constraint to livestock production in Nigeria. This is particularly so of ticks and especially in cattle, which are parasitised by as many as about 30 different species although three are generally very serious and another four, occasionally (Table 1).

Table 1. Species of ticks attacking cattle in Nigeria.

<i>Amblyomma gemma</i>
<i>Amblyomma lepidum</i>
<i>Amblyomma pomposum</i>
<i>Amblyomma splendidum</i>
^a <i>Amblyomma variegatum</i>
^b <i>Boophilus annulatus</i>
^a <i>Boophilus decoloratus</i>
^a <i>Boophilus geigy</i>
<i>Haemaphysalis aciculifer</i>
<i>Haemaphysalis leachi</i>
<i>Hyalomma dromedarii</i>
<i>Hyalomma impeltatum</i>
^b <i>Hyalomma mipressum</i>
<i>Hyalomma nutidum</i>
^b <i>Hyalomma rufipes</i>
^b <i>Hyalomma truncatum</i>
<i>Rhipicephalus cliffordi</i>
<i>Rhipicephalus evertsi</i>
<i>Rhipicephalus guilhonii</i>
<i>Rhipicephalus longus</i>
<i>Rhipicephalus lunulatus</i>
^b <i>Rhipicephalus muhsamae</i>
<i>Rhipicephalus parvatus</i>
<i>Rhipicephalus praeustus</i>
<i>Rhipicephalus sanguineus</i>
<i>Rhipicephalus senegalensis</i>
<i>Rhipicephalus sulcatus</i>
<i>Rhipicephalus zimmermanni</i>

^aGenerally found in large numbers

^bGenerally found in moderate numbers

Production loss arises from:

1. Infestation with micro-organisms (Table 2) several of which especially *Anaplasma marginale*, *Babesia bigemina*, *Cowdria ruminatum*, and *Dermatophilus congolensis* are very important. The first three often cause considerable morbidity and on occasions, death.

Table 2. Organisms transmitted by cattle ticks in Nigeria.

<i>Anaplasma centrale</i>
^a <i>Anaplasma marginale</i>
^a <i>Babesia bigemina</i>
<i>Babesia bovis</i>
Bhanja virus
<i>Borrelia theileri</i>
Congo virus
^a <i>Cowdria ruminatum</i>
^a <i>Dermatophilus congolensis</i>
Dugbe virus
<i>Eperythrozoon wenyonii</i>
<i>Haemobartonella bovis</i>
<i>Styphlococcus pyrogens</i>
<i>Theileria mutans</i>
<i>Theileria velifera</i>
Thogoto virus

^aParticularly important.

2. Severe irritation caused by their bites especially when numerous. This is commonly called 'tick worry' and results in severe emaciation as animals do not settle down to eat properly and rest.
3. The large volume of blood they suck when they occur in large numbers can lead to anaemia, which in turn results in weakened stock especially in reproductive status.
4. Their bites cause serious damage to hides and skins, which are valuable export commodities.
5. Their bites can pave way for secondary bacterial infections or to fly-strike especially by *Chrysomya Bezziana*.

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6. Tick attacks also render animals more susceptible to other infections and infestations.
7. Sweating sickness, (or moist eczema of the skin) caused by *Hyalomma truncatum* is also known to occur, although sporadically.

Because of the above, efforts have been intensified especially during recent years to control ticks on cattle in order to reduce economic losses to the barest minimum. The control strategy adopted is outlined below.

Objectives of Control

In Nigeria complete eradication is not feasible due to a number of problems that include acaricide resistance, poor dip management, the presence of abundant wild life that can serve as alternative hosts for ticks, and the occurrence of extensive unmaned border areas where cattle can be introduced into Nigeria from neighbouring countries that are not so anxious to control ticks. Risks from re-introduction, even with well manned borders, still exist since ticks can be dispersed by wind from neighbouring countries.

Control Methods

Because of the above problems and the fact that protozoan tick-borne diseases occurring in Nigeria are enzootic and do not normally constitute clinical disease problems when premunition gained during calthood is maintained by continuous exposure to ticks, control is geared to maintaining tick numbers at harmlessly low levels. In this case they are sufficient to produce and maintain premunity to tick-borne diseases but not to the extent to cause physical damage, tick worry, and anaemia. Under this condition exposure of all calves to low infections are ensured from shortly after birth and maintained throughout life. Since young calves up to 9 months do not normally develop clinical infection there is no mortality nor apparent signs of disease.

Control with Acaricides

Treatment at weekly intervals in the wet season when tick activity is high and at fortnightly intervals in the dry season when tick activity is relatively low achieves such objectives. This is applicable with acaricides whose residual effects

extend for 3-5 days, which is characteristic of the modern acaricides.

Acaricides are applied using spray races in Government establishments. Where only a few animals are kept, hand spraying is used.

Dipping is employed in some establishments. Less frequently, hand washing is employed.

Acaricides in Use

Currently in use are BHC, Toxaphene, Asuntol Delnav, Supona, and Pfizona. Serious resistance has been observed in respect of Supona and Pfizona, especially in northern areas.

Control Other Than with Acaricides

Although the above is the main method used for control, spelling of pastures for 4-5 months has been advocated to supplement control efforts. Most unfed ticks naturally die in the absence of suitable hosts within this period. The presence of wild animals which constitute alternative hosts render this method of control less significant.

The extent that the annual burning of grass during the dry season contributes to the control efforts has been a subject of controversy. It is not likely that it plays a significant role because few developmental stages are found on pasture at this time.

Discussion

The above methods of control of ticks have greatly reduced mortality to the barest minimum from micro-organisms transmitted by ticks, provided animals are not unduly strained. When stressed there is a low level flare-up of these micro-organisms resulting in clinical diseases. Stress factors include concurrent infections, vaccination with virulent vaccines such as rinderpest vaccines, and hoof migration (stress of long journey). Also, when adult stock are brought into the country from places where the indigenous diseases are absent, such as the United Kingdom, or from few areas of the country where adequate exposure to ticks to ensure premunition has not occurred, outbreaks of these diseases often occur under the tick control scheme. Animals exposed for the first time when adults, unlike when exposed young, succumb to clinical infection. Outbreaks under

such situations have been seen in Vom especially with exotic breeds.

Under such circumstances we have now thought it desirable to immunize animals by vaccination, where feasible, prior to exposure. In situations where vaccination is not desirable, the use of Imicorb is particularly being considered in the case of anaplasmosis and babesiosis. According to Roy-Smith (1971), one dose administered to non-infected animals will prevent the occurrence of clinical babesiosis for about a month, and at the same time allow natural infection to become established during the period and immunity to develop. It is wise to vaccinate after the residual effect of the drug wanes as the rate of *Babesia* transmission may not be fast enough to infect all animals within this period. In the case of heartwater, chemotherapeutic immunization using oxytetracycline seems necessary to protect susceptible cattle from contracting the disease.

Also, although the above acaricide application schedules have been found useful in most areas, few records indicate that under such a scheme *Boophilus* and *Amblyomma* tick popu-

lations are often too low to maintain premunition leading to outbreaks. Such an outbreak was observed in Shika in 1974.

This indicates that more investigation is needed regarding the intervals of application, especially in the dry season. Work in Shika in 1963 suggests 3 week intervals to be appropriate in this area. More investigation is needed on this aspect on cattle on ranches, cultivated lands etc., and should be carried out for a long time.

Elsewhere, resistance is known to be built up in the course of tick infestation. The resistance mechanism is said to be an allergic phenomenon. *Bos indicus* cattle are susceptible on their first exposure to ticks, but their immunity develops more quickly after exposure and is greater than that shown by resistant individuals amongst *Bos taurus* breeds.

In some countries such as Australia, so much importance is placed on differences in breed susceptibility to ticks that it is often advocated as a means of curtailing the menace of tick and tick-borne diseases. This aspect needs investigation in Nigeria.

Animal Trypanosomiasis in Nigeria

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Trypanosomiasis still remains one of the most important factors limiting the development of the livestock industry in Nigeria, as well as in other parts of Africa. Animal trypanosomiasis in Nigeria comprise a group of diseases of domestic and wild animals caused by haemoprotozoan parasites of the genus *Trypanosoma*. The most important trypanosomes of livestock are *T. vivax*, *T. congolense* and *T. brucei*, which cause the disease in cattle, sheep, goats, and horses, and *T. simiae*, which causes the fulminating form of trypanosomiasis in pigs. Other trypanosomes of livestock are *T. evansi* of camels and horses, and *T. equiperdum*, which causes the venereal form of the disease in horses. The trypanosomes are transmitted to the host animal through the bite of a vector, the tsetse fly (*Glossina*), of which there are eleven species in Nigeria. However, other biting flies can transmit the infection mechanically. *Trypanosoma evansi* and *T. equiperdum* are not tsetse-borne; the former is transmitted mechanically by biting flies (such as Tabanidae) while the latter is transmitted by direct contact during the sexual act.

It is estimated that about 4 million square miles of moderately fertile land in Africa is devoid of cattle due to trypanosomiasis (Wilson *et al.* 1963). It is also estimated that 75% of the entire area of Nigeria is infested with tsetse, including 25% infested only seasonally and 50% infested throughout the year (ILCA monograph 2, Vol. 2). The control of this important disease is therefore highly necessary for increasing agricultural production and much needed animal protein in Nigeria, as this will facilitate the establishment of more livestock farms and dairy farms throughout the country.

Losses in Animal Productivity Due to Trypanosomiasis

The outcome of a trypanosome infection in a given livestock is dependent on a number of factors, which include the virulence of the strain of the parasite, the resistance of the host, nutritional factors, and the presence of intercurrent diseases. Depending on these factors, there are varying severities of disease ranging from subclinical to chronic and acute infections. Depending on the form of the disease, the livestock owner experiences the following adverse effects on his livestock:

1. Death:

An animal can die at any stage of the disease either following an acute infection or after a long chronic wasting syndrome. Putt *et al.* (1980) reported that among cattle treated for trypanosomiasis in Nigeria, the death rate varied between 2.8 and 10.0% while in certain situations, about 50% of untreated animals died. The situation is even worse in swine trypanosomiasis where a death rate of 100% is very common.

2. Loss of weight, meat, or milk:

This is obvious when an animal goes into a chronic form of the disease. The animal goes into a wasting period characterized by physiological starvation in which there is loss of appetite (Fiennes 1958). The animal is highly emaciated and there is a marked reduction in meat and milk production.

3. Reproductive problems:

This is characterized by late abortions (Krampitz 1970); inter-uterine infections (Ikede and Losos 1972), and other infertility problems that arise from sperm abnormalities (Anosa 1977).

4. Intercurrent diseases:

Immunodepression is a recognized phenomenon

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in trypanosomiasis. Although the implications of this are not fully determined, it is also well recognized that cattle suffering from trypanosome infection may succumb to other secondary infections (Scott *et al.* 1977).

5. High cost of production:

The cost of providing trypanocidal drugs and other control measures in addition to providing trained personnel to handle the trypanosomiasis problem, all increase the cost of livestock production.

Control of Animal Trypanosomiasis

In considering the control of animal trypanosomiasis, the important issues are the vector that transmits the infection, the host animal that suffers as a result of the infection, and also the parasite itself. In the past such methods as the clearing of vegetation to destroy the habitat of tsetse and the destruction of game animals, which provide food for the tsetse as well as serving as a reservoir of the parasites, were widely used. At present the following effective methods of control are in use:

1. Trypanocidal Drugs

Trypanocides that are highly active against various species of trypanosomes either as curatives or prophylactics are available. These prevent the animals from becoming infected over a given period, depending on the rate of the tsetse challenge. The number of these effective drugs in the market is however continuously decreasing. This is because the drugs are being withdrawn from the market due to widespread development of resistance to them (Williamson 1976). Unfortunately new drugs for clinical use are now too expensive to develop and produce. At the moment, only two effective curative drugs are in the market, viz. Homidium (Novidium and Ethidium) and diminazine aceturate (Berenil). Only one prophylactic drug is in the market, i.e. isometamidium chloride (Samorin).

Control of animal trypanosomiasis by use of trypanocides is very widely used in Nigeria. Its major constraint is the development of drug resistance. This is very important not only

because the drug resistance persists even after the passage of trypanosomes through the tsetse (Gray and Roberts 1968) but also the trypanosome strains may be resistant to other drugs belonging to different chemical groups.

2. Vector Control

The control of tsetse flies has ranged from hand catching and the use of different types of traps, some in the presence of odour attractants (Vale 1982) to the use of insecticides. At present almost all methods used for the large-scale control of tsetse depend on insecticides. They have been very widely used in Nigeria and this has resulted in the reclamation of a large area infested with flies (Jordan 1978). Insecticides are applied by spraying either from the ground or from the air from helicopters. Large-scale tsetse control using insecticides can be very expensive and requires a large number of trained personnel. The operation can also be a major environmental hazard.

Another promising method of tsetse control is the use of the sterile insect technique. This, however, involves the production of large numbers of insects for release. It therefore requires time and expertise to develop. The main advantage of the technique is that it is most effective when the density of the natural population is very low. The technique can therefore be integrated with other control methods to eradicate the residual populations remaining after the application of other control methods.

3. Use of Trypanotolerant Breeds of Cattle

There is now a considerable body of evidence that trypanotolerant breeds of cattle and other livestock do exist (Roberts and Gray 1973; Esuruoso 1977; Trail 1979; Murray and Morrison 1979; Murray *et al.* 1981). These workers and others have shown the ability of Muturu and/or N'Dama breeds of cattle to be more productive in the course of trypanosome infection than the Zebu. The wider use of these trypanotolerant breeds of cattle should be encouraged, particularly in the moist savannah and forest areas of Nigeria where the tsetse challenge is high and other tsetse control methods are more difficult to apply.

Role of the Nigerian Institute for Trypanosomiasis Research (NITR) in Animal Trypanosomiasis in Nigeria

One of the functions of the Nigerian Institute for Trypanosomiasis Research (NITR) is to undertake research in the field and laboratories on all aspects of trypanosomiasis and consequently to serve as a clearing house for information on the disease, and as an advisory bureau. NITR has pursued this objective very vigorously and consequently has made invaluable contributions on all aspects of trypanosomiasis, both within and outside the country. By so doing NITR has provided better tools for medical, veterinary, and other field workers, who are directly concerned with the control of the disease.

Because of limited time and space, only a very short summary of the highlights of these achievements is presented, as follows:

1. Diagnosis

Proper diagnosis is very essential for the final control of any disease. In animal trypanosomiasis, it is only by demonstrating the parasite, that diagnosis can be made with certainty. NITR, therefore devoted a lot of research on the problem of diagnosis of trypanosomiasis. To enhance the possibility of detecting parasites at low concentrations, Godfrey and Killick-Kendrick (1961) introduced the animal inoculation technique of diagnosis. Here, blood of suspected animals is inoculated into laboratory animals. This method was later extended to the inoculation of tissues of suspected animals as well as other body fluids (cerebrospinal fluid, gland juice) into laboratory animals. Killick-Kendrick and Godfrey (1963) also introduced the examination of fresh and stained lymph node smears as a means of diagnosis.

The capillary-tube agglutination test (Aiyedun and Amodu 1973) was developed in the Institute to aid diagnosis. More recently Ogbunude and Magiji (1982) developed the silicone centrifugation technique, which is based on the density difference between the host's erythrocytes and those of the parasite.

2. Surveys

The Institute has carried out a lot of surveys that

helped to determine the incidence of trypanosomiasis in the field, and also to obtain strains of trypanosomes for closer laboratory study.

From these surveys a lot of basic data have been collected on many species of tsetse flies, such as their distribution, resting sites, seasonal movements, and breeding locations. With these data, the Institute can give useful advice on the formulation of control measures against tsetse flies.

3. Chemotherapy and Toxicology

The Institute has made outstanding contributions in the systematic tests of the efficacy of trypanocides both as curatives and prophylactics. Workers in the Institute had formulated and introduced the use of drug combinations not only to increase their therapeutic activity, but also to reduce the occurrence of drug resistance. Notable among these drug combinations was the antrycide-Suramin complex (Williamson 1957; Stephen and Gray 1960), which was about the only effective drug in the control of trypanosomiasis in the pigs.

Trypanocides that were toxic to animals, were carefully studied by workers in the Institute not only to understand the nature of the toxicity but also to devise ways of overcoming the toxic reactions (Stephen and Williamson 1958). More recently Braide and Eghianruwa (1980) have determined the residual level of a trypanocide in tissues of goats with the aim of emphasizing the public health aspect of the use of such a drug.

Other Areas

Pioneer work on antigenic variation was started in this Institute (Gray 1965). This has gone a long way to explaining the pathogenesis of trypanosomiasis and the problems of developing a vaccine against the disease. Also, earlier work in the Institute revealed the difference in susceptibility to infection between the Zebu on one hand and N'Dama and Muturu on the other hand (Desowitz 1959; Chandler 1952). The sensitivity of tsetse flies to various insecticides and the persistence of the insecticides have also been fully studied. A lot of work has been conducted in the Institute to assess the pathogenic effects of trypanosome species in our domestic animals. Such studies have

revealed the effects of the parasite on various blood values and various organs of the body.

In addition to research, the Institute carries out advisory duties to government livestock farms as well as to private livestock farmers.

Present Status of NITR in Research in Animal Trypanosomiasis

NITR is still as committed as ever in research into the control of animal trypanosomiasis. Research is being energetically conducted on these diseases.

In the field of vector biology and control, scientists in the Institute are carrying out tests on susceptibility of tsetse to various insecticides as well as field trials of insecticide persistence. Tsetse fly behaviour is being studied particularly in regard to contact sex attractants (pheromones). Tsetse surveys are conducted in response to requests received from various livestock establishments, and also as a routine to assess continuously the tsetse problems. In collaboration with the Federal Department of Pest Control and the International Atomic Energy Agency, NITR is involved in laboratory colonization of tsetse flies. The colonies are flourishing and a pilot project on sterile insect techniques has already been started.

Regarding the diagnosis of trypanosomiasis, the Institute is carrying out research on improved immunological and parasitological methods of diagnosis that are aimed at a quick and early detection of infections. Such good methods as the miniature anion exchanger centrifugation technique is being adapted for routine detection of trypanosomes in low concentration. Work is also continuing on the pathology of different species of trypanosomes on sheep, goats, cattle, and pigs.

The Institute realizes that the use of a vaccine will be an ideal method of control and so a lot of work is directed towards the development of a vaccine. Basic work on the elucidation of the mechanism of antigenic variation, as well as studies on the antigenic repertoire of variant antigens, are going on with *T. brucei*, *T. congolense*, and *T. vivax*. *In vitro* cultivation of trypanosomes is receiving a lot of attention from the Institute as a back-up project to the development of vaccine.

Surveys are undertaken to determine the incidence of animal trypanosomiasis as well as to isolate new strains of the parasite for laboratory studies. Drug sensitivity tests are carried out on the newly isolated strain to determine the occurrence of drug resistant strains of trypanosomes. Work is also being conducted on the mechanism of the development of drug resistance.

Investigations are being made vigorously to assess fully the trypanotolerant breeds of cattle (N'Dama, Muturu). To this effect, detailed comparative performance of these breeds in terms of meat production, growth rates, disease susceptibility, reproductive capacity, and also performance under such adverse conditions as intercurrent diseases, different levels of fly challenge and different levels of nutrition, are in progress.

In the field of chemotherapy, work is proceeding on the use of drug combinations in the treatment of infections. Moreover, nucleoside drugs are being screened for activity against some species of trypanosomes. Also, enzyme studies of different species of trypanosomes are in progress.

Recommendations and Conclusion

In spite of the widespread occurrence of trypanosomiasis in Nigeria, some healthy looking cattle still exist in some parts of the country, including the tsetse areas. This, therefore means that there is much promise for a viable livestock industry in Nigeria. All that is required is a well planned and effective control system. The use of vaccines in the control of trypanosomiasis would be the ideal practice, but while research in this direction continues, the existing control methods should be utilized to the maximum.

The following recommendations are put forward for effective control of trypanosomiasis:

1. Integrated Control System:

The present control methods for trypanosomiasis are still effective. For instance, various formulations of insecticides are still effective against tsetse. However, there is the problem of re-invasion of a cleared area either from adjacent infested areas or by recrudescence of

small foci within the cleared area that are difficult to locate. This problem can be overcome by using an integrated control system. A prescribed area, particularly in the dry savannah zone, is treated with insecticides and barriers are mounted at the borders of this area. Barriers can be by use of persistent insecticides, bush clearing or by natural barriers. The residual tsetse population in the prescribed area following the application of insecticides can be eradicated by the use of the sterile insect technique.

This control program is then followed up with a well defined land use (Finelle 1979; Jordan 1978). Well defined area development projects should be intensified in the cleared areas. Settlement in these areas will modify the environment and thus make it difficult for tsetse to survive. By applying this integrated control system, re-invasion of the prescribed area will be prevented and more economic use of the land will be assured, thus justifying the high cost of the control system.

2. Use of Trypanotolerant Breeds of Cattle:

In the moist savannah and forest areas of the country, where control of tsetse by use of insecticides is more difficult, wider use of the trypanotolerant breeds (N'Dama and Muturu) is highly recommended. Both chemotherapy and chemoprophylaxis can be used to supplement the natural resistance of the breeds.

3. Control of Cattle Movement:

Movement of cattle from north to south during the drier months of the year and from south to north in the wet season is a common sight in Nigeria. The movement is undertaken by nomad communities in their desire to secure food for their cattle. This movement although of a good intention has its disadvantages. Apart from carrying tsetse flies over considerable distances, the movement also introduces new strains of trypanosomes into the areas through which the cattle pass. This movement therefore helps to break down effective control measures. It is therefore recommended that such movement should be controlled and the nomadic communities be encouraged and helped to settle. Where resettlement is impossible, arrangements should be made to treat and spray their animals at strategic locations along their track.

4. Improved Nutrition:

The two broad seasons (wet and dry) in this country are characterized by abundant pasture during the wet season and marked depletion of pasture during the dry season. Even during the wet season some areas are overgrazed with the result that a good number of our animals are in poor nutritional status. It is well recognized that animals in a low plane of nutrition are vulnerable to a number of diseases, including trypanosomiasis. Improved nutrition of our livestock is recommended as one of the measures against animal trypanosomiasis.

In conclusion, the devastating role of trypanosomiasis to our livestock industry is very obvious. However, with a very well planned and executed effective control program, integrating various methods of control, and a judicious land utilization scheme, there is a bright future for the livestock industry in Nigeria.

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**Farming Systems in
Nigeria
and Australia**

Forage Legumes and Pasture Development in Nigeria

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Nigeria has an area of about 93 million ha of which 40 million are available for grazing by the national herd. Most of these rangelands are in the savannah zones of the country. Due to the heavy infestation of tsetse flies in the derived and Southern Guinea Savannas, most of the country's cattle, sheep, and goats are found in the Sahel, Sudan, and Northern Guinea Savannah zones that are relatively free of tsetse. A large proportion of these areas is deteriorating fast because of overgrazing and burning. As a result of the neglect and poor management of this vast natural resource, the carrying capacity of these zones is very low indeed.

The carrying capacity of these degraded areas can be increased through many ways, namely by using good range management practices and/or replacing some of the undesirable species with higher yielding, higher quality species. In countries like Australia considerable success has been achieved by aerial sowing of pasture legumes such as *Stylosanthes humilis* into the defoliated or undefoliated native pasture. In the Sudan and Northern Guinea Savannas of Nigeria such sowings with *S. humilis* have not been very successful.

The Importance of Legumes in Pastures

Legumes are widespread in Nigeria and are important for inclusion in pastures because of the following reasons:

1. Build-up of soil nitrogen: Legumes, and other plants, may take up soluble nitrogenous compounds from the soil but most of them in addition, use atmospheric nitrogen made available by rhizobia living in symbiosis with

root nodules. By this method, legumes help in building-up soil nitrogen even in uncultivated land.

2. Restoration and maintenance of soil fertility: On cultivated soils, and fallows where soil nitrogen has been depleted through removal by crops, the planting of legumes helps to restore soil fertility. The concept of 'ley-farming' where legumes are used in the rotation is based on the maintenance of soil fertility.
3. Improvement of the feeding quality of the associated grasses: At Ibadan the inclusion of *Centrosema pubescens* in a *Cynodon plectostachyus* pasture (giant star) resulted in significantly higher levels of organic matter and total nitrogen. The N content of the soil under the mixture was 275 kg/ha – a foot per year higher than under the pasture of pure grass. The N content of the associated grass increased from 1.8 to 2.4 %. The daily live-weight gain in Bunaji cattle grazing the mixture over 12 months was 0.37 kg compared with 0.30 kg from pure grass (Moore 1962).
4. Cover crops: Legumes have been used extensively in plantation to protect the soil against erosion in order to maintain soil fertility, and provide feed for stock. Some of the species commonly used in plantations are *Pueraria phaseoloides*, *Centrosema pubescens*, *Calopogonium mucunoides*, and *Glycine wightii*.
5. Provision of high quality feed in the dry season: Legumes maintain their quality longer into the dry season than grasses; and as such are extremely important in the diet of grazing animals in the dry season. The mineral contents of some legumes are shown in Table 1.
6. Prolong the life and feeding value of pasture mixtures.
7. Soil erosion control: Legumes have been used extensively for soil erosion control. In

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Table 1. Mineral contents of some forage legumes.

	CP %	P %	Ca %	Mg %
(A)				
<i>Calopogonium</i> sp	16.7	.16	1.0	
<i>Centrosema</i> sp	16.9	.26	1.14	.27
<i>Desmodium scorpiurus</i>	15.5			
<i>Lablab purpureus</i>	14.4	.29	1.19	
<i>Glycine wightii</i>	17.0	.13	1.32	.36
<i>Indigofera arrecta</i>	26.2	.35	1.36	
<i>I. hirsuta</i>	23.8	.37	1.88	
<i>Leucaena leucocephala</i>	17.9	.26	.97	.32
<i>Siratro</i>	16.8	.21	1.74	.73
<i>Pueraria phaseoloides</i>	18.8	.29		
<i>Stizolobium deeringianum</i>	11.8	.16	1.15	
<i>Stylo guyanensis</i>	13.4			
<i>S. humilis</i>	11.2	.19	.89	.38
<i>Vigna sinensis</i>	16.8			
<i>Cajanus cajan</i>		.25	.27	
<i>Atylosia scarabaeoides</i>			1.6	
(B)				
<i>Acacia albida</i> pods	10.5	.23	.65	
<i>A. nilotica</i> pods	12.4	.14	.51	
<i>A. senegal</i> pod	19.7	1.78	1.40	.09
<i>A. senegal</i> (whole)	23.4	3.98	3.19	.16
<i>A. seyal</i>	10.6	.07	2.50	
<i>Cajanus cajan</i> (young)	19.1	.05	.24	
<i>Dichrostachys cinerea</i> (shoots)	15.0	.18	1.13	.46
<i>Indigofera arrecta</i>	16.4	.29	2.52	.85
<i>Leucaena</i> spp	19.8	.08	2.20	.58
<i>Piliostigma thonningii</i>	9.9	.23	.70	.20
<i>Tamarindus indica</i> (leaves)	13.5	.59	3.48	

Shika, the species that are commonly used are *Stylosanthes guyanensis*, *S. hamata* and *S. humilis*.

Introduction and Evaluation of Forage Legumes in Nigeria

Pasture legumes were first introduced into Nigeria in the 1940s but it was not until 1956 that large-scale introductions were made at Shika and Ibadan. At Ibadan, most of the pasture screening work was carried out between 1957 and 1959 by the FAO Pasture Mission Team in conjunction with some Nigerian staff. From this screening, *Stylosanthes guyanensis* cv Schofield, *Centrosema pubescens*, *Pueraria phaseoloides*, and *Calopogonium mucunoides* emerged as the best legumes for the derived savannah and forest zones. Further evaluations at Ibadan were based on mixtures of these legumes and grasses such as *Panicum maxi-*

mum, *Andropogon gayanus*, *Cynodon* species, and *Pennisetum purpureum*.

The main centre for pasture introductions and evaluations in Nigeria is NAPRI, Shika. Between 1956 and 1977, over 700 entries of 97 legume species were made in Shika, of which 54 species were found to be adapted to the different ecological zones of the Nigerian savannah, with 18 species being recommended for large-scale use (Agishi 1979). These species are listed in Tables 2 and 3. Some of the species such as *S. humilis* and *Alysicarpus vaginalis* were originally rejected because of low productivity but are now highly rated.

The forage legumes that are being evaluated in Nigeria can be divided conveniently into pasture, fodder, and browse legumes.

1. Pasture Legumes

These are legumes that can be sown in mixtures with grasses and are sufficiently low growing

Table 2. Forage legumes recommended for the Nigerian savannahs.

Species	Common Name	Ecological Zones			
		Mon-tane	N.G.S.	S.S.	Indig-enous
		S.G.S.			
<i>Arachis hypogaea</i>	Groundnut (peanut)	+	+	+	+
<i>Cajanus cajan</i>	Pigeon pea	+	+	+	
<i>Calopogonium mucunoides</i>	Calopo	+	+		X
<i>Centrosema pubescens</i>	Centro	+	+	+	
<i>Desmodium intortum</i>	Greenleaf desmodium	+	+		
<i>Glycine mase</i>	Soyabean	+	+	+	
<i>Glycine wightii</i>	Glycine	+	+		X
<i>Lablab purpureus</i>	Lablab		+	+	+
<i>Leucaena leucocephala</i>	Leucaena	+	+	+	+
<i>Macroptilium atropurpureum</i>	Siratro		+	+	
<i>Pueraria phaseoloides</i>	Puero	+	+		
<i>Stylosanthes guyanensis</i> cv Cook	Cook stylo	+	+	+	
<i>S. guyanensis</i> cv Endeavour	Endeavour stylo	+	+	+	
<i>S. guyanensis</i> cv Schofield	Schofield stylo	+	+	+	
<i>S. hamata</i> cv Verano	Verano (Caribbean stylo)		+	+	+
<i>S. humilis</i>	Townsville stylo		+	+	+
<i>Stizolobium deeringianum</i>	Mucuna, velvet bean	+	+	+	X
<i>Vigna sinensis</i>	Cowpea	+	+	+	+

* Note that all the recommended species could be grown in the Sudan zone under irrigation.

SGS = Southern Guinea Savannah.

NGS = Northern Guinea Savannah.

SS = Sudan Savannah.

+

X = Indigenous.

enough to be grazed by stock. They belong to the sub-family, Papilionaceae. They include *Stylosanthes*, *Desmodium*, *Centrosema*, *Glycine*, *Leucaena*, *Macroptilium*, *Pueraria* and *Vigna*. They have received a lot of research attention in Nigeria involving seed germination, establishment, fertilizer requirements, defoliation under cutting and grazing, and seed production. The general findings are:

(i) Establishment

For most tropical legumes, seed treatment is necessary to improve germination. The hot water method of scarification has been found to be cheap and simple. Though early seedling growth is slow, once established legumes compete successfully with associated grasses and weeds. They can be successfully established during the dry season under irrigation.

(ii) Fertilizer Requirements

Nigerian soils are generally low in nitrogen and

phosphorus. The addition of phosphate fertilizer has resulted in marked increases in legume growth, and seed production. At Shika, maximum herbage yield responses of Stylo and Townsville stylo occurred after 800 and 600 kg/ha of single superphosphate were applied. For *Stylosanthes mucronata* (*S. fruticosa*) this maximum was achieved at 400 kg/ha. Once established, only 100 kg/ha/yr of single superphosphate is required for maintenance. Small quantities of nitrogen fertilizer (50 kg N/ha) are required at the establishment phase of legumes before they become active in producing their own nitrogen.

(iii) Herbage Yields

Legumes are normally established in mixtures with grasses, and their dry matter in such an association depends largely on the system of management. The addition of high levels of N may suppress the legume in favour of grasses. On the other hand, phosphate addition is more

Table 3. Forage legumes adapted to the savannah zones.

Species	Ilorin S.G.S.	Shika N.G.S.	Katsina S.S.	Indig- enous Nigeria
<i>Alysicarpus glumaceus</i>	—	1	2	x
<i>A. vaginalis</i>	—	1	—	x
<i>Atlysia scarabaeoides</i>	2	1	—	
<i>Cajanus cajan</i>	1	1	—	
<i>Calopogonium mucunoides</i>	1	1	x	
<i>Centrosema plumieri</i>	1	1	2	x
<i>Centrosema pubescens</i>	1	1	2	x
<i>Clitoria ternatea</i>	1	1	2	x
<i>Crotalaria poulina</i>				
<i>C. retusa</i>	—	1	1	x
<i>C. spectabilis</i>	—	—	1	x
<i>C. goreensis</i>				x
<i>C. anagyroides</i>	3	—	—	
<i>Desmodium gyroides</i>	1	—	—	
<i>D. intortum</i>		2		
<i>D. lasiocarpum</i>	1	—	1	
<i>D. scorpiurus</i>	1	1	2	x
<i>D. ramosissimum</i>	—	3	—	x
<i>D. uncinatum</i>	3	2	—	
<i>Dolichos lab lab</i> (<i>Lab lab purpureus</i>)	1	1	2	x
<i>Glycine wightii</i>	1	1	2	
<i>Glycine max</i>	1	1	3	
<i>Indigofera endecaphylla</i>	3	1	—	
<i>I. hirsuta</i>	—	3	—	x
<i>I. retroflexa</i>	—	1	—	x
<i>I. suffruticosa</i>	1	1	1	x
<i>Leucaena leucocephala</i>	1	1	2	
<i>Medicago scutellata</i>	—	3	2	
<i>Phaseolus lathyroides</i>	1	1	—	
<i>Macroptilum atropurpureus</i> (<i>siratro</i>)	1	1	2	
<i>Pueraria phaseoloides</i>	1	1	—	
<i>Sesbania aegyptica</i>	1	1	—	
<i>Stizolobium deeringianum</i>	1	1	—	
<i>Stylosanthes bojeri</i>	1	1	1	x
<i>S. guyanensis</i>	1	1	1	x
<i>S. hamata</i>	1	1	1	
<i>S. humilis</i>	1	1	1	
<i>S. scabra</i>	—	1	—	
<i>Stylosanthes viscosa</i>	—	1	—	
<i>Sphenostylis schweinfurthii</i>	1	—	—	x
<i>Tephrosia caudata</i>	1	1		
<i>T. vogelli</i>	1	1		x
<i>Teramnus labialis</i>	3	2		x
<i>T. uncinatus</i>	2	1		
<i>Trifolium fragiferum</i>	—	2		
<i>T. subterraneum</i>	—	2		
<i>T. incarnatum</i>	—	3		
<i>T. rueppelianum</i>	—	3		
<i>T. cherangariensis</i>	—	3		
<i>T. usambarense</i>	—	3		
<i>Vigna marina</i>	2	2		x
<i>Vigna unguiculata</i>	2	1		x
<i>Zornia diphylla</i>				
<i>Z. glaucoidiata</i>	—	3		x

1 = Good.

2 = Fair.

3 = Marginal.

x = Indigenous.

— = Either not sown or no records taken.

S.G.S. = Southern Guinea Savannah.

N.G.S. = Northern Guinea Savannah.

S.S. = Sudan Savannah.

beneficial to legume growth. Table 4 summarizes the dry matter yield from legumes and legume/grass pastures at Shika.

Dry matter yields of some forage legumes under irrigation at Shika after about 4 months of growth have also been reported (Table 5).

Although these yields are not outstanding, the crude protein contents of these species ranged between 15.1 and 19.5%. Since native pastures contain as little as 2% crude protein in the dry season, the hays produced from irrigated legumes would significantly increase the quality of stock diet during the dry season.

(iv) Animal Production

The numerous grazing trials carried out at Ibadan and Fashola on legume/grass mixtures have indicated how beneficial the inclusion of legumes is to the growth of livestock. Many of these trials however have been carried out in such small areas of land that it is difficult to extrapolate the results to commercial farm areas.

At Shika, in a trial involving over 32 ha of native grass oversown with Stylo and grazed for two years, Hagggar *et al.* (1971) obtained an increase in liveweight gain of 28% over that

Table 4. Dry matter yields of legume and legume/grass pastures.

Experiment	Species	Yield t. DM/ha	Percent Legume
A. Legume/grass pastures			
	1 <i>Brachiaria</i> /centro	9.89	10
	2 <i>Brachiaria</i> /stylo	14.43	25
	3 <i>Brachiaria</i> /townsville stylo	14.81	10
	4 <i>Chloris</i> /centro	7.27	21
	5 <i>Chloris gayana</i> /stylo	9.20	58
	6 <i>Chloris gayana</i> /stylo	9.62	44
B. Legumes			
	7 Stylo	9.20	95
	8 Townsville stylo	5.44	70
	9 Verano stylo	6.09	77

1,3 = means of 2 harvests/season over 2 years. Annual application of 67 kg P₂O₅/ha (Hagggar *et al.* 1971).

2 = As in 1, 3 above, but an additional application of 84 kg S/ha.

4,5 = Establishment year. Interrow seeding of legumes; fertilizers applied = 60 kg N, 30 kg P, and 30 kg K/ha.

7 = End of season yield of 3 year old pasture, leniently grazed in the rainy season: 20 kg P₂O₅/ha/year applied (NAPRI, Annual Report 1972).

8 = Establishment crop: 20 kg P₂O₅/ha applied (Roelevald 1978).

9 = 3 year old pasture: 20 kg P₂O₅/ha/yr. (NAPRI, Annual Report 1973).

Table 5. Dry matter yields of forage legumes under irrigation (kg DM/ha).

Species	Growth Stage	DM Yield
<i>Cajanus cajan</i> , Local	Vegetative	2820
<i>C. cajan</i> UQ 50	Pod forming	5256
<i>Glycine max</i> G11	Flowering	3221
<i>G. max</i> G17	Flowering	4738
<i>Centrosema pubescens</i>	Vegetative	702
<i>Desmodium intortum</i>	Vegetative	2000
<i>D. scorpiurus</i>	Vegetative	687
<i>D. uncinatum</i>	Vegetative	2075

After Akinola, J.O. 1975.

from native pasture. This difference increased to 60% when cattle grazing Stylo were supplemented with 227 gm of cottonseed cake per day. Animals grazing range or sown grasses usually start losing weight at the onset of the dry season.

Data from cattle grazing trials at Shika have shown that the inclusion of Verano in buffel grass delayed the commencement of weight loss. For the stocking rates of 1.1, 1.67, and 8.33 heifers/ha, cottonseed supplementation was only necessary from late February, early February, and early January respectively. Live-weight gains over a period of a 222 day grazing period (1st April to 10th November) are presented in Table 6 (Agishi 1979).

The buffel/Verano pasture was established on a fallow land that had become too weedy for maize cropping, and was fertilized at 20 kg P_2O_5 and 26 kg N/ha in the establishment year with an annual maintenance rate of 10 kg P_2O_5 /ha. Table 6 shows that the inclusion of a legume in the pasture not only increased the stocking rate per hectare but also the liveweight gain per animal. Partial cost analysis shows that live-stock production on sown grass/legume mixtures is profitable. This is in agreement with earlier findings by de Leeuw and Agishi (1978) when they compared different grazing systems in the savannah zones of Nigeria.

(5) Seed Production

This is an area that has long been neglected. Recently however, trials were carried out at Shika to determine the seed yield potential of *Stylosanthes guyanensis* cv Cook, Endeavour and Schofield, *S. hamata*, and *S. humilis*. It was found that seed production was greatly influenced by phosphate fertilizer addition. Lower rates of phosphate application, 60 kg P_2O_5 /ha,

are required for optimum seed production in *S. guyanensis*. Higher rates tend to cause serious lodging. In Verano and Townsville stylos, optimum seed yields occur at about 90 kg P_2O_5 /ha (Agishi 1981). The potential seed yield of Cook stylo is about 1200 kg/ha but the recovery is low (200-500 kg/ha). Verano has given seed yields as high as 1775 kg/ha, but commercially only 600-800 kg/ha are recovered during harvesting (Agishi 1979).

Seed yields in the climbing legumes such as Siratro and Centro are also high, but indeed are due to excessive shattering. Manual seed harvesting of legumes is very expensive, but recently Agishi (1979) showed that this cost can be significantly reduced by more than 60% if the 'harvester ant method of seed harvesting is adopted'. In this method, ants are allowed to gather seeds of stylos into mounds, and these can then be collected into containers at weekly intervals. With ants there are no resting times due to fatigue, no labour disputes and strikes, nor salary increases!

2. Fodder Legumes

In the Northern Guinea and Sudan Savannah zones of Nigeria, livestock feed supply is at its lowest during the dry months of January to June. Then animals feed mostly on crop residues. Apart from the leguminous crop residues such as groundnut haulms and cowpeas, the other crop residues like sorghum, millet, rice, wheat, maize, and cotton are low in quality. Though groundnut and cowpea hays are used throughout the zones, they do not meet total requirements. There is a place in the farming system for legume crops grown especially for hay and silage.

Legumes that have shown some value for conservation are groundnuts (*Arachis hypogaea*),

Table 6. Effect of stocking rates on cattle liveweight gains from grazing Verano/buffel pasture for 222 days.

Stocking rates (ha/head)	2.00 ⁺	0.90	0.60	0.30
Stocking rates (head/ha)	0.50	1.11	1.67	3.33
Mean liveweight gain (kg/hd)	66.6	95.0	90.0	88.0
Average daily gain(kg/hd/day)	0.30	0.428	0.405	0.396
Liveweight gain/ha	33.3	105.6	150.0	293.3
Return/ha (Gross ⁺⁺)	66.6	211.2	300.0	586.6

+ Control (Native pasture).
++ Assume N2.00/kg liveweight

soyabeans (*Glycine max*), Cowpea (*Vigna sinensis*), Mucuna or Velvet bean (*Stizolobium deeringianum*), and Lablab (*Lablab purpureus*). These legumes if properly used in conjunction with improved native pasture, sown pasture and browse plants, will help to reduce the heavy livestock liveweight losses that are common in the dry season. So far the crop farmers are leading the way in forage legume feed conservation. Bales of groundnut haulms and cowpea that are sold by farmers along the Zaria-Kaduna road are of the highest quality. Little attention has so far been paid by pasture agronomists to this area of feed conservation. There is therefore an urgent need for research work to be carried out in fodder crop conservation as a source of feed for livestock.

3. Browse Legumes

These are herbs, shrubs, and trees that are of considerable importance as stock food during the latter half of the dry season in the Sahel, Sudan and Northern Guinea vegetation zones when most of the grass cover has been removed by grazing animals or fire. Many legumes that are browsed by stock are well known to herdsman who frequently cut their branches down for stock feed. The fruits of some of these browse legumes form an important item in the dry season diet of stock, particularly in the Sahel and Sudan zones. Pods of *Piliostigma reticulata*, *P. thonningii*, *Acacia albida*, *A. nilotica*, *Tamarindus indica*, and *Parkia clappertoniana*, are among the ones that are readily eaten.

Very little research has been conducted into the propagation, management, and seed production requirements of browse plants in Nigeria. So far only pigeon pea (*Cajanus cajan*) has been studied in detail, but even here the experiments have been restricted to small plots. The possibility of introducing this important drought resistant legume into the range has not been examined. *Leucaena* (*Leucaena leucocephala*) is widely respected as one of the best browse legumes and has naturalized in some parts of Nigeria, and yet no large-scale sowing or grazing trials using cattle have been undertaken on it.

The acacias are found throughout the Guinea Savannah zones, and dominate the Sahel and Sudan vegetation. Their value as browse is well known but not a single

agronomic or grazing trial has been carried out on them. Many other browse legumes exist in the country, which have not been examined for their potential. The author has identified over 100 of these (Agishi 1982), 52 of which are being analysed for their mineral contents. Part of the results obtained so far are shown in Table 7. These figures can be compared with those shown in Table 1, which were taken from different parts of the tropics.

Forage Legume Resources of Nigeria

The family Leguminosae is divided into *Caesalpinaceae*, *Mimosaceae*, and *Papilionaceae*. In Nigeria, the *Caesalpinaceae*, *Mimosaceae*, and *Papilionaceae* are represented by about 43, 21, and 68 genera respectively, and collectively these genera contribute over 300 species to our flora. Records of the Pasture Species Introductions in Nigeria show that only 29 indigenous legume species have received some screening. Some of these were planted, but no records were taken. Those that failed to germinate, due to dormancy or hardseededness, were abandoned but were still classified as 'not adapted' or 'suitable for further testing'. Thus we see today some of the indigenous legumes like *Alysicarpus vaginalis*, *Desmodium gangeticum*, *Crotalaria retusa*, *Sphenostylis schweinfurthii*, *Crotalaria macrocalyx*, and *Indigofera pulchra* that were either rejected or not screened at all, as being the main source of feed for livestock from the onset of the dry season.

Though the Sahel and Sudan zones are dominated by the acacias, there is no record of their screening. Thus for more than a quarter of a century of pasture research work in this country we have spent tremendous energies in trying to adapt the exotics to our environment while rejecting the indigenous species that have evolved over the centuries in the same environment. For example, lucerne or alfalfa (*Medicago sativa*), which is a temperate legume, was imported 44 times into Shika. Another temperate legume, subterranean clover (*Trifolium subterraneum*) was brought into Shika 22 times. Examples abound of other temperate legumes that were similarly brought in. None of these temperates performed well in the low lying areas of the country.

Table 7. Mineral contents of legume browse plants at Shika.

LEGUMES ⁺⁺	N % DM	P %	K %	Ca %	Mg %	Zn (ppm)
<i>Acacia albida</i> (% DM)	1.7	.11	.96	.87	.20	77
<i>Adenodolichos paniculatus</i>	1.7	.12	1.06	.55	.20	84
<i>Afrormosia laxiflora</i>	3.9	.15	.83	.27	.12	52
<i>Azalia africana</i>	2.9	.14	.91	.61	.34	63
<i>Banhinia refescens</i>	1.7	.07	2.92	2.19	.35	78
<i>Crotalaria retusa</i>	2.2	.09	1.01	1.39	.45	107
<i>Daniellia oliveri</i>	3.2	.21	1.80	.27	.25	67
<i>Desmodium gangeticum</i>	3.5	.24	2.18	1.17	.22	107
<i>Detarium microcarpum</i>	1.5	.12	1.04	.15	.16	41
<i>Dichrostachys cinera</i>	2.2	.09	0.98	.63	.21	60
<i>Erythrina senegalensis</i>	4.4	.23	1.95	.85	.22	104
<i>Indigofera pulchra</i>	1.7	.19	.77	1.63	.31	92
<i>Leucaena leucocephala</i>	3.2	.16	1.34	1.38	.37	84
<i>Parkia clappertoniana</i>	2.4	.11	.91	0.31	.17	48
<i>Piliostigma reticulata</i>	1.5	.13	1.01	0.66	.17	63
<i>P. thonningii</i>	2.1	.14	1.63	1.18	.24	73
<i>Prosopis africana</i>	2.5	.14	1.26	1.13	.40	72
<i>Pterocarpus erinaceus</i>	3.7	.18	2.91	.39	.54	94
<i>Sphenostylis schweinfurthii</i>	1.5	.04	1.00	.45	.27	98
<i>Swartzia madagascariensis</i>	2.6	.14	.68	.28	.11	38
<i>Tamarindus indica</i>	1.5	.25	.87	.22	.29	71

+ % Dry matter.

++ Analyses were carried out on plant samples (leaves and twigs) taken in early April.

Species of tropical origin in genera such as *Centrosema*, *Desmodium*, *Glycine*, *Lablab*, *Macroptilium*, *Macrothloma*, and *Stylosanthes* etc. have been more successful. In any case, however successful these exotics are in our environment, there is still a great need for us to evaluate our indigenous species for their forage value.

Future Research

Research on pasture legumes in Nigeria is still in its infancy, and as such there are so many areas that need urgent attention. The major areas that should be of top priority in our future research work are:

1. Survey of indigenous species.
2. Species: There is a need to find legumes for the following environments:
 - (1) Seasonally flooded or water logged areas.
 - (2) Montane regions eg. Mambilla.
 - (3) Semi-arid and arid regions.
 - (4) Plantations – use as cover crops.

3. Establishment

- (1) Development of the minimal cost methods.
- (2) Methods for reseeding previously improved lands.
- (3) Methods of undersowing legumes into cereal crops.
- (4) Fallow land improvement.

4. Fertilizer Use

- (1) Map out fertilizer requirements for different soil types.
- (2) Find optimum levels for each species.

5. Weed Control: Manual, mechanical, and chemical methods.

6. Seed Production

- (1) Field establishment and weed control.
- (2) Management practices.
- (3) Harvesting methods.
- (4) Storage.

7. Irrigated Legumes: Basic agronomic studies.

8. Browse Plants

- (1) Survey, establishment, management and seed production.
- (2) Quality determinations.

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Integrated Livestock and Crop Production

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The range resources of Nigeria are restricted to a belt extending from the sub-Sahel to the derived savannah ecological zones of the country between 8° and 13.5° N latitude. Within the belt, over 40 million ha are or could be made available for grazing use. Mean annual rainfall increases from 600-1600 mm, while herbage production increases from 1000 to over 10 000 kg DM/ha from the northern to its southern limits. The zone supports most of the nation's 20 million Tropical Animal Units of ruminant livestock. Over 90% of the livestock of this are in the hands of the traditional herdsman. Most of the pastoralists are known to be settled while the rest are transhumant. Their animals depend almost entirely on natural pastures for their nutritional requirements. Livestock in the traditional system graze upland ranges and fallow lands during the wet season; in the dry season the available residual forage of the upland ranges is complemented by utilization of crop residues, fadama grassland, and browse.

The grazing resources available to the traditional pastoralists are under increasing pressure from both within and without the system. Livestock numbers have increased as a result of improved health services, stock, water developments, and low off-takes. Uncontrolled burning of rangeland destroys much of the dry-season fodder resources while large riverine areas cannot be fully utilized because of tsetse fly infestation. Similarly as a result of changes in land-use patterns (urbanization, advent of large scale upland farms and irrigation schemes) within the years since independence, land available for grazing has been considerably reduced. To what extent this process of diminishing grazing resources has advanced over the last decades became manifest during the 1972-1974 drought, when shortage of

fodder supplies caused widespread starvation and mortality of livestock. The effects of the current drought are yet to be assessed.

Fodder Resources Improvement

The basic paradox is that too much has been said, and also too much has been done but the desired goal is far from attained. One thing known to all individuals concerned with animal production is that pure ranching that depends entirely on the savannah fodder resources has low productivity per ha. To what extent this can be improved has prompted the various research and development approaches.

Research Approach

Considerable work has been done towards improving the primary productivity of savannah. Main emphasis in the 1950s was devoted to sown pastures. Many indigenous and exotic grasses and legumes were evaluated in terms of their adaptability and agronomic characteristics (Foster and Mundeg 1961; Miller and Rains 1963), nutritive value (Miller 1961) and their suitability for conservation as hay or silage (Miller and Rains 1963; Miller *et al.* 1963; Miller *et al.* 1964). Recommendations are also made on the suitability of various legume mixtures for producing silage (Thorpe 1964). Legumes, such as the *Stylosanthes* oversown into savannah grassland (Haggar *et al.* 1971) were shown to improve the quality and carrying capacity of the range. As a result of these and many trials, the workers at Shika have identified a number of species many of which were recommended for large-scale pasture production.

Development Approach

The basic approach has been to combine research results experience. One such approach had been the 'USAID Plan'. In 1960 the defunct

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Northern Nigerian government sought the assistance of the United States Government through the United States Agency for International Development (USAID) to introduce range management techniques that will improve the productivity of rangeland and promote efficient utilization of natural resources. By 1968 over 700 000 ha were in grazing reserves within the USAID Plan. Main emphasis was on improving watering facilities, access and fire protection, and extension of veterinary and marketing services. In the 70s further efforts were put on the establishment of more grazing reserves and the development of existing ones. Developmental strategy adopted then was the World Bank proposed 'Group Ranch', which incorporated the USAID Plan but also recommended that 25% of each group ranch be oversown with Townsville stylo. In the latter part of the decade, the Livestock Project Unit (LPU) of the Federal Livestock Department played a major role in rangeland development. The LPU scheme, while incorporating all the elements of its predecessors, added the 'fodder bank concept' and 'small-holder fattening scheme'.

In spite of the tremendous inputs, in both equipment and technical man-power in all the plans, the improvement of productivity on savannah rangeland is far from the desired goals. Productivity in some of the earlier established grazing reserves has deteriorated far below the level existing at the time of its establishment.

Much had been said about the poor results obtained from the various improvement measures designed to increase range productivity of the Nigerian savannah. The environment, the attitude of pastoralists, the apathy of technicians and policy makers have all shared some of the blame. While it is not within the scope of this paper to discuss the various view points, it can be stated that almost all the development approaches have something in common, i.e. the apparent disregard of available local information and a distorted view of the traditional system of livestock production. Thus instead of looking at transhumance and nomadism as grazing strategies to cope with a fragile environment, the anthropological view of primitive cultures was more stressed. In the original concept of the grazing reserves the inclusion of arable

cropping, and the symbiotic relations between livestock and crop system were never considered, even though it was known that the majority of pastoralists are settled and conduct farming as a major or subsidiary activity (Malumfashi 1968).

The idea of mixed farming is not new in this country. It is within its framework that the traditional system of livestock production operates. As early as 1950, mixed farming was widely encouraged in the arable crop sector. The idea then was to provide work bulls and also farmyard manure. The idea should be expanded to incorporate the livestock production sector.

Future Needs in Integrated Research

The first step should be to consolidate our present knowledge and initiate new research. Such research must depart from the traditional functional, or single-product oriented research. It should also be designed to explain why, and not merely report what happened.

For intensive livestock production there is the need for information on the alternating of sown pastures with arable crops, intercropping of forage into arable crops, and efficient utilization of agro-by-products by the animal sector. These and the unexplored area of irrigated pastures need urgent attention. Studies should identify suitable forage plants to act as break crops in the arable cropping rotations and to provide much needed grazing for the animal population that occurs around irrigation sites. Their water-use efficiencies and their responses to management practices should be clearly defined for a meaningful integration of livestock with irrigation schemes.

For the extensive system, the 'fodder bank concept' and 'strip seeding' seem to be limited by brush invasions and the indiscriminate bush fires on savannah. The ecology, methods, and economics of their control need to be investigated. Research towards finding more aggressive forages that can compete more successfully should be accelerated. More research is also needed on the grazing management of savannah vegetation. Grazing trials are required to determine optimum levels of stocking rate and the economic levels of supplementary feeding

while animals are on pasture. The research direction is to develop grazing management systems that are based on the physiology of the key forage species in response to the environment, rather than from conventional grazing trials.

Directory of Programs/ Projects of NAPRI

Program: Indigenous Beef Cattle Production Research

Projects

1. Evaluation of indigenous breeds of cattle for beef production in their specific ecological zones.
2. Genetic improvement of promising breeds by selective breeding.
3. Nutritional studies on growth and reproduction of beef cattle on range with minimum supplementation.
4. Comparative studies on different systems of feedlot fattening of bulls.
5. Economics of beef production and studies on marketing.
6. Socio-economic studies on beef production.

Program: Dairy Production Research

Projects

1. Development of dairy herd by crossbreeding indigenous cattle with an exotic dairy breed.
2. Nutrition of the growing and lactating dairy cow.
3. Research on environmental physiology to assess the effect of climatic and other factors on milk production and ways of overcoming them.
4. Establishment of a milk processing facility for studies on milk processing, dairy products, and quality control in relation to local needs.

Program: N'dama Cattle Multiplication and Improvement

Projects

1. Comparative studies on the production potential of indigenous trypano-tolerant breeds and their evaluation against N'dama.
2. Research on trypano-tolerance and methods of enhancing this trait.

Program: Sheep and Goat Improvement and Production Research (Indigenous breeds in the Savannah and Humid Zones)

Projects

1. Evaluation of the performance of indigenous breeds of sheep and goats.
2. Genetic improvements of promising breeds by selective breeding.
3. Assessment of the nutritional requirements during the different stages such as growth, pregnancy and lactation.
4. Evaluation of local ingredients and formulation of economic rations based on local feedstuffs.
5. Development of a commercial ram feedlot scheme and assessment of economic viability.
6. Socio-economic studies on rural sheep and goat farming.

Program: Poultry Production Research

Projects

1. Development of National Poultry Foundation stock for production of grandparent and parent stock locally and thus minimise day-old chick importations.
2. Research into different management practices and housing methods for economic production.
3. Determination of nutrient requirements of chicken, turkey, ducks and guinea fowl.
4. Investigation of the utilization of locally available ingredients including agro-industrial by-products for economic ration formulation.

Program: Pasture Agronomy and Fodder Production

Projects

1. Introduction and evaluation of new species, varieties, and cultivars of grasses and legumes.
2. Research on agronomic practices for optimizing productivity and quality forage.
3. Establishment and management of grass/legume swards and introduction of forage legumes into cereal crop cultivations.
4. Evaluation of browse plants and propagation of promising types.
5. Range studies on methods of improving animal production from range.

Program: Improvement of Genetic Potential, Reproductive Efficiency of Livestock and Extension of National Artificial Insemination

Projects

1. Expansion of the Central Artificial Insemination centre in NAPRI to provide A.I. services to other states.
2. Investigations on reproductive hormones to determine factors limiting reproductive efficiency in all classes of livestock.
3. Development of techniques for improving reproductive performance of ruminants suitable for extensive and intensive production systems.

4. Research into productive diseases of all livestock species.

Program: Swine Production Research

Projects

1. Selective breeding of improved breeds of pigs with a view to supplying selected boars to farmers.
2. Nutritional studies to determine the nutritional requirements of pigs and to evaluate the usefulness of local feedstuffs in pig production.
3. Research on the management and economics of pig production.

ILCA's Research on Crop-Livestock Interactions in the Subhumid Zone of Nigeria

J.M. Powell*

In the Subhumid Zone of Nigeria, ILCA's Systems Research efforts are concentrated on relieving the major constraint to livestock production, i.e. inadequate nutrition during the six-month dry season. This involves a primary focus on cattle, which represent approximately 80% of the ruminant livestock biomass in the Zone (Bayer 1982), and on the Fulani, who are the principal owners of cattle. Over the centuries of their presence in West Africa, Fulani pastoralists have adjusted their migratory patterns of animal production. In Nigeria, for example, it has been estimated that more than half of the cattle-keeping Fulani are now settled (van Raay 1975) and an increasing immigration of Fulani southwards into the more humid Middle Belt has been detected (Bourn 1983).

The Nigerian Government has created grazing reserves for the Fulani, but total cattle numbers render it impossible for all to be supported on grazing reserves. Moreover, many Fulani prefer to settle in the midst of farming communities. The reasons for the close proximity of livestock and cropping include the availability of crop residues as dry season fodder, fallow-land grazing, use of animal manure in cropping, and various socio-economic interactions between the Fulani and farmers. With the increasing demand on land to produce more food, cultivated areas will expand and prime grazing areas will diminish. A closer integration between cropping and livestock will be necessary with animals becoming increasingly dependent on obtaining fodder from crop land. In turn, the role of livestock in providing manure, power and/or transportation to the crop sector must increase.

ILCA's investigations into crop-livestock interactions are concentrated in two case-study areas of similar climatic and soil conditions but differing human and livestock concentrations. Kurmin Biri, one case study area, falls within the

Kachia Grazing Reserve, established by the Government for Fulani settlement. Here, human population is approximately 12 people/km², animal concentration during the wet season is 5 head/km², and 15% of the total land area is under cultivation (Milligan *et al.* 1979).

The second case study at Abet, characterized by spontaneous settlement of Fulani amidst farming communities, has a much higher human and wet-season cattle population of approximately 70 people and 23 head/km², and a higher percentage of land under cultivation, at 25%. In Abet, the Fulani constitute about 10% of the total population. Given the relatively high concentration of cropping and livestock in Abet, this area offers an ideal setting to evaluate current levels of crop-livestock integration and to identify and investigate methods by which these interactions can be strengthened to the mutual benefit of both sectors.

Identifying Cropping Patterns, Fodder Resources and Research Priorities

Baseline surveys were conducted with farmers and Fulani to define land use, cropping patterns, production inputs, yields and constraints, in order to identify and design appropriate methods for increasing the quantity, quality, and availability of fodder resources from the crop sector. Indigenous farmers claim traditional rights to the land; the Fulani must negotiate with them for settlement and cropping rights. Animal husbandry remains the prime occupation of the settled Fulani; the average settled herd consists of 50-60 cattle plus a few sheep. However, most settled Fulani do some cropping; from 0.20-1.2 ha/adult male to reduce household expenditures on grain. In contrast, the population goal in cropping by non-pastoralists is to meet subsistence needs; adult males cultivate about 1.5-3.5 ha. Since all cropping operations are done manually, labour is the major input in

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cropping. Therefore, the amount of land cultivated per household each year is mainly a function of family and/or hired labour available. For the Fulani, the amount of cultivable land that can be obtained in a given year is also a factor in area under cropping.

Being situated in the Middle Belt or Sub-humid Zone of Nigeria, cropping patterns in Abet feature the predominant crops of the semi-arid north, including sorghum, millet, and groundnuts, as well as the tubers (yams, cocoyams, and cassava), maize, and rice of the humid south. Soyabeans and ginger are cash crops for the farmers. The Fulani put particular emphasis on rice and iburu (*Digitaria iburea*). From grain harvest, in mid to late November, through the six month dry season, cereal stover, soyabean and rice threshing by-products and rice regrowth are grazed by Fulani cattle. These crop residues constitute a major part of diet when natural forages are of very low nutritive value. Crop residues for dry season grazing or feeding, and the vegetation on recently fallowed land for wet season grazing are the principal contributions from cropping enterprises to the livestock sector in the Subhumid Zone.

Given the subsistence goals and high labour requirements for cropping, innovations to improve fodder must not jeopardize grain yields and should bring a high return to labour. The first year survey indicated other constraints, such as unimproved cultivars, low plant populations, wide prevalence of *Striga*, and inappropriate use and uncertain availability of chemical fertilizers, to be responsible for low crop yields. Trials were set up to evaluate the effect of recommended crop management practices obtained from IAR, ICRISAT and IITA (cultivars, planting dates, plant populations, and fertilizer rates) on the predominant sole and intercrop grain and dry matter (DM) yield under farmer conditions.

Crop Residues: A Resource Assessment and Determination of their Relative Importance in Cattle Diet

Investigations have been carried out to assess the quantity and quality of crop residues, and availability to cattle during the dry season. At

grain harvest, highly significant correlations were found between sorghum, millet and maize grain, and respective leaf and stalk DM yields, and between soyabean and groundnut grain and respective total DM yields. Therefore, during years of normal rainfall distribution, grain yields of the predominant crops grown in Abet could be used to predict the quantity and relative quality of crop residue DM. Given the upward translocation of nutrients during the later stages of cereal growth, leaf and stalk components were further divided into upper and lower plant parts, and the quantity of sorghum and millet panicles remaining after harvest was also estimated.

The grazing behaviour of cattle on crop residues was recorded by following three herds during the 1982-83 dry season to determine the relative contribution of all residues and the components of sorghum and millet residues to the dry season diet. Cattle spent approximately 40% of their dry season grazing time on crop residues, representing 20% of the total annual grazing time. From the end of November to the end of January, or the first 7 weeks of crop residue grazing, only sorghum and millet fields were grazed. Soyabean threshing areas became important in January and February, and rice stubble, regrowth and threshing by-products were grazed considerably from February to April, accounting for the highest percentage of time spent on crop residues.

Although maize was determined to be an important crop in Abet, its stover had the lowest preference by cattle. Since maize is harvested in mid-September, and is almost exclusively intercropped, stover is unavailable for grazing until other crops are harvested. After two months of weathering, the stover is deteriorated and of very low feeding value.

In sorghum and millet fields, panicles and upper leaves were the most preferred fractions of the stover. As these disappeared from feed on offer, more lower leaves and weeds were selected. Noticeable termite (*Macrotermes subhyalinus* Rambur) activity on remaining sorghum and millet stover was observed from the eighth week onwards. During the latter 6 weeks of the dry season, selection of upper stalk material increased considerably. The feeding value of panicles, upper and lower leaves, and stalks is currently being analyzed to

obtain a more complete understanding of the relative contribution each fraction makes to the dry season diet.

Improving the Feeding Value and Availability of Crop Residues

Methods for increasing the quantity, quality, and availability of crop residues under investigation include: introducing forage and dual purpose grain legumes into cereal cropping, comparing the performance of improved and local cereal and grain legume varieties in sole and intercropping conditions at various levels of management, and evaluating the potential of harvesting and storing crop residues for later dry season feeding. Selected trials are conducted both on-station (researcher-managed and executed) and in farmers' fields (researcher/farmer-managed and farmer-executed) to assess the variability of results obtained from experimental and farmer conditions, and to gain farmers' feedback and a better understanding of cropping practices.

Introducing stylo (*Stylosanthes guyanensis* cv Cook and *S. hamata* cv Verano) into sorghum and millet sole crops, using various under-sowing and inter-row sowing techniques, and transplanting the cereal directly into established stylo has been tested (Saleem 1981). Under-sowing stylo 3 weeks after sorghum did not adversely affect grain yields of the local sorghum variety and resulted in a net increase of 100 kg of crude protein/ha (Saleem 1983). Using recommended cultivars of sorghum (IAR), maize, and soyabeans (IITA), various plant populations and fertilizer levels, on-station and on-farm trials were conducted to compare recommended crop management with traditional management. N, P, and K response curves were established for the cereals and P response for soyabeans as sole and intercrop. Improved varieties of maize and soyabeans, at recommended fertilizer levels and plant populations, gave substantial increases over traditionally managed varieties. The on-farm trials provided more data on the management and labour requirements of cereals, allowing for a more effective design of experimentation on introducing legumes into the cropping system.

The labour requirement for harvesting sorghum in the traditional manner (knocking entire stalk to ground before removing grain heads) versus cutting the uppermost metre of stalk with leaves, gathering, and then removing grain heads was recorded, and showed no additional labour input for the latter method. The upper stalk and leaf fractions of sorghum and millet stover and groundnut hay were stored in fan-palm (*Borassus aethiopicum* Mart) and locust-bean (*Parkia clappertoniana*) trees (common in farmers' fields) and on the ground. Monthly measurements on the stored residue showed that termites heavily attacked bundles on the ground, while those in trees remained untouched. The role of children in harvesting is currently being assessed, and alternatives or compensations identified, to see if harvesting the upper, most nutritious fraction of the residue is likely to be implemented by the Fulani and/or farmers.

Fallow Land Improvement

Bush and grass fallowing is commonly practised in the Subhumid and Humid Zones of West Africa as a means of restoring soil fertility and controlling the incidence of pests. Fallow lands are grazed by cattle, sheep, and goats and provide an important fodder resource, especially in tsetse free areas. In Abet, it has been estimated that one-third of the total land area is in fallow (Milligan *et al.* 1979). However, with the availability of chemical fertilizer and a declining labour force on account of urban drift and schooling, the number of fallow lands coming back into cropping is decreasing (Powell 1981).

Fulani perceive fallow lands as prime grazing areas, a reason why they choose to settle in cropping areas. Some farmers are known to encourage short-term Fulani settlement on their fallow lands to later take advantage of the deposited manure. ILCA, in conjunction with the Livestock Project Unit of the Federal Livestock Department, is conducting research on establishing and managing fallow lands sown to forage legumes. Fodder banks, of approximately 4 ha areas sown to stylo, are being set up and maintained by Fulani in the Kachia, Kurmin Biri, and Abet areas of Kaduna State. Pastoralists corral their herds, then sow stylo systematically

until the entire area is covered. Grasses are controlled by grazing during the early wet season. The area is then left ungrazed until January, or approximately 6 weeks after crop residue grazing has begun. Pregnant and lactating cows graze the fodder bank for approximately 2 hours/day to supplement their diet on natural pasture.

Since fodder banks are established on fallow lands that may be reverted to cropping, additional research is on-going to determine methods and related constraints of cultivating in stylo stands, and to compare the effectiveness of the fodder bank versus natural fallow in improving soil fertility.

Manure in Cropping

Goat manure plays a role in crop-livestock interactions. Farmers keep an average of 6 goats/household and the limited amount of manure is spread on fields close to the compound and used in fertilizing millet nurseries. However, the major input of manure in cropping comes from Fulani cattle. In 20 sorghum, millet, and maize fields, it was estimated that the return from cattle manure during the 20 weeks of crop residue grazing averaged 111.0 kg DM/ha. Over half of the manure was deposited during the first 3 weeks of grazing. Although there was a relationship between the amount of time animals spent in fields and manure droppings, no correlation was found between the quantity of stover DM on offer and the quantity of manure in the fields. During the dry season, manure was rapidly broken down by termites.

Yields recorded in eight farmers' fields, where Fulani corralled their herds, showed that manure gave a 25-115% increase in grain yields over adjacent not-corralled areas. Half of 22 surveyed farmers hired Fulani to corral on cropland. Payments were made in cash, grain, thatching grass and/or in return for Fulani settlement rights. For a herd of 50 cattle, the weekly price was approximately N6.50, although Fulani having larger herds generally charged less per head of cattle. Areas corralled for the farmers ranged from 0.04 to 0.16 ha, which were principally used for ginger cultivation, a cash crop. Fulani corralled all of their own cultivated areas, each field every two years.

The dry season corraling practice is for the farmer to break the ridges, then the Fulani corrals his animals in one spot for 5 nights before shifting to a contiguous plot. This systematic shifting is continued until the designated area is covered. When the rains establish in late May or early June, corraling management changes to only 2-3 nights in one spot to avoid soil compaction. By this time, the Fulani have generally moved to their own fields.

Soil compaction and increased weeds in areas manured during the early wet season were reported to be major problems in the system. Trials are being conducted in farmer and Fulani fields to determine the nitrogen contribution of manure to cropping and to assess the severity of weeds and soil compaction before designing future research.

Conclusion

In the ILCA case-study areas, the various existing crop-livestock interactions have been identified and have been, or are being, defined both quantitatively and qualitatively. To design innovations that will maintain or increase crop yields and fodder resources is a difficult issue. The major livestock resource, cattle, is owned by one group, the Fulani, while the crop sector largely lies in the hands of another group, the farmers, who also control the land. This is further complicated by the situation where cultivated areas are relatively small 1.5-3.5 ha, and available labour is in short supply. Although there is certainly a system of interactions between the two sectors, improving interactions through innovations that will mutually benefit and satisfy both groups remains the challenge.

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Communicating with Nigerian Farmers

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Communication with Nigerian farmers involves the same principles as those used with farmers in most developing countries. As in any extension system, the purpose of the communication is to transfer new knowledge to the farmers so that they can improve their agriculture and learn about farmers' problems so that they can be solved.

This paper briefly discusses institutions where extension staff are trained, the source of technical information that is passed to the farmers, the linkage between research and extension, as well as the farmers themselves. Mention will be made of the various techniques that have been employed in communicating with farmers in Nigeria and some of our major problems of communication. Finally the areas where more research work is needed are highlighted.

Extension Workers and Institutions

There are generally three categories of extension staff in Nigeria, viz. the administrators, supervisors, and the field staff.

The administrators are mainly found in the headquarters of the Ministries of Agriculture where they formulate policies and generally direct the day to day running of the extension services in each state. While the bulk of their time is spent at the headquarters, they occasionally tour the states to keep abreast of developments, give encouragement to field staff, and generally assess problems on the spot. They are generally people with considerable training and experience, who have passed through the ranks and are knowledgeable on the agricultural matters in the state.

The status of these officers are the Permanent Secretary, who in some cases may or may not be an agriculturist, with supporting professional staff of Chief Agricultural Officers and three or four Principal Agricultural Officers and Senior Agricultural Officers. These officers may have specialized training, depending on the various divisions that exist at the headquarters.

There may be divisions of Agriculture, Veterinary, Forestry, Co-operatives and Produce Inspection. However, in some states, more than two or three ministries may cover these fields. In recent years, extension work is carried out in some states of the Federation by as many as five ministries, i.e. Ministries of Agriculture, Animal and Forest Resources, Community Development, Co-operatives, and Local Government.

The supervisory staff are Agricultural Officers, Agricultural Superintendents, and Assistant Agricultural Superintendents. The Agricultural Officers have degrees such as a B.Sc. in Agriculture and related subjects, while the Agricultural Superintendents and Assistant Agricultural Superintendents have a higher diploma and diploma respectively, and have gained some experience in the field. They are located at Zonal and Divisional Headquarters and supervise staff at the Local Government areas. They may be in charge of two or more Local Government areas, depending on the size.

The field staff consist of the Agricultural Assistants and the Agricultural Instructors (or Field Overseers) who are in daily contact with farmers. The Agricultural Assistants (A.As.) have a diploma in agriculture while the latter, have had six years general education and one year agricultural training at a Farm Training Centre.

At the moment, 8-10 universities offer degrees in agriculture while many polytechnics and colleges of agriculture offer diploma and higher diploma courses in agriculture. In all, over fifty colleges and schools of agriculture offer courses in agriculture.

Because of proliferation of Ministries with a

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responsibility in extension and the generally poor condition of extension services in the country, the Federal Department of Agriculture commissioned a study in 1981 to evaluate extension and make recommendations for improvement. The study showed that the manpower needs of the country would be met up to 1990 with the existing institutions with an extension worker to farmer ratio of 1:500 compared with 1:2500 at the time of the study. Almost all the recommendations made by the committee were accepted, but the major one that called for the establishment of an Extension Board to co-ordinate extension work in the states, was not accepted. This has left a major co-ordinating problem in some states.

Sources of Technical Information — Research Institutes

As in every country in the world, research and research results are the main source of information that is communicated to the farmers, and field problems constitute the major ingredients for investigation by research centres.

Research in Nigeria commenced in 1893 when a Department of Botanical Gardens was established in Lagos. The Headquarters was transferred to Olokemeji in Oyo State in 1905. Later, in the same year, the British Cotton Growing Association established a station for the British Textiles Industry at Moor Plantation, Ibadan. This became the Headquarters of the Department of Agriculture in Southern Nigeria in 1910. By 1912, the Department of Agriculture, Northern Nigeria, was established at Samaru, Zaria.

In 1921, the Northern and Southern Departments of Agriculture were amalgamated, but Samaru and Moor Plantation continued to remain research centres. Later, another research centre was established at Umudike in the eastern part of the country. These three centres formed the media of the three regions that were later established.

During the British Administration, there were research institutions such as the West Africa Cocoa Research Institute (WACRI) with Head-

quarters in Ghana; West African Oil Palm Research Institute (WAIFOR) with Headquarters in Nigeria; West African Rice Research Institute (WARRI) with Headquarters in Sierra Leone etc. established as joint research centres which served the British West African territories. With independence, these institutions were nationalized and gave rise to research institutions such as the Cocoa Research Institute of Nigeria (CRIN), the Nigerian Oil Palm Research Institute (NIFOR) etc.

There are at the moment 22 research institutes under the Federal Ministry of Education, Science and Technology, 21 of which are involved in research work on all aspects of crops and livestock. This is in addition to universities that conduct basic as well as applied research.

Some of the research institutes such as the Institute for Agricultural Research at Samaru, and the Institute of Agricultural Research and Training at Moor Plantation, Ibadan have regional coverage while others such as the Cereal Research Institute of Nigeria and the National Animal Production Institute have national coverage.

Many of these research institutes have substations where they conduct research and make recommendations on a regional basis. Research results are made available through international journals, or journals produced by the research institutes, newsletters, and in some cases in popular publications that are produced specifically for farmers. Some of these research institutes organize special training for extension staff, especially where such requests are made by the state Ministries of Agriculture.

A few of the research institutes have training institutions attached to them and staff are trained by both research workers and teachers, who are specifically employed for the purpose.

Most research institutes now have 3-5 subject matter specialists who try to produce simple publications from the research work conducted by the institutes and make these available to the states.

The research institutes conduct field days specially to acquaint farmers with their work. Through the above channels, the institutes make the results of their work available to field extension staff, who in turn inform farmers about new techniques.

Linkage Between Research and Extension

The understanding of research reports and the critical examination of field problems and feedback to research, requires a trained mind. It is a job that cannot easily be carried out by average field extension staff working with farmers in rural areas.

Research results must be simplified and made practical without losing their value. Field problems need to be investigated with a searching mind and the application of existing knowledge, in order to determine whether a problem requires detailed research or only simple measures that a farmer can carry out, with or without supervision of an extension worker.

To carry out this task requires staff who have an understanding of research methodology and research problems, as well as an understanding of farmers and their problems. It is in the realization of this that one of the 22 research institutes has the major function of providing a linkage between research and extension.

The Agricultural Extension and Research Liaison Service (AERLS) transforms research results into various forms for use by extension workers and farmers. It also investigates field problems and where appropriate, conveys the problems to research institutes for investigation.

The institutes at present have a staff strength of about 46 subject-matter specialists. Research results find expression via the following channels:

Journal

Twice a year the Institute publishes a journal, which contains articles on various aspects of extension and is open to contributors from any institution in any part of the country. The journal is of recent introduction and finds audience among researchers and extension workers in Nigeria and overseas.

Newsletter

A newsletter is produced quarterly and distributed to extension staff in the states. It contains information from research and the field, deals with matters of general interest, and with issues about AERLS.

Guides on Production of Crops and Livestock

These publications describe how to carry out operations, e.g. how to grow a crop from land preparation to harvest, storage and marketing, or production of livestock, control of pests and diseases, marketing etc. They contain much information from research work conducted by research institutes. Where research results are not available, proven practices are provided as a guide to carrying out farming activities.

Recommended Practices

These are publications, which are similar to Guides, that are a grade higher because they contain more information on proven research and little on general guidelines.

Bulletin

They contain still more information on proven research and offer more detailed information than the Recommended Practices publications. Unlike the Guides and Recommended Practices, which are produced in pocket size and can be carried about by the extension staff, the Bulletins are meant to be more like reference material.

The organization has produced about 140 Guides, Bulletins, and Recommended Practices on various crops and livestock.

Posters

AERLS also produces posters designed to carry a single pictorial message with a caption in 11 vernacular languages. Limited tests carried out with farmers have shown that they can comprehend single practical ideas. Generally, new technology is also produced on posters and distributed to various states, according to the language and languages spoken in the area.

Leaflets

These contain simple pictorial messages usually in six to eight stages, specifically designed for farmers. They are also produced in 11 languages and are supposed to be distributed after discussion at a farmers' meeting.

Slides

Series of slides have been produced that show the important stages of crop production. They are produced in sets and distributed to the states for showing to farmers.

Training

Every year at a meeting between research workers and extension staff, proposals are submitted for the training of field staff. There are two general trainings, i.e. in March (preparatory to the rainy season activities) and another one in October (preparatory to the dry season activities). There are also specialized trainings on pests and diseases, engineering, livestock, economics, audio visuals, home economics etc. The states consider the topics, the locations, and the timing before they give formal approval. Once approved, AERLS staff travel to the states where the extension staff assemble and the training is provided. A total of 10-15 trainings are conducted in a year.

Regarding audio-visual training, staff are trained on how to prepare and use simple visuals (using locally available materials), the advantages and disadvantages of posters, leaflets, slides, films, video etc.

There are information units in the states that are responsible for distributing publications and showing slides and films in the villages. The staff who show the films and slides are also trained by AERLS staff on how to use the equipment effectively.

Video and Films

Facilities have now been established to produce video and films for use in the states.

Radio

AERLS has a daily radio program on the network of the Federal Radio Corporation of Nigeria, through which regular and timely advice is given to farmers. A special programmer, who is attached to the station, tours the states regularly to interview farmers. The interviews are relayed over the air. Farmers ask questions on all aspects of agriculture and the answers are broadcast. The program is so popular that farmers in the neighbouring West African countries such as Ghana, Niger, and Camerouns listen to the program.

Television

There is a twice weekly program that is designed to meet the needs of the relatively well-to-do farmers, who can afford television, as well as other farmers who watch it at the Viewing Centres established by Kaduna and Kano State Governments.

Newspaper Articles

Newspaper articles, especially in the vernacular Hausa language are regularly sent to farmers who are literate in both Roman and Arabic scripts. Farmers' questions are also answered through the papers.

Conferences and Seminars

Where problems are identified that require dialogue among professionals, AERLS organizes such conferences. Proceedings and recommendations are prepared and made available to all concerned, for necessary action.

Collaborative Activities — AERLS and the States

On the field side, these include:

Adaptive Research

AERLS is the National Centre for sorghum, millet and wheat in collaboration with the Institute for Agricultural Research (IAR). Adaptive research that is carried out in the states through the co-operation of state extension staff, takes the form of mini-kits and production kits organized on farmers' farms. The seed and other inputs are provided by AERLS and collected from IAR. The number of mini kits and production kits to be conducted are decided at a meeting between AERLS, the National Co-ordinator, IAR, and the State Coordinators.

Visits

AERLS carries out routine visits to the states to keep in touch with developments and where necessary, to offer any advice that may be needed.

In times of an emergency, the states call on AERLS staff to visit the area and advise on what steps to take to overcome the problem.

Agricultural Shows

Each year, the states invite AERLS staff to their agricultural shows as judges and observers. AERLS also has an exhibit stand that is displayed at agricultural shows.

Evaluation

Every year AERLS organizes evaluation trips to the states, particularly regarding the mini kits and the production kits plots. Farmers and the extension workers assemble on these plots. The demonstrators explain to other farmers what they have done and extension workers assist by answering farmers' questions. In this way, AERLS staff can evaluate interactions between farmers and extension workers and assess what farmers have learnt during the season. A report is then prepared and made available to all concerned.

Feed-back

A special proforma has been prepared that is distributed to the states at the end of each year. It gives information on the amount of inputs distributed to farmers such as fertilizers, seeds, equipment, insecticides, herbicides etc., nature of the season, production of crops and livestock, and problems encountered, etc. This information serves as feed-back information to research workers on what is happening in the field.

Similarly, when an AERLS staff member goes on tour, he writes a report that is sent to the research institutes for information.

Thus, through its activities, AERLS provides linkage between research and extension.

The Nigerian Farmer

It is estimated that there are over 7 million farming families in Nigeria who are mostly illiterate. Their holdings are fragmented, ranging from two to as many as seven or even more, and which total 0.5-10 ha. The larger-scale farmers have holdings of over 50 ha and a few farmers have up to 5000 ha.

The family size ranges between three and eight and the general cropping pattern is intercropping. Crop cultivation is seasonal with isolated areas of irrigated agriculture.

The Nigerian farmer is simple, but shrewd,

and contrary to some views he is by no means lazy. Together with his family, he does all the farm work, mends his fences, builds his house, feeds his animals and in some areas does dry season farming to supplement the family income.

The Nigerian farmer is alert to the profit motive, rarely argues with extension workers or constituted authority, and does not respond to technology that is strongly in conflict with his traditional norm; in the early stages of adoption he will generally mix new technology with the old. He is best convinced by practical demonstration and reacts sharply to market demand.

Communication with Farmers

In the traditional system, agricultural information is passed from father to son, a process which starts from a very early age and continues throughout life.

In villages, there are traditional farming titles for which people are respected. Many activities are tied to farming and special ceremonies are organized on special occasions. In local religions, there are various gods associated with farming and sacrifices are made to appease them as and when occasions demand.

Colonial Era

During the colonial era, many agricultural ideas were communicated to farmers through the chiefs, obas, and emirs and virtual threats and/or force were used. For example, when fertilizers were first introduced, farmers were given them free of charge and were later forced to pay for them. Because they did not appreciate their value on crops, they were using them against termites in their compounds.

Demonstration on Government Farms

In order to set examples for farmers, they were taken to Government farms and shown what good crops should look like. However, they were never shown all the important operations carried out before the final stages. The reaction of farmers was that the Government should pay the costs, but the farmers could not.

Demonstration on Farmers Farms

To further convince farmers to accept new ideas, small demonstrations were installed on farmers' farms. All the inputs were provided free of charge. Before any operation was carried out on the plot, Village Agricultural Committees comprising local leaders were consulted and the demonstrator was also selected by the Committee. The extension worker would carry out method demonstration to ensure that farmers understood what was going to be done. Where appropriate, slides were shown to introduce farmers to the practice.

However, what is demonstrated to the farmers is the practice that research has found to be the best for farmers.

The result was that farmers were convinced by the demonstration and put the ideas into practice but in a modified form, i.e. where sole cropping is recommended, they use inter-cropping with new inputs.

Adaptive Research Method

The adaptive research method is very similar to the demonstration method, but is organized by the researcher, the subject matter specialist, the extension worker, and the farmer. The technology is made available by the research worker before it reaches the final stage and all the people concerned put their heads together and help explain the demonstration to the farmer. On the basis of the alternatives available, and the results that have been shown, the farmer makes his choice. All the new phenomena are explained to the farmer.

In this way, the farmer forms part of the decision-making process; he adopts the new techniques after he is convinced of their value.

This method saves time and develops a cordial relationship between farmer, research worker, and extension agents. The only disadvantage is that only a very few such demonstrations can be carried out due to the limited number of research staff that can supervise them.

Information Sources

Limited studies carried out by Voh (1979), Bogunjoko (Table 1), Yazidu and Prawl (1974) in the Northern States showed that radio is by far the most effective source of information available to farmers.

The studies also showed the small use of extension agents as a source of information. Furthermore, the farmers socio-economic characteristics were not statistically related to the farmers use of extension agents as a source of farm information (Table 2).

The above findings agree with Williams and Williams (1971) in Western Nigeria and with those of Sharma (1966) in India.

The prominent role played by radio as a major source of information may be connected with the low number of extension workers available, i.e. 1:2500 compared with 1:500 in developed countries.

Problems Affecting Communication with Farmers

Institutional

The situation in which different research institutes conduct research on the same crop in the same area or ecological zone only leads to

Table 1. Percentage distribution of respondents according to use of sources of farm information.
Source: Bogunjoko.

Sources of Information	Whether Sources Used		
	No	Yes	Total
Agric. extension agents	96.5	3.5	100
Radio	17.5	82.5	100
Fellow farmers	95.0	5.0	100
Family or relatives	96.0	4.0	100
Farmers organizations	100.0	0.0	100
Demonstrations	100.0	0.0	100

Table 2. Relationship between selected socio-economic characteristics of farmers and use of extension officers as a source of information for improved farm practices
(Source: *Bogunjoko*).

Socio-Economic Characteristics		Use of extension officer as a source of information				Level of Significance
		No. of Farmers	Yes %	No %	Chi Square X^2	
Age	30 years or less	57	1.8	98.2	.737	NS
	31-50 years	92	4.3	95.7		
	Above 50 years	51	3.9	96.1		
Level of education	Attended school	170	3.5	96.5	.235	NS
	Did not attend school	30	3.3	96.7		
Number of years of farming	15 years or less	47	2.0	98.0	1.582	NS
	16-30 years	104	2.9	97.1		
	above 30 years	47	6.4	93.6		
Plots owned	3 acres or less	104	2.9	97.1	4.191	NS
	4-6 acres	80	2.5	97.5		
	Above 6 acres	116	12.5	87.5		
Net annual income from farming	250 Naira or less	76	1.3	98.7	8.307	NS
	251-500 Naira	53	7.5	92.5		
	501-750 Naira	26	0.0	100.0		
	751-1 000 Naira	26	10.0	90.0		
	Above 1 000 Naira	19	10.5	89.5		

NS = Not significant at 0.05 level; S = Significant at 0.05 level.

confusion and makes recommendation to farmers difficult. However, the recent decision of the Federal Ministry of Education, Science and Technology to establish Zonal Research Institutes through which other research institutes will channel their research in the area will eliminate this problem. Furthermore, the association of AERLS with each Zonal Research Institute will ensure that the much needed communication linkage between research and extension is strengthened.

Films

Virtually all films currently used on agriculture in Nigeria are foreign and have no relationship to Nigerian agriculture. The attempt that is being made by AERLS to produce local films will partly solve this problem.

Use of Other Languages on Posters

Many of the local languages have not been sufficiently refined to enable the audience to interpret the captions properly. This may lead to confusion and conveying the wrong message. It is therefore desirable to make further studies on these languages to improve the captions.

Equipment and Tools for Extension Workers

In many cases, extension workers do not have enough materials to prepare simple visuals in spite of the fact that they have been trained to prepare such items for teaching farmers. Extension staff therefore need to be well equipped to carry out their work effectively.

Touring Facilities

Extension workers in many states cannot tour as often as possible to advise farmers, which probably explains why they are not so effective. There is, therefore, a need to ensure that there are enough financial resources to enable them to assist farmers as often as necessary.

Areas Needing Further Research

There have been fewer studies on communication, and extension generally, than on agronomy of crops or pests and diseases.

The Farmer

There is need to carry out more studies on the

Nigerian farmer himself — who is he, what are his likes and dislikes, and what are the factors that motivate him into action?

Channels of Communication

There is need to investigate further the various channels of communication. Radio appears to be a very important channel at the moment, but due to better incomes and improved standards of living or education, other channels may assume greater importance. Therefore it is desirable to continue with further studies on these channels.

Leaflets and Posters

There is always a scramble for leaflets and posters when they are being distributed to farmers in the villages. More studies should be carried out to determine whether farmers fight for these materials mainly because they need them as educational materials, or because they like them primarily as wrapping materials.

Literacy

How important is literacy? Is it so important that special emphasis needs to be placed on improving the literacy level of farmers with a view to improving adoption rather than emphasizing visuals as a means of communicating new technology?

Traditional Leadership

Studies are needed to determine the significance of traditional leadership in communicating new technology for adoption.

Conclusion

To summarize, it is obvious from the discussions and the presentations made by representatives of the various research institutes that a lot of research has been carried out in Nigeria. From the above outline, I have also tried to show how the results of research have been and are being

communicated to the farmers and how the problems are fed back to research.

The results of these efforts are reflected in the increases in the yields of various crops grown by farmers compared with those who do not apply the new technology. This goes to show that Nigerian farmers are not as conservative as some people want us to believe.

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Research on a No-Till, Tropical Legume-Ley Farming Strategy*

R.K. Jones and R.L. McCown**

Summary

Legume-ley farming systems have been highly successful in benefiting both crop and animal production in temperate areas of southern Australia. This paper explores the prospects for developing comparable legume-ley farming systems for the semi-arid tropics (SAT) of northern Australia and elsewhere.

Although technology now exists for improving the productivity of grazing lands in Australia's SAT by oversowing with legumes and applying fertilizers, it is generally not profitable, and the land is used mainly for the extensive grazing of beef cattle. Dryland cropping appears to hold considerable promise, but the costs of the technology are high and the returns relatively low.

The paper reports on the evaluation of a farming strategy in which net benefits are enhanced by synergies gained by integrating beef production and cropping. This strategy is stated as a hypothetical system with the following features:

- Self-regenerating legume-ley pastures of 1-3 years duration are grown in rotation with maize or sorghum.
- Cattle graze native-grass pastures in the green season and leguminous pastures and crop residues in the dry season.
- Crops are planted directly into the pasture, which is chemically killed at, or shortly before, planting.

- The pasture legume sward, which volunteers from hard seed, is allowed to form an understorey in the main crop.

The research program uses a systems approach in evaluating the biological feasibility of the strategy for this climatic zone. Emphasis is placed on elucidating dependence on climatic and edaphic variables so that the results can be extrapolated to other regions. Important early findings include:

1. One year of legume-ley has generally provided a succeeding crop with the equivalent of at least 50 kg/ha of fertilizer N. Longer leys have had greater effects and a longer residual effect.
2. Mulch retention and no-tillage has generally resulted in increases to maize grain yield of over 20%.
3. Herbicide and planting technologies have been developed to a stage where on-farm evaluation can proceed.
4. Cattle have gained weight during the dry season when grazing legume leys and maize stover.

The prospects for developing related ley-farming systems for the SAT of eastern Africa are examined from the point of view of the availability of suitable legumes, the need to overcome soil fertility constraints, the relevance of the concept of no-till, and the availability of cheap herbicides to produce the mulch for the no-till system.

Introduction

In the temperate areas of southern Australia that experience a mediterranean climate, legume-ley farming systems have been the basis of successful wheat and sheep production for almost half a century. The pasture legumes, namely subterranean clover (*Trifolium subterranean*) and various medics (*Medicago*

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littoralis, *M. truncatula* and *M. sativa*), have been the key to this success, contributing nitrogen by biological fixation for use by succeeding cereal crops as well as improving the nutritional value of the herbage for livestock (Greenland 1971; White *et al.* 1978). In these systems, both the cropping and the livestock enterprises benefit enormously from the introduction of an adapted pasture legume. In recent years, direct drilling (no-tillage) of crops into pastures, which have been killed with herbicides, has also increased sharply.

This example of a very successful farming system in an environment with a highly-seasoned rainfall raises the question: 'Is it possible to develop a comparable no-till legume-ley farming system for the semi-arid or subhumid tropics that is both biologically and economically efficient and conservative of scarce resources – particularly soil and water?'

In this paper we describe some recent research aimed at evaluating a ley-farming system for Australia's semi-arid tropics (SAT) and discuss the possibility that some of the concepts might be transferable to comparable regions of Africa.

Some Problems of Agricultural Production in Australia's SAT

Australia has a vast area of land in the tropics (i.e. north of the Tropic of Capricorn) with a mean annual rainfall of between about 500 and 1200 mm. The main features of land use are:

1. The area is very sparsely settled.
2. The dominant enterprise is extensive grazing of beef cattle in large herds on large holdings and at low stocking rates.
3. The proportion of the land under crop or improved pastures is low, and the usage of fertilizers on pastures is extremely low.

A major constraint to cattle production in large areas of this region is the poor nutritive value of the grass pastures in the dry season. Research has given a technology for overcoming this constraint (viz. oversowing the native pasture with legumes and correcting the nutrient deficiencies of the soils), but to date it has not been economic to implement this technology on a large scale. The reasons for this can be found in the high costs of the inputs and

the low prices and fluctuating demand for beef on the export market.

Major constraints to crop production are the low soil fertility and the high risks of experiencing adverse climatic factors during the growth of the crop. The soils are always deficient in N and P and sometimes other nutrients such as K, S, Cu, Zn, and Mo (Jones *et al.* 1983; Rayment *et al.* 1983); correcting these constraints can be very costly, particularly for N. The climatic risks are numerous. The period between the earliest ploughing rains and the arrival of the monsoonal rains, when soil moisture conditions are suitable for planting, can be very short; in the past this has led to overcapitalization on tractors and machinery to prepare and plant large areas of land in the short time available (Fisher *et al.* 1978). Adverse soil temperature/soil moisture conditions often affect crop establishment; rapid drying of the bare soil surface results in excessively high soil temperatures and/or strong surface seals that seriously reduce emergence of seedlings (Arndt 1965; McCown *et al.* 1980).

The most serious risk associated with climate however, is undoubtedly that of soil erosion; high rainfall intensities on loose, exposed soil result in high losses of both soil and nutrients (Greenland and Lal 1977).

If agricultural productivity from this vast region is to be increased and the natural resources conserved, some new approaches will be required. One approach which appeared attractive to us was to develop no-till legume-ley farming systems suited to the climate and soils of the region that would closely integrate dryland grain cropping with the existing extensive cattle industry.

A Strategy For An Improved Farming System

Our research has been centred on a hypothetical farming system outlined in Table 1. The field experimentation is based at a research station at Katherine, Northern Territory (N.T.), in the wet semi-arid or monsoonal tropics (900 mm unimodal rainfall).

The hypothetical system combines the concepts of legume-ley farming and no-tillage with the existing system of grazed native pastures. The key feature (Table 1, No. 1) is the rotation of

Table 1. Features of the hypothetical farming system.

1. Self-regenerating legume-ley pastures of 1-3 years duration are grown in rotation with maize or sorghum.
2. Cattle graze native-grass pastures in the green season and leguminous pastures and crop residues in the dry season.
3. Crops are planted directly into the pasture that is chemically killed at, or shortly before, planting.
4. The legume sward, which volunteers from hard seed after the pasture is killed, is allowed to form an understorey ('live mulch') in the main crop.

a self-regenerating legume pasture and a maize or sorghum crop, with the legume supplying all or most of the N fertilizer requirement of the crop. A number of legumes accidentally or deliberately introduced to Australia during the last 75 years have proved to be well-adapted to the pasture environments of the SAT and capable of fixing substantial amounts of N. For example, Townsville stylo (*Stylosanthes humilis*) has been found to fix between 75 and 130 kg N/ha/year in studies conducted in the northern part of the N.T. during the 1950s and 60s (Vallis and Gardener in press, Table 1). Since then, other more-productive legumes (e.g. *S. hamata* cv Verano) have been found and hold promise of fixing more N than Townsville stylo. However, the success of a ley system depends very greatly on what proportion of the N fixed by the legume finds its way into the succeeding crop(s). Although little is known about the magnitudes of various N losses in these environments, especially under grazing, the amount of N fixed by a number of the legumes seems large enough to meet most of the crops requirement, even if losses are substantial.

The second feature (Table 1, No. 2) concerns the integration of cropping with the existing system in which cattle graze native pastures. In this region, the strategy of having cattle on native-grass pastures during the green season, when they are at their best, and on sown leguminous pastures in the dry season, is that of Norman (1968). Cattle grazing dry standing hay of the annual legume Townsville stylo, normally gained weight during the dry season (Norman 1968; Woods 1970). Although even modest amounts of rain on dry legume can cause

spoilage and a marked reduction in acceptance by cattle (Norman 1968; McCown *et al.* 1981), the low frequency of dry season rain at Katherine (R.L. McCown, unpublished data) makes the grazing of dry legume an attractive strategy for dry season nutrition of cattle. However, the test of this strategy in the late 1960s and early 1970s failed, because of the inability of Townsville stylo to compete satisfactorily with invading annual grasses and, ultimately, to its susceptibility to the fungal disease anthracnose. The availability of several 'new' legumes with superior competitive ability and resistance to anthracnose makes a new attempt at implementing this strategy feasible. (The growing of a nitrophilous crop every 1-3 years should further contribute towards maintaining legume dominance by regularly depleting soil N, and by providing an opportunity for economic use of a herbicide selective for grass weeds.)

The third feature of this hypothetical farming system (Table 1, No. 3) is that of the retention of surface mulch by use of no-tillage planting technology. Although experience in the tropics is as yet limited, there are indications that the potential benefit is greater here than at higher latitudes. In temperate regions, reduced or zero-tillage is widely practised where soil and water conservation are important (e.g. in parts of North America). In other temperate areas the amounts of plant residues from previous crops or pastures may be excessive and can often exacerbate problems of low soil temperature or excessive wetness at planting (Baeumer and Bakermans 1973; Cannell 1981). In the tropics, by contrast, the need for improved soil conservation in cropping is universal and the benefits of mulch retention on this are very great (Lal 1975; Hayward *et al.* 1981; Obi 1982). Moreover, the effect of mulch in retarding evaporation losses and the consequent rise in soil temperature is beneficial to young crops in the tropics generally (Lal 1983; Hayward *et al.* 1981), because the potential evaporation is generally very high and rainfall very unreliable during this crucial establishment phase. Thus, surface mulch affects the soil moisture and temperature environment of the young crop similarly in temperate and tropical zones, but in the former the effect is often detrimental and in the latter, almost always beneficial.

The fourth major feature of our hypothetical system concerns a type of intercropping (Table 1, No. 4). The herbaceous pasture legumes, which are well adapted to this climate, invariably produce a proportion of seed that is still 'hard' when the re-established pasture is killed with herbicide and a crop planted early in the next rainy season. With subsequent rain, however, newly germinable seed from the 'hard-seed' pool produces a new stand of legume that is unaffected by the herbicide. Although this can be prevented by use of a pre-emergent herbicide, this legume intercrop (*live mulch*) offers several potential benefits: it does not cost anything to establish; it provides a longer-lasting protective cover for the soil than the dead mulch; it provides high-protein forage to complement the low-protein stover available for grazing in the following dry season; and it provides an additional source of seed for pasture re-establishment in the following season.

The main potential detriment is that the understorey of pasture legume may depress the yield of the grain crop. In this particular version of intercropping, this would be a very undesirable outcome because the grain crop has a much higher monetary value than the forage intercrop, and only small reductions in grain yield can be

tolerated (Willey 1979). The degree to which competition for water or nutrients during the growing season jeopardized the success of this forage intercropping strategy in the SAT is unknown. However, recent results from the humid tropics of West Africa have shown that yields of crops sown into legume swards killed only on the row zones can compare favourably with those of crops grown without this live mulch (Akobundu 1982).

An attempt is made in Figure 1 to depict the inter-relationships of the important components of this hypothetical farming system as a flow diagram. Recognition of a number of internal cycles aids our understanding of the system. On the left, cattle from native pasture enter a ley-pasture cycle during the dry season where they graze crop residues and dry legume herbage. At the end of the dry season, cattle return to native pastures. If the pasture area is cropped in the wet season, the pasture phase contributes mulch and soil nitrogen, as well as legume seed for the volunteer legume understorey. The latter is depicted (centre) as part of a life cycle that produces seed either for re-establishment of the pasture, or for mulch and legume understorey in a successive crop. From the crop phase emerge the edible residues, and the cycle is completed.

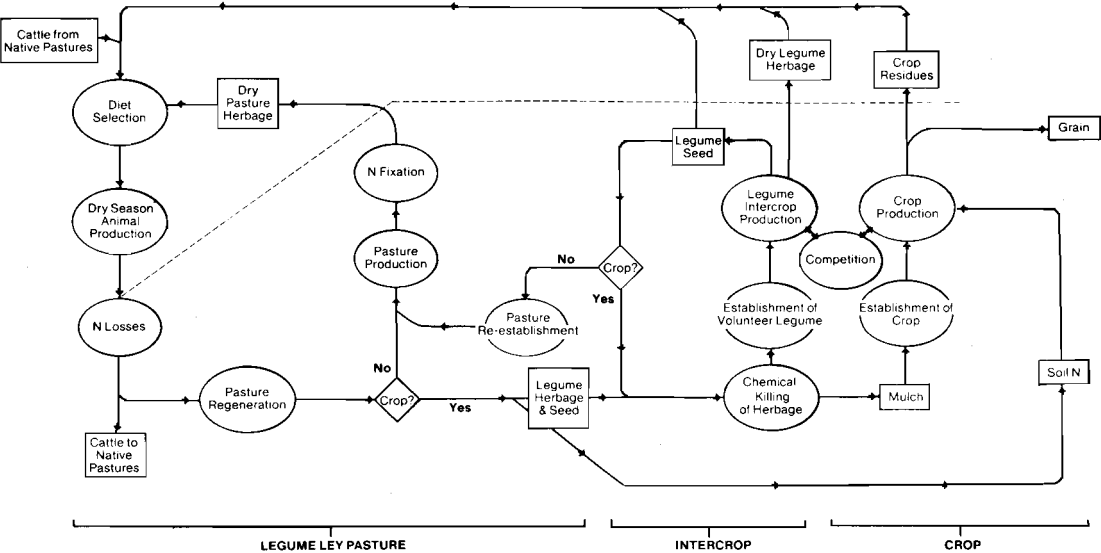


Figure 1. The hypothetical farming system being evaluated at Katherine showing flow of inputs and outputs among sub-systems (boxes) and important processes being researched (ovals).

Research Goals and Approach

How have we gone about testing this hypothetical legume-ley farming system? In the initial phase of the project (1978 to present), we have concentrated our research resources on evaluating the potential farming system at one location in northern Australia, i.e. Katherine, N.T. The Katherine region has soils and climate that are broadly similar to the SAT of northern Australia and sub-Saharan Africa, and the research station there has good facilities for pasture, crop, and animal research. If we can demonstrate that the system shows promise here, we will be able to proceed with the evaluation in other environments with greater confidence. Our ultimate goal, of course, is to evaluate the no-till legume-ley farming strategy for the SAT in general. The extent to which we can achieve this will depend on the degree of understanding of the processes within the system that we can obtain from studies at one or a few sites, and on the extent of the interaction of these processes with climatic and soil factors.

The research resources required to understand all the important processes, at the level of detail that they are often studied, are enormous. Our problem was to identify a procedure for studying this complex subject in such a way that achieves our goals, but with a small team, a modest budget, and within a 10 year period. We have found two concepts especially helpful in allocating our limited resources to this large task.

The first concerns the identification of sub-systems which, in the words of Spedding (1975), 'possess an integrity of their own, such that when studied in relative isolation the resulting increased knowledge about them can be fitted back into the whole system, from which they were derived, and contribute to our knowledge of the latter'. We have identified four major sub-systems: (1) the effect of legume-ley/crop rotation on crop production, (2) the effect of no-tillage technology on crop production, (3) the effect of competition from the pasture-legume intercrop on crop production, and (4) the effect of cattle/ley-pasture rotations on both animal and crop production. These sub-systems are manageable research areas and can

be staged over time, are discrete areas for special funding, and can be studied at multiple sites if this is appropriate.

The second concept of 'hierarchy' enables the ordering of questions to be answered and hence of research priorities in each sub-system. Figure 2 shows the hierarchy of questions requiring answers in the legume-ley/crop rotation sub-system. Initial experiments were designed to answer questions at level 1, and where expedient to do so, at lower levels as well.

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1. How much of the N requirement of a coarse grain crop can be supplied by a tropical legume-ley in rotation?
 2. How much do legumes differ in their ability to contribute N to succeeding crops?
 3. What proportion of the N fixed by a legume is available to succeeding crops?
 4. How much of the legume N is lost via volatilization of ammonia?
 5. What is the rate of mineralization of N from dead leaves, stems, and roots of legumes?
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Figure 2

Hierarchy of research questions pertaining to the legume-ley/crop rotation sub-system.

In our view, there is no doubt about the convenience afforded by the study of major sub-systems separately. Nevertheless, there are benefits to be gained by a study of the whole system as an entity. It provides a check on the assumptions used in isolating sub-systems, and also serves as a superior form of demonstration to those best situated to further evaluate this farming strategy at more tactical levels, e.g. workers on field stations of state agricultural departments, pilot farms, etc. We have commenced one long-term study of the system as a whole.

One might ask whether we are doing what is normally described as 'Farming Systems Research'. It seems to us that the application of general systems theory to agricultural systems has taken two distinct paths. The first (the 'systems approach') is characterized by the use of methods of systems analysis and simulation; research is generally aimed at developing mathematical models of the biological or bio-economic functioning of production systems

(see Spedding 1975). The second path has developed in response to the urgent need to improve the farming systems of small-holders in developing countries. In this case, the existing farming systems are analysed conceptually to identify needs for research, most of which is then conducted on farms, with farmers. This methodology has come to be referred to as FSR (Farming Systems Research) (Shaner *et al.* 1982; Dillon and Virmani 1983). In research-for-development, where there is a need for substantial changes in technology (e.g. the System Replacement case of Dillon and Virmani), the methods of these two branches of systems research can be combined. While FSR identifies the need for the research, it is best conducted initially on research stations where there are advantages in research facilities, logistics, and control. Our research approach is an attempt to adopt appropriate concepts of the 'systems approach' to enhance the efficiency of research conducted in an FSR framework.

Research Progress

Sub-system 1 — The Effect of Legume-Ley/Crop Rotation on Crop Production

In studying this sub-system, the high-order objectives are to quantify the N contribution to the following grain crops by leys of various legumes grown for between 1 and 4 years (Figure 2). Substantial losses of N under grazing are expected, and elucidation of the relative importance of losses from litter, urine, and dung are objectives of a lower order and priority. It is to be expected that soil type will strongly influence N transfer processes, so studies of this sub-system are being conducted on contrasting Alfisols— a heavy-textured red earth and a sandy red earth.

A very direct experimental approach is used to estimate the N contribution by legumes, whereby a crop of maize or sorghum is used in a bio-assay. Rates of fertilizer N are superimposed on the crop so that its responses to N, additional to that supplied by the preceding legume or grass (control) swards, can be measured and compared. Supporting measurements include soil N prior to cropping, and yield and chemical composition of both the ley and the crop.

Salient results from six experiments, most of which are still in progress, include:

1. On the loamy soil, maize grain yield with no N fertilizer, following one-year leys of various pasture legumes, was equivalent to that on plots receiving at least 50 kg N/ha following one year of grass. (Figure 3 shows data from one experiment.) Legume leys of longer duration had greater effects in the first crop and a greater residual effect on the second crop.
2. For a given level of dry matter production by a short ley of caribbean stylo (*S. hamata* cv Verano), the apparent N contribution to the following crop is much less on the sandy soil than on the loamy one.
3. Legume species do not differ greatly in N contribution after one-year leys, but large differences occur following four-year leys.

A study of N loss from urine has also been conducted on the loamy soil. Of the 15N applied in urine in the mid-dry season, 60% was found in the soil 5 weeks later. Since no rain fell and 94% of 15N in urine applied 15 cm beneath the soil surface was recovered, it seems likely that the 40% loss was as ammonia (I. Vallis and R. K. Jones, unpublished data).

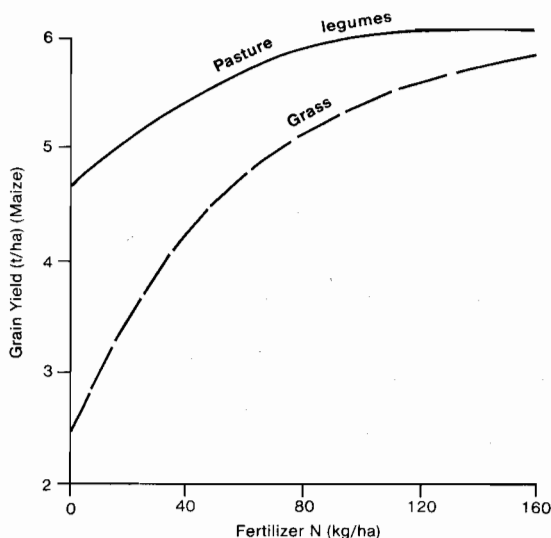


Figure 3

Maize grain yield responses to N fertilizer in the first crop following one year of legume or grass leys on a loamy red earth soil.

Sub-system 2 — The Effect of No-tillage Technology on Crop Production

The priority objective here was to quantify the advantages/disadvantages of no-till planting of crops in relation to conventional tillage. The compelling reason for inclusion of this practice is that, wherever comparisons have been made, the inherent benefit of no-tillage in conserving soil has been demonstrated. However, the shorter-term effects of this new technology on crop yields in the SAT are not well understood.

Our first experiment was designed to test whether high soil temperatures could explain very poor maize growth on the sandy red earth. In the absence of mulch, there was high mortality of seedlings at emergence, and survivors showed thermal injury lesions and slow growth.

The results from a subsequent experiment demonstrate how important mulch is on this soil. In order to have control over water, irrigation was used and the experiment was conducted in November, just before the onset of storm rains. A single layer of hessian was used as a convenient form of experimental mulch. By the time seedlings were emerging, daily maximum soil temperatures at 1 cm were above 55°C (Figure 4). Under this rather thin layer of mulch, temperatures were reduced by only about 4°C, but this had dramatic effects on

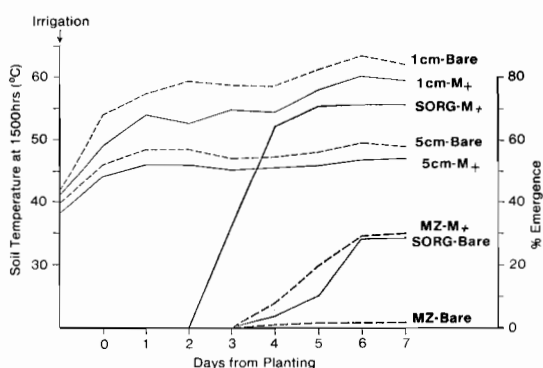


Figure 4

The effect of mulch on (a) soil temperatures at 1 and 5 cm below the soil surface, and on (b) seedling emergence of maize (MZ) and sorghum, when planted at a depth of 5 cm on a sandy red earth soil.

establishment of both maize and sorghum (Figure 4). Although conditions in this study were extreme, our overall experience is that it is not possible to establish satisfactory stands of maize on this sandy soil without a substantial mulch. In other studies on this soil, no-till and mulch retention has resulted in an average increase in maize yields of 35% in two crops, but no increase in sorghum yields in four crops.

On the loamy red earth, injurious soil temperatures are less frequent than on the sandy red earth, but they are still too high, without mulch, for optimum seedling growth. However, this soil does have an additional problem, viz. on drying, it tends to form strong surface seals that impede seedling emergence (Arndt 1965). Mulch reduces this problem by slowing the drying of the soil. In four crops, mulch retention resulted in an average yield advantage of 18% in maize, but had no effect on sorghum.

Having confirmed that mulch retention and no-tillage often had beneficial effects on establishment and yields, we have turned our attention to answering questions such as— what constitutes a minimum effective mulch, how do we get an effective mulch economically and how do we plant into such a mulch efficiently?

Work to date has been on the loamy soil only and we can make the following observations:

1. As little as 700 kg/ha of dead standing Caribbean stylo reduces soil temperatures substantially (Figure 5).
2. Analysis of the radiation balance has shown that mulch retards the rise in soil temperature (Figure 5) and soil strength by retarding drying. This is due primarily to the interception of radiation by mulch.
3. Pasture mulch is quite efficient in radiation interception; 1900 kg/ha of dead standing Caribbean stylo intercepted 80% and 700 kg/ha intercepted 55%, of direct beam radiation.
4. Tropical grasses and weeds, in general, are killed by dosages of the herbicide glyphosate similar to those used in temperate regions (1.5 to 2.0 l/ha).
5. The most successful planter, in terms of seedling emergence over a wide range of conditions, has been a narrow tyne preceded by a rolling coulter to cut surface mulch and followed by a narrow in-furrow press-wheel.

Research has recently commenced on planting on the sandy soil where there appear to be fewer technical problems than on the loam.

Considering the overall results of the various studies in this subsystem, our tentative conclusion is that no-tillage technology for this farming system is feasible in all major aspects, and that further progress will most likely be made in 'on-farm' research and development, which is about to commence.

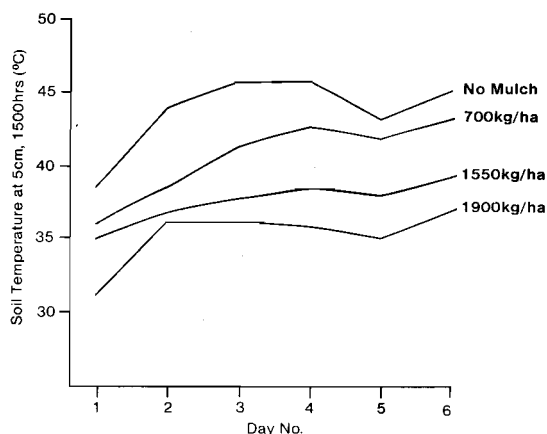


Figure 5

The effect of various amounts of mulch (dead Stylo) on soil temperatures over a 6 day period.

Sub-system 3 — The Effects of Competition from Pasture-Legume Intercrop on Crop Production

The objectives of this research are to:-

1. Assess the effect of a pasture-legume intercrop on the yield of the main crop of maize or sorghum.
2. Elucidate the nature of the interaction between the legume intercrop and the main crop.
3. Evaluate various legumes that are successful in pastures for their suitability as intercrops.
4. Learn how to control grass weeds in this intercropping system.

Two studies have been conducted to assess the effect of Caribbean stylo, *Alysicarpus vaginalis*, and *Centrosema pascuorum* intercrops on maize yield. In one, intercropped maize yielded 15% more than sole maize, but in the other it yielded 30% less. To date, we have

only collected data on yield, chemical composition, and weather, and it is clear that these are inadequate to explain the results. More recent work is studying the competition between the crop and the intercrop for the two resources most likely to be deficient in this system, i.e. water and nitrogen. The necessary control of water is provided by an automatic rain shelter and ^{15}N -labelled fertilizer is providing a means of distinguishing fixed N from soil and fertilizer N.

Comparison of the suitability of these three legumes indicate that:

1. The large-seeded *C. pascuorum* establishes much less readily than the other species.
2. All three are capable of producing about the same amount of herbage (1.5-2.5 t/ha) prior to maize maturity, but the later flowering *C. pascuorum* can produce more than the others after this time.
3. Caribbean stylo produces very little seed as an intercrop due to its failure to flower in the shade of a full maize canopy (50 000 plants/ha, 75 cm rows).
4. In contrast, *A. vaginalis* produces 2000-4000 seeds/m², an amount sufficient to establish a dense pasture the following season.

Research on the control of grass weeds in the legume plus gramineous crop mixture has yet to commence, but a number of promising herbicides have been identified.

Sub-system 4 — The Effect of Cattle/ley-pasture Rotations on Animal and Crop Production

Study of this sub-system is conducted within our 'whole-system' experiment. The objectives of this are to:

1. Quantify the N contribution to a succeeding crop by various legumes under realistic dry-season grazing management.
2. Compare liveweight performance in the legume-ley system with that on continuously-grazed native pastures on improved pastures.
3. Document the ecological stability of pastures of Caribbean stylo, *A. vaginalis* and *C. pascuorum*, particularly in relation to re-establishment and ability to resist invasion by annual grasses.

4. Document the trends in weed abundance in both crop and pasture and to identify possible weed-management strategies.
5. Quantify costs of production and yields of maize under more realistic operational conditions (with respect to planting and harvesting) than are possible in small-scale experimentation.

The cropland component of this study consists of three paddocks in which the legume-ley is Caribbean stylo, *A. vaginalis* or *C. pascuorum*. Within each paddock, there are three areas of equal size. This allows a 1 year maize:2 year legume-ley rotation, with a maize crop in every year. Adjacent is a large area of unimproved native pasture under Eucalypt woodland, as well as an on-going experiment on improved pasture (cleared, large amounts of superphosphate over 10 years, sown legumes, and sown grasses).

The native pasture area is stocked during the green season at an appropriate density (0.2 beasts/ha) with equal numbers of weaners and yearling steers. After crop harvest, three groups of four cattle (2 weaners + 2 yearlings) are moved into the cropland paddocks; an equal number remain on the native pasture. At the end of the dry season, yearlings are turned off and weaners return to native pasture; the latter return in the following year to their respective legume paddocks for finishing.

Maize is planted by no-till after spraying the regenerating pasture with glyphosate. In half of the crop area, the legume understorey is allowed to develop; in the other half this is prevented by the application of a pre-emergent herbicide. A range of N rates is superimposed on parts of the maize crop to assess response to N above that contributed by the 2 year leys.

Botanical composition of ley pastures is measured annually near the end of the green season. Pasture on offer, and the proportions and chemical composition of leaf, stem, and seed are measured periodically through the dry season in conjunction with diet sampling with oesophageal-fistulated cattle.

This experiment was only planted in January 1982, so time trends in pasture production and ecology, as influenced by crop/pasture rotation, are not yet available. Animal production, however, is not as dependent on crop-ley sequences, and results from the first dry season

should be as informative as those to come. The liveweight gain on legume ley/stover, averaged over legume species, was nearly 80 kg per head greater than on native pasture for the 4 month period mid-July to mid-November. In the cropland, during the first 7 weeks, 10-20% of time spent grazing was in the stover and, after that, virtually all grazing was on legume. There was virtually no effect of legume species on liveweight performance.

Caribbean stylo and *A. vaginalis* re-established in the second year at very high densities. The density of *C. pascuorum*, however, was disappointingly low, in spite of abundant seed. This adds to other evidence that re-establishment without disturbance may be a serious deficiency of this large-seeded annual, which is so promising as a ley plant in other respects.

An Assessment of Progress to Date and Future Research Priorities

The results to date are, we feel, encouraging in that the legumes, when adequately fertilized, appear to be contributing substantial amounts of N to following crops; regenerating legumes and weeds can be killed to produce a satisfactory mulch for soil and crop protection; and excellent animal production is achievable during the dry season on pasture and crop residues.

Our results, however, indicate a need for accelerated research effort in three areas. Firstly, a much better understanding of differences in the performance of the crop/legume rotation sub-system on the soils of contrasting texture is needed. This will require elucidation of the nitrogen and water balances to enable generalization to other conditions.

Secondly, elucidation of the quantitative dependence of N fixed by the various legumes on P supply is a necessary basis for optimizing P fertilizer inputs. This N-P relationship is especially important for a realistic evaluation of the potential of a legume-ley strategy for agriculture in regions where P fertilizer costs are high.

Thirdly, quantification of the hydrological implications of this farming system is urgently needed. Local pilot farms, presently practising conventional tillage and continuous cropping, are relying on conventional earth structures to control surface water. This approach is proving

to be too costly and less than fully effective. To what extent can a no-till system reduce the need for such structures? To provide answers that are not location-specific, the research must relate readily-measured properties of soil, mulch, and vegetation to hydrological processes, particularly the partitioning of rainfall into infiltration and runoff.

Possible Implications for Nigeria

In designing the farming strategy that we are now evaluating, we have used the model of the wheat-sheep system of the Australian mediterranean climatic zone. In concluding their review of the management of the soils of the West African savannah, Jones and Wild (1975) pointed to the Australian wheat-sheep system as one with relevance and promise as a model for agriculture in the West African savannah. They emphasized the prospect of the dual benefits of forage legume-improved fallows of soil fertility restoration and improved animal production. On the other hand Ruthenberg (1980) concluded that the probability of successful implementation of sown-ley systems in the savannah is low. 'A ley system must show itself to be better than a tumbledown grassland or other fallow system in (1) having a better fertility-restoring capacity, (2) supporting more livestock production, and (3) allowing a more efficient use of the farm labour, and the combined effect must be higher by a substantial margin than the costs of establishing a full ley-farming system. These conditions rarely exist' (Ruthenberg 1980, p. 123).

While we accept Ruthenberg's criteria for success of such a system, new pasture legumes that have been domesticated only in the last decade or so, provide a much better prospect of satisfying criteria (1) and (2) than those on which he based his judgement. Combination with no-tillage technology promises to contribute to the satisfying of (3).

This degree to which the Katherine results contribute to progress in developing the concept of a legume-ley in the West African savannah depends partly on the similarity of climates and soils between the two regions. Figure 6 shows the zonal similarities between Australia and the northern part of Africa when the problem of

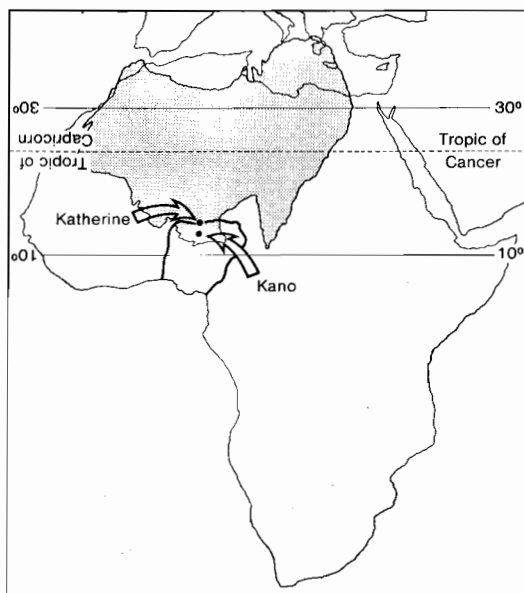


Figure 6

A map of Australia superimposed on Africa with coincidence of latitudes.

being in opposite hemispheres is eliminated.

Australia's mediterranean-like climates coincide with the true-mediterranean zone, Australia's great central desert with the Sahara, and the savannah zone of Australia's Northern Territory with the savannah of northern Nigeria. The climates of Katherine and Kano are very similar in terms of total rainfall, rainfall distribution, and monthly maximum and minimum temperatures (Fig. 7a). In the respective sub-humid zones, comparable similarities in rainfall exist (Fig. 7b).

It is now clear that the Ferruginous and Ferrallitic soils in the West African savannah closely correspond to the Yellow Earths and Red Earths so prevalent in tropical Australia. It is only in the last decade that a systematic study has been made of these soils in Australia to provide physical and chemical data for comparison with published data from West Africa. Pedological similarities were confirmed recently by Prof. Roger Fauck of ORSTOM during a tour with pedologists in northern Australia. Here, however, contrary to the more or less zonal distribution in West Africa, with Ferruginous soils dominating in the savannah (Jones and Wild 1975), Red Earths (Ferrallitic), Yellow-Earths (Ferruginous), and Grey Earths (hydro-

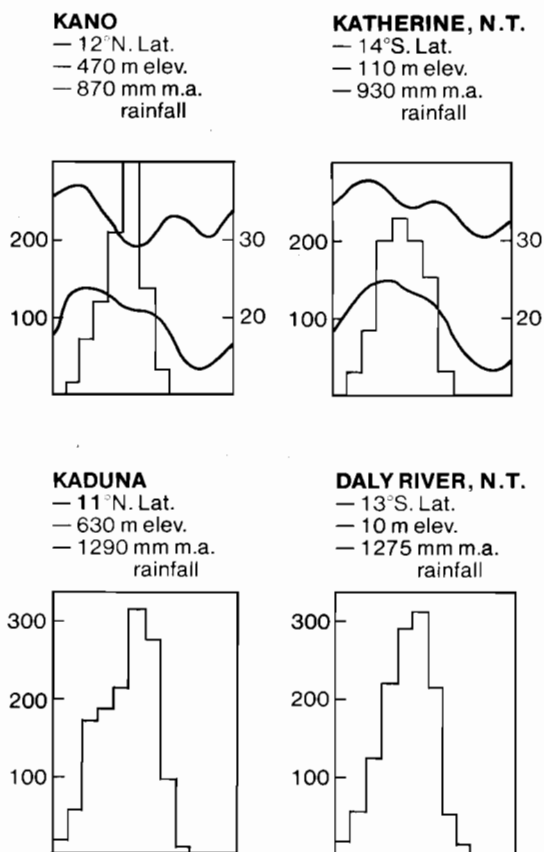


Figure 7

Physical geographic comparisons of (a) Kano, Nigeria and Katherine, Australia and (b) Kaduna, Nigeria and Daly River, Australia.

morphic) tend to be found side by side, often in toposequences (Isbell and Smith 1976).

With such close similarities in physical environment it is to be expected that similarities in biological performance also exist. Forage legumes that have excelled in northern Australia have also grown well in northern Nigeria (*Stylosanthes guyanensis*, Haggard 1971 and *et al.* 1971; Cook and Verano *et al.*, ILCA 1983). The lengthy and costly legume introduction and screening program conducted in northern Australia since 1965 would not need to be repeated in northern Nigeria to identify plants adequate to test the feasibility of a legume-leys strategy here.

There is clearly a common interest in no-tillage farming as indicated by recent papers

from northern Nigeria (Dunham and Aremu 1979; Ndahi 1982; Ogborn 1982). We, of course, have been strongly influenced by the results of research conducted in Nigeria, initially at IITA.

Evidence of the benefits of no-till on water and soil conservation on crop establishment and yields in the SAT is accumulating, along with evidence of the inadequacy of alternative systems of surface management of these sesquioxenic soils in this climatic zone. For example, ICRISAT has found that a graded bed and furrow system, successful on deep Vertisols, exacerbates the problem on the sesquioxenic soils (ICRISAT 1982). Although much research and development remains to be done and some serious obstacles overcome before no-till is feasible in the SAT, we believe this route offers the best prospect for checking the degradation of land now occurring.

Clearly, a major obstacle is the farmer's present inability to control weeds without cultivation. Success of no-till will depend on the availability of a herbicide that is effective, non-residual, safe, and inexpensive. 'Roundup' has been shown to be very effective (e.g. Ndahi 1982) and is very safe. Real costs of 'Roundup' have fallen progressively over the last 10 years, and the patent is due to expire soon. The pressing question is, how much further will the price drop? For obvious reasons, it is virtually impossible at present to find out the inherent cost of the product. However, we are not aware of any evidence that would prevent its manufacture in Africa, in the medium term, and its subsequent sale to progressive farmers at moderate prices.

We are optimistic that if research shows the benefits to be sufficiently great, a chemical at an acceptable price will eventuate (assuming that real costs of production are not inescapably high). This might require a major struggle in the North-South political arena, but the rewards of winning, in terms of the benefits for small farmers (and their successors), would be enormous. The onus is now on agricultural scientists to refine the technology and to demonstrate the benefits convincingly.

It would appear that the homologies of climate and soil and commonality of concern with bio-physical problems of agriculture in this environment could provide a basis for mutually

beneficial information transfer and collaboration between scientists in northern Nigeria and northern Australia.

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Potential for Research Collaboration

The Potential Role of ACIAR in West Africa

J.G. Ryan*

The Australian Centre for International Agricultural Research (ACIAR) appreciated the invitation to visit Nigeria to discuss agricultural research priorities and to identify how Australia might contribute towards solving some of the more important agricultural problems that Nigeria faces. We regard this Workshop as part of a continuing process of dialogue between agricultural scientists in our two countries that will lead to collaborative research activities, which ACIAR could help support.

Nigeria's northern region has many agro-climatic similarities with northern Australia. Both have semi-arid tropical (SAT) environments and similar soils. Livestock are important components of the farming systems in both regions and there is great diversity in these systems as one moves along the rainfall gradients. A common feature in both is the extreme climatic variability which makes farming, especially crop production, a risky venture. Agriculture is of course much more labor intensive in northern Nigeria in view of the higher density of population. Crops are a feature of Nigerian farming systems whereas they are rarely grown under rainfed conditions in northern Australia.

The agroclimatic similarities between the northern regions of our two countries provide the major rationale for collaboration in agricultural research. There is already a long history of research in the SAT regions of both countries that clearly illustrates this. By endeavouring to exploit possible complementarities, ACIAR hopes that the product of collaboration will be much greater than the sum of the current related, but independent, activities. Of course, before such joint research is designed it is important to recognize the socio-economic differences between the agricultural sectors of the two countries if the research is to lead eventually to viable technologies for farmers in

Nigeria. The strong socio-economics research groups in the Institute of Agricultural Research/Ahmadu Bello University, which have an international reputation, will need to be explicitly involved in helping to design the research strategies to ensure that they have a high probability of being adopted by farmers.

In this paper I would like to describe ACIAR and its programs. I will stress those with which I am personally involved, viz. the Farming Systems and Socio-economics Programs.

The Role of ACIAR

This Centre was established as a statutory authority by the Australian Parliament in June, 1982. Its purpose is to encourage and support research into the agricultural problems of developing countries in fields in which Australia has special competence. It does this by commissioning research by Australian institutions, in partnership with developing country research groups. The work is carried out both in Australia and in developing countries.

ACIAR's approach is problem-oriented: it is aimed at identifying problems and finding solutions. The Centre's objective is to improve agricultural production in the developing countries and the well-being of their people.

ACIAR's activities are one component of Australia's overall aid effort. The Centre's focus on problem-solving research complements the direct institution-strengthening efforts of the Australian Development Assistance Bureau (ADAB) and the Australian Universities International Development Program (AUIDP) in developing countries. The Centre's work also complements ADAB's agricultural and rural development programs and Australia's contributions to the international agricultural research centres, sponsored by the Consultative Group for International Agricultural Research (CGIAR), a donor consortium of which Australia is a member.

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Agricultural research collaboration with developing countries is seen by the Australian Government as a cost-effective form of foreign aid. Agricultural research in developing countries has a high payoff, both in terms of the return on the investments required, and in terms of equity. The 23 studies of agricultural research productivity in developing countries reviewed by Ruttan (1980) had an average rate of return on investment of 55%. The studies covered research on food crops, livestock, and commercial crops such as cotton and rubber. Over the period 1966-75 international research on rice in Asia showed a rate of return of between 74 and 102% per year (Evenson and Flores (1978) as cited by Ruttan (1980)). Rice research in the tropics over the same period had an annual rate of return in the range 46-71% (Flores, Evenson, and Hayami (1978) as quoted in Ruttan (1980)).

For the initial adoption period of 1966-67 to 1969-70, Evenson (1977) estimates that for every one dollar (US) invested in CIMMYT the extra wheat production generated was worth \$US303. In the later period (1970-71 to 1972-73) when the initial impact had eroded somewhat due to the spread of the high yielding varieties (HYVs) into more marginal environments, the additional production fell to \$US62 per dollar invested. Comparable figures for rice were a \$142 increase in production per dollar investment for first generation HYVs from IRRI, and \$108 for the second generation.

These high rates of return to agricultural research suggest that the levels of research investment in developing countries remain well below what they should be to exploit fully the opportunities for increased agricultural production and enhancement of economic development and human welfare. This is a major rationale for the existence of ACIAR.

ACIAR seeks suggestions from either Australian or developing country institutions that fit into a priorities framework, established by the Centre on the basis of consultation with the developing countries and an assessment of Australia's capacity to assist. This framework is outlined in more detail in the document *Partners in Agricultural Research* published by ACIAR in 1983.

In developing its research programs the Centre has formulated a number of priority areas within which a series of projects, preferably

inter-related, will be developed. The Centre entered into a broad and continuing process of consultation with the Australian and international scientific research and aid communities in developing this priority framework. In doing so, it had the advantage of authoritative advice from its international Policy Advisory Council of which the Chairman of this Workshop, Dr. Bukar Shaib, is a member. The framework provides the basis for an orderly and focused attack on a series of major problem areas by the Centre.

The 11 areas in which the Centre is developing its research programs are:

1. Soil and water management and land use.
2. Plant improvement.
3. Plant protection.
4. Plant nutrition.
5. Animal production.
6. Animal health.
7. Farming systems.
8. Socio-economics.
9. Forestry.
10. Postharvest technology.
11. Communications.

Suggestions may find their way to ACIAR by a variety of routes. They may be received directly from institutions responsible for research coordination and planning in developing countries, or from institutions in Australia; they may arise from discussions within the Centre or elsewhere; they may be deliberately generated in an ACIAR-sponsored workshop or study on research needs; or they may arise in connection with an existing project of ADAB. Wherever possible, ACIAR attempts to develop research projects that complement the research priorities of the collaborating research institutions, both in Australia and overseas.

ACIAR's Regional Priorities

ACIAR's main focus for its research activities will be Australia's near neighbours in SE Asia, especially the ASEAN countries, the South Pacific, and Papua New Guinea. The Centre's limited resources will restrict its activities outside this primary focus. But there are special circumstances that justify joint projects in Africa south of the Sahara, South Asia, and China. In the case of Africa, support is justified on the grounds that the continent faces the worst

threat to food self-sufficiency of any developing region, and also because Australia's research experience in its own semi-arid northern tropics has much to offer those countries in Eastern and West Africa with similar environmental conditions.

The United States Department of Agriculture (USDA 1980, p.i) in a recent study pointed out 'Sub-Saharan Africa is the only region in the world where per capita food production declined over the past two decades'. In 1978, the index of per capita food production in the 40 countries of Sub-Saharan Africa (SSA) was about 21% below the level in 1961-65. In Asia, the index rose 15% during the same period, while in Latin America it rose 13% (USDA 1980, p.2). Projected food import gaps for SSA in 1990 under various assumptions range from 9.5-21.1 million tonnes. In addition, estimates of unmet food needs in 1990 required to bring diets up to minimum calorie consumption levels of 2300 (cal/person per day) range from 9.1-13 million tonnes. Current food imports in SSA cost about 600% more than they did in 1970 and represent 220% of the 1970 volume (USDA 1980, p.6). The present and prospective food and nutrition problem in SSA is both a production and distribution problem. This is unlike parts of Asia and Latin America where the problem is primarily one of distribution. In SSA, 'Aggregate supplies are inadequate - even assuming totally equalitarian (sic) distribution' (USDA 1980, pp. 49-50). For the above reasons, it would seem that the major agricultural research and development efforts of the 80s should focus on the SSA region.

The above statistics clearly justify a significant role for ACIAR in Africa on grounds of need. An additional reason for an ACIAR role in Africa is the similarity they have to large areas of northern Australia, both in terms of agroclimatic characteristics and the extensive nature of the agriculture. It is in the SAT regions of Africa where it seems the major food security problems are going to emerge in the next twenty years. Hence, not only is there an urgent need for agricultural research in the SAT zones of Africa but there is a high probability that Australia's cumulative basic and strategic research experience in the SAT northern areas of Australia will be particularly relevant in similar regions of Africa.

The specific research themes that we feel might have most relevance for the SAT regions of northern Nigeria and elsewhere in the continent, and in which Australia has competence, are as follows:

1. The role of legumes (forage and grain) in cropping systems, including their effects on soil fertility and crop and livestock production.
2. Weed control and minimum tillage practices in cereal/legume cropping systems.
3. The implications of the above two concepts for closer integration of crop and livestock production.
4. Animal nutrition, health, and breeding.
5. Farming systems research, including the role of social scientists.

My colleagues at the Workshop will describe the relevant Australian research on the first four topics. In the ensuing sections I will dwell upon the activities ACIAR envisages in the Farming Systems and Socio-economics areas and highlight the particular strengths of Australia's social scientists.

The Farming Systems Approach to Research

World agricultural extension costs are about one-third of research costs. Almost one-half of the extension costs occur in developing countries. Hence, the ratio of research to extension costs is highest in developed countries. In the 1970s North America and Oceania spent \$4.50 on research for each dollar spent on extension as compared with \$0.60 for Africa and \$1.40 for Latin America. Boyce and Evenson (1975) have shown that there is an inverse relationship between expenditures on extension and per capita GNP, and a positive one between expenditures on research (agricultural) and per capita GNP. The suggestion is that extension may have been used as a substitute for research in the 50s, 60s, and 70s in developing countries. Returns to agricultural research in developing countries as high as 55% on average, with figures of 90% not uncommon, lends support to the notion that there remains under-investment in agricultural research in developing countries (and also probably developed countries, but to a lesser extent?).

Low rates of adoption of new technology among small-scale farmers are frequently attributed to ineffective extension services. But is this the correct interpretation of the facts? Whereas the ability of extension services to assure adoption of new technology may indeed be deficient, a primary reason for low adoption rates may well be that available technology does *not* meet the most urgent needs and preferences of small-scale farmers. These same low rates of technology adoption suggest that there is a need for a farming systems approach to agricultural research and development in developing countries, to ensure that the special needs and constraints facing small-scale farmers are appropriately addressed.

Farming systems research supported by ACIAR will aim at:

1. Describing the major components of farming systems so as to improve our understanding of the rationale behind farmer practices.
2. Identifying the biological, economic, and social constraints limiting production.
3. Developing and testing innovations to minimize the unwanted effects of these constraints; research may find that output is already optimal.

Thus, the Farming Systems Approach to Research (FSAR) will typically involve a multi-disciplinary approach by agricultural economists, crop and pasture agronomists, animal scientists, and others.

The primary focus for activities involving the FSAR will be subsistence-oriented smallholders in developing countries. Because of the complexity of their farming systems, the lack of knowledge of the circumstances under which they operate and the fact that historically they have been a relatively neglected element in agricultural research priorities, the FSAR is seen

to be an appropriate way of increasing the prospects of developing viable technology options for them. An understanding of the interactions between all the components of present systems is a pre-requisite to the design and adoption of improved technologies, which often will be focused on a single component. Unless a holistic approach is adopted, in which research begins and ends with the farmer, the technology that emerges may not prove viable when evaluated in real-world conditions. Recognition is increasing of the need for such an approach.

As shown in Table 1, the FSAR can be described as involving three basic strategies of research:

- Base Data Analysis (BDA).
- On-Station Research (OSR).
- On-Farm Research (OFR).

These three are employed in various combinations in each of four phases involved in the conduct of the FSAR:

1. Description of existing farming systems and diagnosis of problems.
2. Design of improved technology options.
3. Testing and verification of the performance of prospective technology options.
4. Extension and demonstration of the improved technology options, and training of extension and development staff in implementation and formulation of policy needs.

Social Science Research in Agriculture in Australia and ACIAR

Biological solutions alone are inadequate to solve the complex problems of rural development. Socio-economic studies are required to understand constraints to increased food pro-

Table 1. The farming systems approach to research.

Phases	Strategies		
	Base data analysis (BDA)	On-station research (OSR)	On-farm research (OFR)
Description/diagnosis	////////		////////
Design	////	////////	////////
Verification/testing			////////
Extension/training/policy			////////

duction and agricultural development in developing countries. From such analyses, evaluations can be made of alternative technological and institutional changes that might be employed to alleviate these constraints.

In ACIAR's Socio-economics Program two types of initiative are envisaged. First, wherever it seems desirable to include a socio-economics component in a project that is either being conceived in another ACIAR program area or that has reached a stage in the conduct of the approved research where such an input is required, it will be incorporated. Sometimes this will be best done by formulating a separate but closely related project. On other occasions it may be desirable to include the socio-economic component as an integrated portion of the primary project. Second, those types of socio-economics projects that address major agriculturally related socio-economic policy issues in developing countries.

Social scientists in Australia are active in research on agricultural problems. Increasingly this involves a multidisciplinary approach, which is so necessary for successful farming systems research. Some examples of the types of social science research undertaken in Australia that may be relevant to developing countries are provided below:

Farming Systems-related Research

- Farm survey techniques and data analysis.
- Farm management records and analysis.
- Economics of joint products and by-product utilization.
- Crop and livestock integration, especially sheep/wheat.
- Activity analysis/modelling to identify farmer constraints and to assist in designing technology.
- Risk and technology adoption.
- Economic analysis of agricultural experiments.
- On-farm and on-station experimental designs to optimize data generation for socio-economic analysis.
- Socio-cultural and human factors in the design and adoption of new technology.
- Agricultural extension strategies and methods.
- Social costs of rural adjustment to technological and demographic change.

Agricultural Policy Research

- Price policy analysis for inputs and outputs and risk.
- Price/income stabilization schemes.
- Farmers' supply responses.
- Economics of irrigation strategies.
- Technology policy.
- Agricultural credit.
- Infrastructural constraints and technology adoption.
- Efficiency and equity effects of technological change, including employment and human nutrition.
- Household studies, including interactions of technology, agriculture, demography, and human nutrition.
- Effects of subsidies, taxes, and protections on efficiency of agricultural production, distribution, and trade.
- Natural resource and environmental policies, including conservation.
- Viability of the family farm.
- Rural/urban terms of trade.
- Group farming, contract farming, and farmer cooperatives.

Commodity and Market Research

- Demand and market projections.
- Forecasting.
- Trend and outlook analyses.
- Market reporting and statistical analysis.
- Location and design of drying, protection, handling, storage, processing, and marketing facilities.
- Alternative marketing strategies (Marketing Boards, Co-operatives, Auctions).
- Role of agribusiness in agricultural development.
- Stock adjustment/stabilization schemes.
- Product transport/distribution problems.

Research Resource Allocation

- *Ex ante* criteria for use in technology design.
- *Ex poste* analysis of the benefits/costs of agricultural research.
- Economic assessment of losses from diseases and pests, and design of control measures.
- Economic analysis of priorities in national/regional agricultural research expenditures.

- Use of modelling and simulation in assessing research and technology design options.
- Basic research versus applied research.

There are undoubtedly other themes that I have not included where Australian social scientists have considerable reputations. However, the foregoing provide a fair sample of the range.

Conclusion

I trust that the information provided in this paper and in those of my colleagues will enable our Nigerian peers to distill sufficient information to decide how best ACIAR might focus its collaborative research activities in Nigeria. Correspondingly, we will read the papers from our hosts with considerable interest with the intention of gaining a better understanding of the major agricultural problems and research priorities in the Nigerian SAT. Our aim should be to identify precise topics around which we could develop research projects that ACIAR could help support.

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An Overview of Research in the Australian Livestock Industry and Possible Areas of Research Collaboration

J.W. Copland*

The animal, particularly the ruminant, is the key to the utilization of low-quality land and forage that until more productive crops are available, would otherwise go to waste as a food-producing resource, i.e. land that is too steep, arid, or otherwise difficult to use for plant production.

Animal diseases are a major constraint to livestock production in Africa, where many of the major infectious diseases are present, such as rinderpest, foot-and-mouth disease, trypanosomiasis, and others. Australia has been fortunate so far in preventing the introduction of the serious pathogens to its national sheep flocks and cattle herds. However, this does not mean Australian animal scientists are not interested, or unable to participate, in research into exotic diseases. The constant risk of the introduction of exotic pathogens demands that Australian scientists maintain an active and effective understanding of the major exotic diseases. It is not often realized that Australia has had outbreaks of rinderpest and surra, three outbreaks of foot-and-mouth disease, fowl plague, rabies, and other major diseases during the last century (Table 1). Most of these diseases were introduced by the importation of live animals and were contained by a mixture of drastic control measures and a relatively small population of susceptible animals at that time.

The importance given by the Australian authorities to many diseases endemic in Africa and elsewhere can be gauged by the considerable investment in the construction of the Australian National Animal Health Laboratory (ANAH), which is a maximum security laboratory to carry out research into many exotic diseases that potentially threaten the Australian agricultural industry. Compared with Africa, Australia is relatively free of serious animal diseases, and animal health resources are integrated into the

broad front of livestock production. The approach is an extensive multidisciplinary exercise to address the many facets of livestock production.

Table 1. Exotic disease outbreaks in Australia that have occurred and been eradicated.

Foot-and-mouth disease	1803, 1871, 1872
Surra	1907
Rinderpest	1923
Bovine pleuro-pneumonia	1858-1973
Rabies	1866
Swine fever	1903, 1927, 1942, 1961
Newcastle disease of poultry	1930, 1932
Scrapie	1951
Fowl plague	1976

Source: Gee (1980).

The Livestock Industry in Northern Australia

A brief description of the livestock industry in Australia, with particular emphasis on the semi-arid areas, may demonstrate some of the similarities and differences between Nigeria and Australia.

The management of cattle in the semi-arid areas basically consists of uncontrolled breeding systems. In these areas, such as the Northern Territory, the Kimberly area of West Australia, and northern Queensland, the stocking density is low and few sheep, if any, are kept. Further south in the first named two areas, the rainfall decreases and desert conditions prevail. Towards the southern coastal regions of both Queensland and West Australia, the stock-density increases and more intensive management is practised (Fig. 1). The sheep numbers increase in the southern areas of Northern Queensland.

The major constraint to animal health is the seasonal nutrition stress that can result in

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secondary diseases due to decreased resistance. However, the potential effect of the increased susceptibility is offset by the low stocking rate in this region. During the wet season, from approximately November to March, the land is

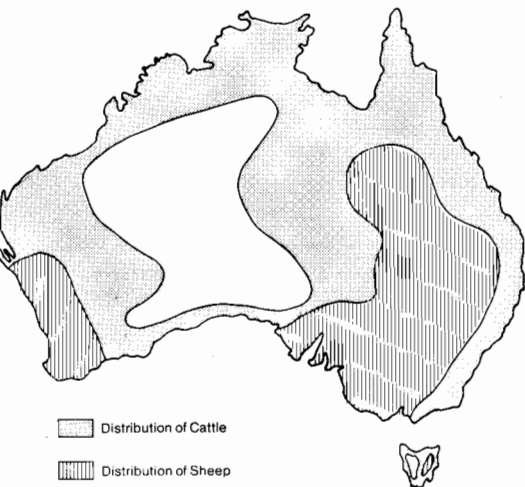


Figure 1.
Map showing distribution of cattle and sheep in Australia.

inaccessible. Due to overriding nutritional problems and the extensive nature of cattle raising, there are few cattle diseases that require attention, and the role of infectious diseases requires further research. In the semi-arid region, the water-holes as a disease-spreading environment have yet to be fully evaluated, although bovine tuberculosis is thought to be transmitted at water-holes. Mandatory treatment is required for tick control for any cattle moving out of the region.

A broad comparison of the African and Australian livestock industries is listed below (Tables 2 and 3).

Animal Research Infrastructure

Animal research in Australia is carried out by three organizations, i.e. the State Departments of Agriculture, the Commonwealth Scientific and Industrial Research Organization (CSIRO), and the universities.

The responsibilities for regional research and the application of research results rest with the individual State Department of Agriculture. Each

Table 2. Some major differences in livestock enterprises in Africa and northern Australia.

Description	Africa	Northern Australia
Owner contact	constant/frequent	low
Flexibility of management	little	moderate
Size of farms	small/nomadic	large commercial enterprises
Socio-economic factors	important, mainly social	important, mainly economic
Disease status	major problem	minor problem
Ticks present	several species	<i>Boophilus microplus</i>
Production restraints	disease/nutrition	nutrition

Table 3. Some important similarities in livestock enterprises in northern Australia and Africa.

Description	Africa	Northern Australia
Species	cattle, sheep, goat, camel, wildlife	cattle, buffalo, pig. Feral donkey and camels
Stocking rate	high to low	low
Nutritional status	low	low
Impact on environment	increasing/serious	increasing/isolated
Tick fever	yes	yes
Reproductive failure	present	present
Reproductive mortality	present	present

State has research facilities and, in general, concentrates on animal diseases of State significance. To carry out the research there is a Central Laboratory and often satellite laboratories. Generally, the research is of a short-term nature, ranging from basic to applied, and responsive to the information that comes from the farmer/field staff interface. The difficulties in carrying out this diagnostic service and research in the semi-arid areas are the long distances between the laboratory and field staff. There are two laboratories in the northern region of Australia, one in Townsville and one in Darwin.

The CSIRO is the main national research organization; it concentrates on selected long-term research topics, ranging from basic to applied. It is divided up into institutes in which there are several divisions. The Institute of Animal and Food Sciences undertakes most production and disease-related research, although the Institute of Biological Sciences also has an important interest in animal pests and insects; the Divisions of Entomology and Wildlife Research and Rangeland Management are important in these areas.

The bulk of the host-related work on animal diseases by CSIRO is carried out by the Divisions of Animal Health, Animal Production, and Tropical Animal Science of the Institute of Animal and Food Sciences. Each Division has several large laboratories and shared field stations. It is fair to say that the CSIRO is the most sophisticated research organization in Australia, and is able to bring a wide range of in-depth, multidisciplinary skills to individual research programs. As there are many common animal production problems in Africa and Australia, it is likely that some of the current research programs of CSIRO will offer opportunities for collaborative research, particularly in the areas of immunological and parasitological aspects of animal diseases and improving breed adaptability and pastures for cattle.

To determine national research priorities and assist in their co-ordination, there are many multi-linked advisory committees consisting of farmer representatives, scientists, and government officials.

The universities, with four Veterinary Schools and several Agricultural Schools, carry out animal production-related research of a more varied nature. Certain schools (such as the

Graduate Tropical Veterinary School at James Cook University) have a long-term interest in the problems of livestock production in northern Australia and other tropical countries. Often the direction of research is guided by the success of research grants and individual interests of the university staff.

The Multidisciplinary Approach of Animal Production Research

Most scientists are aware, or are becoming aware, of the complexities of the land-crop-animal system, and that production levels from this system are highly interdependent. For example, one of the limiting factors in the southern belt of Nigeria is the disease trypanosomiasis, which is a serious production constraint. There are other areas where non-infectious factors are more prominent, such as inadequate nutrition and lack of water for stock and pasture. The latter two constraints reflect the situation in Australia. However, both infectious and non-infectious disease factors can affect the overall productivity of the livestock industry.

In Australia the view that is gaining momentum is that improvement of animal productivity in the overall agricultural production system can only be achieved biologically by modification of either the genetic and/or environmental factors.

No longer is the concept completely acceptable that maximum animal production can only be achieved by a single disciplinary approach; integration of all the relevant research components is required. Perhaps the most recent formal expression of this multidisciplinary theme is the recent formation of the Division of Tropical Animal Science by CSIRO. It should be pointed out that there is still a need for intensive disciplinary research within a research program. A possible outline of the multidisciplinary approach to animal production research is shown in Figure 2.

Nigeria, like Australia, has a livestock industry in a wide range of climates, and of equal importance are the socio-economic factors involved in animal farming systems, particularly in Nigeria. The richness of demographic

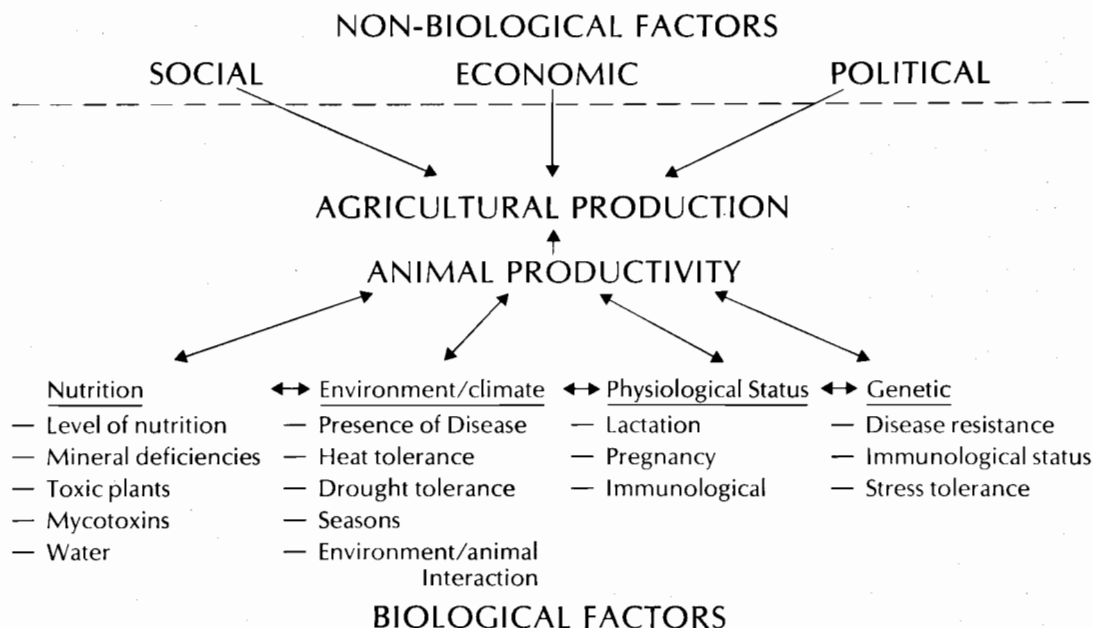


Figure 2.

The inter-relationship of the main factors in animal productivity of livestock.

differences in Nigeria is likely to require greater emphasis be given to the socio-economic factors of animal research planning than that in Australia. Attention has already been drawn to this important component of animal research by Chema (1983). In both countries, the economic and political aspects of animal health research will play a decisive role in any national research programs.

Scientists in both Nigeria and Australia will be able to make significant advances into the biological aspects of animal health, such as nutrition, environmental impact, and in the areas of patho-physiological and genetic research.

Some specific topics of animal health research in Australia that offer opportunities for collaborative research are outlined below.

Major Research Areas

1. Research on Animal Disease Control and Eradication Programs

As stated earlier, Australia has been fortunate in being free of the major infectious diseases of the world. Also, despite the extensive manage-

ment systems of cattle production in northern Australia, a successful eradication campaign has been completed against bovine pleuropneumonia. Currently, bovine brucellosis and tuberculosis are in the final phases of eradication, with large parts of Australia now being free from the two diseases. It is anticipated that bovine brucellosis will be eradicated in the next few years. The aim at present is to be free by 1992.

The experience in carrying out the three disease eradication programs and others mentioned earlier, has given animal authorities considerable knowledge of methods involved in disease control management. To carry out an eradication plan, considerable research is required to determine the most suitable approaches. This can involve fundamental research into the prevalence of the disease in question, completion of the epidemiological models, development of suitable tests and the confidence levels of the test in question, seasonal factors and many other aspects of the animal disease that is under consideration.

Disease control in extensive areas such as in northern Australia and perhaps Nigeria is difficult and expensive. Also, the scarcity of

trained staff in these extensive areas prevents a broad all-encompassing approach. To overcome these problems, a trace-back system has been developed in Australia that allows the detection and origin of cattle having particular diseases, and thus enables the available scientific staff to concentrate on high priority herds (ABAH 1979). In order to carry out successful abattoir monitoring, suitable diagnostic tests are required and as yet such tests are not available for all diseases. Areas for collaborative research in animal disease control revolve around the specific diseases, the development of suitable tests, vaccine control, and methods of disease data analysis.

2. Epidemiological Research

Australian scientists have made a major research thrust in identifying, modelling, and interpretation of epidemiological disease characteristics. Epidemiology is a study of the relationship between various factors that determine the frequency and distribution of the disease in the animal populations. One of the reasons why a study of epidemiological characteristics of a particular animal disease has attracted considerable support is because it provides a conceptual framework to evaluate and interpret all available biological knowledge of the infected host, the pathogen, and the environment. An epidemiological analysis of diseases allows the establishment of research priorities when control or eradication plans are contemplated. The use of epidemiological models is further enhanced by the ability of agricultural economics to provide effective economic parameters of a particular disease and the cost-benefit ratio of proposed disease control measures (Roe 1982). As a result, in Australia an epidemiological approach to animal diseases is acceptable to the policy-makers, animal health scientists, and economists.

Epidemiological research is an important area for disease control in a country such as Australia where there are no obvious production-limiting diseases. Where there are serious animal diseases such as rinderpest and bovine trypanosomiasis, as in Nigeria, there is less need for an elaborate epidemiological study to determine the cost of the disease and selection of research priorities.

3. Vaccine Production Research — Biotechnology

The ultimate aim of disease control for most Australian farmers and veterinary scientists is to have a simple, one dose, cheap vaccine. To provide such a vaccine, large investments in research are frequently required. The areas of research range from basic immunological studies to applied biotechnological research of mass vaccine production. The largest producer of vaccines in Australia is probably the Commonwealth Serum Laboratory (CSL). Involved in the manufacturing activities of CSL are several research teams who aim to produce new and better vaccines. An example of the close collaboration between the biotechnologists of CSL and CSIRO scientists is the mass production of a vibriosis vaccine by CSL that was developed by the Division of Animal Health, CSIRO. Should vaccine production or biotechnology require a research input in Nigeria, it should be possible to design research projects that utilize both Nigerian and Australian scientists, such as CSL researchers.

4. Virological Research

As Australia is free of the serious endemic viral diseases, the main research has been on the detection and classification of what viral diseases we do have, namely the arboviruses and their insect vectors (St. George and Kay 1982).

(i) Bluetongue Infections of Sheep

In 1977, Australia was informed that a viral isolate from insects, CSIRO 19, was indistinguishable from bluetongue. Since that day, all sectors of the animal health community, both Commonwealth and State, have been involved in an active research program to identify the spread, significance, and pathogenicity of the 'new disease'. The impact of this news on Australia's export trade was significant and it took 3 years before most trade restrictions were lifted.

Bluetongue is endemic in Africa. The discovery of the virus in northern Australia triggered off intensive research into the viral classification of bluetongue strains and of other closely related viruses, such as the orbiviruses, which also belong to the arbovirus group.

The taxonomy of the virus is still under intensive investigation, using both biochemical and serological methods. The taxonomy of the intermediate host, a *Culicoides* sp and its role in the spread of CSIRO 19 virus, is also currently under investigation. For the record, Australia has 3 sero-types of bluetongue virus, (BTV20, BTV1, BTV21) (Anon 1982) and 3 sero-types of orbiviruses. The research emphasis on viral taxonomy is required, due to serological cross-reactions that are caused by the closely related orbivirus in cattle tested for bluetongue prior to import into Australia. Because of the antigenic relationship of bluetongue virus to orbivirus, there will be a considerable ongoing research input to clarify the taxonomy, in spite of the fact that no clinical bluetongue disease has been described. Bluetongue is more important in countries of Africa.

5. Research on Bacterial Diseases

(i) Foot Rot of Sheep

The most important infectious disease affecting Australian sheep is foot rot caused by *Bacteroides nodosus*. Other bacterial diseases, such as those caused by *Clostridia*, are routinely controlled by vaccination and are not important production-limiting constraints. The major bacterial disease of cattle, bovine pleuropneumonia, has been eradicated.

The intensive research on foot rot has resulted in the production of a commercial vaccine that was based on the earlier immunological results of a CSIRO research project. There is considerable interest by State Departments of Agriculture and CSIRO for an improved vaccine, using purified antigen and a basic study of the humoral and cellular components of the immunological reaction. Currently, there are three teams investigating which *Bacteroides nodosus* strains are present in order to incorporate them in the vaccine. There is also a major research input into the differentiation of benign and virulent foot rot caused by strains of *Bacteroides nodosus*.

6. Research on Parasites of Livestock

(i) The Cattle Tick

The cattle tick is the major disease-associated

problem of cattle in northern Australia. Its economic effects range from the spread of infectious disease to the depression of the host growth rates through general debilitation. The tick has previously been controlled by use of acaricides; however, chemical resistance has occurred. Crossbreeding between *Bos indicus* and *Bos taurus* has increased tick resistance but physiological changes of lactation and pregnancy do lower such resistance levels.

As the tick is a major pathogen vector in Australia, research is currently being carried out by CSIRO, State Departments, and universities. Current areas of research are:

- a. Identification of tick resistant cattle – the search is on for a simple immunological method to estimate the degree of tick resistance and the role of host compatibility antigens as genetic markers.
- b. Immunization or vaccination against the cattle tick using natural tick tissue culture and adult tick antigens. The tick vaccines have shown some effect on the intestinal cells of adult ticks and have resulted in a lower tick egg viability.

(ii) Tick-borne Diseases

Vaccination methods against *Babesia* are well known; however, they do have considerable disadvantages, such as spread of the organism, short-shelf life, and occasional breakdowns.

Research at Long Pocket CSIRO Laboratories is currently directed to the possibility of using non-live vaccines. The approach is to collect antigens from *Babesia*-infected cells and successful results have been obtained. However, the presence of excess non-specific red cell antigen needs to be removed before it can be recommended for general use. Other methods under consideration involve recombinant DNA methods, mono-clonal antibody techniques, and biochemical analysis of the enzymes in tick.

(iii) Internal Parasites of Livestock

Australian scientists have been aware of the importance of internal parasites as a cause of poor animal health status and resulting economic loss. There are several laboratories where the ecology and population dynamics of helminth infections of grazing livestock are studied, ranging from a basic biological approach

to that of an applied nature. The overall aim is to improve strategic management control methods by manipulation of the susceptible stock and the infective stage larval population.

(iv) Anthelmintic Resistance to Helminths

Resistance by parasites to anthelmintic drugs has been of serious concern to the Australian livestock industry, particularly in the more settled subtropical areas of northern Australia. Currently, there are pockets of multi-drug resistant populations of *Haemonchus* and *Ostertagia* that have given urgency to the research efforts to gain an understanding of the mechanisms involved.

Current research endeavours are focused on the host-parasite mechanism of development of resistance and the intra-host regulation of nematode populations. Basic knowledge of the genetic make-up of drug-resistant *Haemonchus* species and genetic parameters of host susceptibility are being investigated by CSIRO and the University of New England, Armidale, New South Wales. In addition, there is a search for markers of resistance of a relatively simple nature for animal breeding purposes. Preliminary results suggest that bovine lymphocyte antigen may be of use. Detection methods of host anthelmintic resistance currently used are the cumbersome drug response trials; improved *in vitro* methods are also being intensively studied.

The current situation in Australia is that there are populations of trichostrongyles that are resistant to both of the available anthelmintic compounds, i.e. benzimidazole and levamisole groups. The limited range of available anthelmintics, plus the increasing animal populations in Australia, has precipitated considerable reallocation of research resources in this area. Fortunately, it appears that the new compound ivermectin (R) may be effective against all current resistant populations.

Additional approaches to the drug resistance problem are (a) pharmacokinetics of anti-parasite drugs, (b) host-physiological response to parasites, (c) respiratory mechanisms of developing nematode eggs and adults, (d) protein synthesis by the host and protein loss due to parasites, and (e) heritability of sheep resistant to *Haemonchus*.

Should parasitism be considered a priority for research by African scientists, there are many potential areas for collaborative research that would be of importance to Africa and Australia.

7. Immunological Research

In the immunological field, Australia has a world-wide reputation for the achievements that it has made. The two centres that are actively carrying out immunological research on animal health related topics are the Walter and Eliza Hall Institute and the Australian National University. The latter group has been involved in exploring the possibility of identifying immature cattle that have inherited protective immunological responses to specific factors such as ticks and internal parasites, and to establish the genetic patterns of such responses with the eventual aim of breeding fitter cattle. The association between inheritance of histocompatibility genes and susceptibility to diseases has been described (Dorf 1981).

The Walter and Eliza Hall, in conjunction with the University of Melbourne, has spent the last 5 years on a study of the immunological processes of cysticercosis and taeniasis in domestic animals. This group has had considerable success in being able to reduce the incidence of *Cysticercus bovis* by using an inert vaccine. This points the way to the possibility of immunizing stock against the intermediate stages of tape worms, and of protecting the meat-eating human population.

Other scientists have built on the knowledge of basic immunological research to develop improved diagnostic methods for infectious animal diseases. The ELISA (Enzyme Linked Immuno-Sorbent Assay) test appears to offer considerable advances in disease control schemes by providing a cheap, accurate test that has the dual advantage of being able to detect both the antibody as in a serological test, or the antigen, i.e. the disease-causing agent. Detection of the antigen by this system could remove the need to carry out the isolation procedures involved in bacteriology and virology. There is considerable enthusiasm for this test in the more remote parts of Australia that do not have adequate diagnostic facilities or are too far away from a diagnostic laboratory. The benefits in terms of easier management and disease control of 'on the spot' ELISA tests for

the extensive cattle systems of northern Australia are considerable. At present, research resources are being directed to establishing suitable test systems for viral diseases of poultry and certain bacterial diseases of pigs and sheep.

In the framework of the disease priorities established by the Nigerian countries, there could be areas of collaborative research into an ELISA test for animal disease diagnosis that should be useful to regional laboratories and field staff. Provided adequate research inputs are available, the ELISA test has exciting prospects for the future in control of animal diseases.

Possible Areas of Research Collaboration

The areas of animal research in Australia that may be of interest and relevance to Nigerian livestock authorities and scientists are:

1. Viral taxonomy.
2. Many aspects of research into parasites common to both countries, e.g. *Haemonchus* and *Boophilus*.
3. Immunological studies on internal nematode parasites and cattle tick.
4. Biotechnology – vaccine production, monoclonal antibody techniques.
5. Methods of disease control.
6. Improved diagnostic methods and reagents such as the ELISA test.
7. Economic research on animal diseases, using the epidemiological model.

The specific area of collaboration between Nigerian and Australian scientists will depend on the research priorities of each country. However, there is a broad similarity to the

ruminant species farmed and the environments that could form a firm basis for future research collaboration.

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NAPRI/ACIAR Collaborative Research Proposals*

Possible areas of collaborative research are:

1. Dairy cattle breeding and physiology.
2. Integrated livestock and crop production.
3. Newer techniques in ruminant nutrition studies.
4. Accelerated breeding of small ruminants.
5. Utilization of crop residues.

Dairy Cattle Breeding and Physiology

The dairy potential of the indigenous breeds of cattle is low (about 1000 kg per lactation). Crossbreeding experiments carried out in different ecological zones have confirmed the possibility of improving the indigenous animal by crossing with exotic breeds, especially the Friesian. NAPRI has just embarked on a crossbreeding program involving 200 indigenous heifers and Friesian sires. It is realized that in tropical countries, consideration should be given to selection for heat tolerance and resistance to ticks, besides milk yield in selection programs.

Assistance is sought in the field of environmental physiology and selection for tick resistance with particular emphasis on half-bred dairy cattle. Equipment and secondment of experienced scientists for such studies should form an integral part of the assistance.

Integrated Livestock and Crop Production

Pasture as a mono-crop is not acceptable to small farmers. Importance is therefore being given to stock and crop integration. It also has tremendous potential in irrigation schemes and in large, rainfed cropping areas. Initial field trials have been carried out by NAPRI and ILCA.

Information is presently lacking on several aspects of stock-crop integration such as:

1. Alternation of sown pastures/legumes with arable crops – suitable species, cultural practices, socio-economic aspects.
2. Intercropping of forage with arable crops.
3. Increasing the efficiency of utilization of agro by-products by ruminants.

Assistance is required in the form of technical expertise from scientists experienced in this field.

Newer Techniques in Ruminant Nutrition Studies

Considerable work has been done in NAPRI on digestibility and metabolism studies in ruminants using conventional techniques. There is a need to use newer techniques to enable a clearer understanding of the digestive and metabolic processes under non-stressful and stressful (drought) conditions.

Assistance is sought to introduce to NAPRI the following:

1. Different fistulation and cannulation procedures.
2. Use of radio-isotopes for N-metabolism and water-turnover studies.

Accelerated Breeding of Small Ruminants

The indigenous breeds of sheep have an average litter size of 1.15. They breed throughout the year. Advantage can be taken of the latter to increase the number of lambs produced/ewe/year by accelerated breeding aimed at minimizing the period between lambing and subsequent conception.

* Prepared by the executive and staff of NAPRI for consideration at the seminar.

To achieve this, studies on several aspects are required:

1. Physiological studies of reproductive parameters in the ewe.
2. Semen storage studies.
3. Synchronized and artificial/natural breeding techniques.
4. Minimizing lamb mortality.

Utilization of Crop Residues

It is proposed that there be collaborative

research conducted to determine:

1. The yield and nutrient content of crop residues from the cropping system.
2. The carrying capacity of crop residue fields with varying proportions and types of legumes.
3. The levels of nutrient supplementation to livestock grazing on crop aftermath that varies in legume content.
4. Simpler methods of improving the nutritive value of cereal-based crop residues, based on the use of micro-organisms, notably fungi.

IAR/NAPRI/ACIAR/ Collaborative Research Proposals*

There are three main components in a research linkage between these organizations, namely:

1. Livestock and crop production.
2. Soil fertility and crop production.
3. Farming systems.

The three components of the collaborative project are not intended to be treated as mutually exclusive, but to be viewed and executed as an integrated soil-crop-livestock research package.

The Livestock and Crop Production Component

Objectives

The project is aimed at exploring the feasibility of introducing fodders into conventional arable crops by alternating legume-based sown pastures with arable crops and/or intercropping fodder legumes into arable crops under irrigation and rainfed management. Such a combination should promote soil fertility while improving fodder and grain yields in terms of quantity and quality. The specific objectives are to determine:

1. Species or species combinations best adapted to the cropping system.
2. Planting configuration, tillage practices, fertilizer treatment, harvesting and conservation for better utilization by the ruminant.
3. Efficiency of utilization of crop-residues and agro by-products by the ruminant and the level of production from such feedstuffs.
4. Socio-economic implications in proposed farming practices and also defined path-ways through which innovations may be introduced and tested.

Justification

Most of the nation's livestock are owned by

pastoralists who raise their livestock under free-range grazing. Their grazing strategy can be stated as follows: in the wet season livestock graze on range and fallows; in the dry season the latter grazing areas are complemented by grazing on crop-residues, fadama vegetation, and browse. Numerous reports from NAPRI, Shika (e.g. Van Raay and de Leeuw 1970, Van Raay and de Leeuw 1974, de Leeuw 1977, and Perrier 1982) have indicated the importance of crop residues in the diet of pastoral livestock.

For 4 months of the dry season (November-March) crop residues constitute the principal source of fodders for livestock. Insufficient quantity and quality of dry matter has been one major factor causing low productivity of livestock during the dry season. Although developments of large-scale dryland farms and irrigation schemes may have reduced the total hectares available for free-range grazing, such developments would produce tonnes of crop residues as stalks, straws, haulms, cull vegetables, and fruits that are unfit for human consumption. Ruminants can effectively utilize such residues and convert them into high protein products such as meat or milk. Therefore, any effort toward improving the quantity and quality would have a tremendous benefit for both the farmer and the pastoralist.

Furthermore, there is within the irrigation schemes wide scope for the incorporation of pasture leys, which unlike arable crops that provide a single harvest of grains in a season, can provide multiple cuts of forages within a season. Judging from prices of groundnut haulms in urban areas such as Kaduna, Kano, and Sokoto etc., pasture material such as fodder or pasture seeds have higher market value on a per unit weight basis than grains. It may perhaps be a little premature to state categorically but there is increasing evidence that traditional arable crop farmers are turning more and more toward producing fodders (at present mainly as by-products of grain crops) to

* Prepared by IAR and NAPRI for consideration at the seminar.

supplement their farm income. Therefore a research effort towards incorporation of sown pastures, or intercropping of fodders within arable crops, would be highly desirable. To this end researchers at NAPRI are screening various fodder legumes for use in pasture-arable crop rotations and intercropping within cereal crops. The main trials are at Shika but with further assistance such trials can be expanded to other ecological zones.

Procedures

Details of experimental procedure are not herewith stated, only the materials and basic parameters that should be investigated. For the livestock sector, the main emphasis would be placed on increasing yields of fodders and the efficiency of utilization by ruminants.

Site Selection

The experiments should be sited to cover the livestock-producing zones of the country, i.e. sub-Sahel, Sudan and Guinea Savannahs. We suggest locations at Ngala, Bornu State; Talata Mafara, Sokoto State; and Kadawa, Kano State to represent the sub-Sahel and Sudan Savannah. Sites at Shika can represent the Northern Guinea Savannah while sites at Mokwa, Niger State; and Yandev, Benue State could be for the Southern Guinea Savannah. Shika, Zaria should be the coordinating centre. Also the initial trials should be done at Shika and Kadawa for convenience to both NAPRI and IAR in terms of distance and easier supervision of field trials.

Materials

Basically the trials should look into the 'soil-plant-animal' complex relationships. The soil aspects particularly on N, P, and S inter-relationships should be handled by IAR staff, while NAPRI concentrates on the plant-animal component. Grain legumes and fodder legumes would be tried either in rotation with or intercropping within grain crops such as maize (*Zea mays*), sorghum (*Sorghum vulgare*) and millets (*Pennisetum typhoides*). Grain legumes such as cowpea (*Vigna sinensis*), groundnut (*Arachis hypogaea*) and soyabean (*Glycine max*) are good candidates. Fodder legumes may include Lablab (*Lablab purpureus*), mucuna or velvet bean (*Stizolobium deeringianum*), Calop

(*Calopogonium mucunoides*), Siratro (*Macropitilium atropurpureum*), and stylos (*Stylosanthes* spp.).

Initial trials should find the suitable species or species-combinations that are best adapted to the cropping system on the basis of dry matter yields, chemical composition and nutritive value. Chemical composition includes analysis for N, Ca, P, K, Mg, Zn, and trace elements. The fibre components (NDF, ADF, ADL, cellulose and hemicellulose) and digestibility of the dry matter should be investigated. Such analysis is to pave the way for animal trials that would determine and quantify the intake, nutrient utilization, ruminant production, levels of supplementation to livestock feeding on crop residues with varying proportions, and types of legumes. Further investigation should determine simple methods of improving the nutritive value of crop residues, e.g. by partial digestion by micro-organisms or use of additives.

Budget Requirements

Pasture materials, animals, and some categories of staff are available at NAPRI. However there are number of materials not available but which must be made available for the success of the project. In the latter case, there is need for chemicals and equipment that are hard to obtain in the Nigerian market. There is also need for technical expertise on techniques, e.g. cannulation, which are necessary for monitoring forage and nutrient utilization by the ruminant.

The Biochemistry Laboratory at NAPRI, Shika, Nigeria, was in the past modestly equipped to handle a farm or feed advisory service. Currently, most of the equipment in the laboratory is either non-functioning due to the lack of spare parts or expert personnel to service and operate the equipment. Most glassware needs replacement. Laboratory chemicals for most routine work are exhausted from stock. The current economic situation in the country makes it near impossible to acquire stock to replenish these chemicals.

For a long time, the Biochemistry Laboratory has lacked leadership from an experienced and qualified analytical biochemist who could re-organize the laboratory to ensure the rapid production of accurate laboratory results. With some re-organization, re-equipping, and backing from a constant electricity and water supply, the

NAPRI Biochemistry Laboratory could be transformed into an efficient analytical/nutrition laboratory, which would in turn form the core for a farm or feed advisory service.

In the light of the above, an experienced Analytical Biochemist is required to re-organize and re-equip the existing NAPRI Biochemistry Laboratory. To further assist research staff concerned with forage and crop residue evaluation in the proposed integrated livestock and cropping scheme, an expert on general cannulation procedures for ruminant animals is required. In the past local efforts at cannulation of the rumen of farm animals have been unsuccessful due to the absence of the right types of cannulae and staff experienced in the cannulation procedures.

The following is a brief job description of staff assistance sought:

1. Analytical Biochemist

To re-organize the existing Biochemistry Laboratory for routine rapid chemical analysis of feedstuffs, food materials, and various other animal products.

To provide on-the-job training of staff in various assay procedures and general handling of laboratory equipment.

To see to the general administration of the Central Analytical/Nutrition Laboratory.

Duration of attachment : 1 year; renewable.

2. Expert on Cannulation Procedures

To undertake oesophageal, ruminal, or abomasal cannulation of ruminants.

To train local staff in the various cannulation procedures.

Duration attachment: 4 months; renewable.

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Soil Fertility and Crop Production

There is general agreement to concentrate on the following three areas.

1. Nitrogen (The major study)

- (i) To find ways of enhancing or maximizing the contribution of selected legumes to the nitrogen economy of representative agriculturally important soils of the savannah zone.
- (ii) To quantify, using a bio-assay approach (involving cereals), the N contribution from the legumes. The study will involve rotations and intercropping using both grain and forage legumes alongside with, or in combination with, the major savannah cereals (sorghum, maize and millet). It is hoped that this work will complement and increase the on-going biological N fixation studies, and intercropping/rotation studies at IAR.

2. Phosphorus and Sulphur

Since nitrogen and legumes are going to be central to this whole project, there is a need to ensure adequate soil supply of P and S, the two most important nutrients for most legumes. Soils of the Nigerian savannah are, without exception, deficient in N, P, and S. Specifically, we want to develop a system of predicting the P and S fertilizer requirements of the savannah soils taking cognisance of any residual values from previous applications. This is an important consideration under a system of continuous cultivation. Work on P has been greatly slowed down recently at IAR and that on S has stopped altogether, owing to the shortage of staff. This linkage will provide us with an opportunity to resuscitate it. The phosphate and sulphate studies will be fully integrated into the N work.

3. Micronutrients

With the inevitable shift from the traditional bush-fallowing, non-intensive system of farming, to continuous intensive cultivation, micronutrient deficiencies, which were hitherto rare, are now being reported with increasing frequency, especially boron and molybdenum (both of these are very important for legume production). It is intended also that the micronutrient requirements of various legumes be investigated.

Project Requirements

Materials

It is not possible to define in detail what the specific laboratory requirements will be until the experiments are actually designed and the major parameters of interest defined. However, at present we do not have the laboratory analytical facilities for sulphur, molybdenum, and to a certain extent, boron. The studies will no doubt involve intensive and extensive laboratory analyses, which will have to be costed in due course. Items such as housing, project vehicles, secretarial services, and consumables, travel (both domestic and international) etc, will have to be taken into consideration when drawing up any memorandum of understanding.

Personnel

IAR will most likely spare half of the time of one of its very senior research staff to collaborate on the N work. Considering the amount of work involved, it is suggested that a counterpart staff from ACIAR be stationed in Samaru for at least 3 years, to work co-operatively with the IAR specialist.

For the P and S work, IAR shall identify a person to work with the Australian counterpart, who need not be stationed in Samaru, if two or preferably three visits to Nigeria in a year can be arranged.

Duration

It is suggested that the first phase should run for a minimum of five years.

Farming Systems

A proposal is set out below for a study of pastoralist-farmer co-operation in the use of forage legumes in farming systems in the Nigerian savannah.

Background

Recent studies in an environment in Australia with ecology very similar to that of northern Nigeria have indicated the potential benefits of pasture legumes in improving dry-season nutrition and growth of animals, and in substituting for nitrogen fertilizer in subsequent grain crops (Jones and McCown 1983). The applicability of these results in northern Nigerian farming is uncertain because of the limited integration of the livestock sector (involving the Fulani and other pastoral groups) with the crop sector (involving the Hausa and other farming groups). Some exchange or sale of crop residues and dung does occur (Raay and de Leeuw 1970) but the predominant means of maintaining soil fertility in the widespread permanently cropped lands are village refuse, the dung from small ruminants owned by the farming groups, the dung from cattle only during the time when they are grazing crop residues and the pseudo-rotation of crop mixtures with legumes (groundnut and cowpea) and cereal mixtures (Bunthjer 1971; Hill 1972; Schultz 1976). The problem therefore is to assess the possibility that the development of a soil fertility maintenance system based on forage legumes could benefit the farming groups who own limited cattle, but certainly have nitrogen deficient soils.

The conditions described are widespread across the West African semi-arid zone with results being applicable between approximately 10 and 13°N in Nigeria.

Previous research on fertility maintenance has concentrated on the use of chemical fertilizer but there is widespread recognition that a cheaper and possibly ecologically sounder method might be to upgrade the legume component. The priority is therefore rated as high.

Objectives

1. To study existing practices whereby pastoralists and farmers co-operate to their

mutual benefit, especially in the purchase or exchange of crop residues and dung, or the rights to utilize them.

2. To mount 'experiments in co-operation' in several suitable village situations across the range of ecologies. The two groups will be offered the pasture legume technology and encouraged to co-operate in its utilization, e.g. by allowing crop farmers to utilize land previously cropped to fodder legumes by the pastoralists.

Methods

1. Literature search for all relevant material across the West African region.
2. Reconnaissance surveys to generate hypotheses about forms of co-operation not yet documented, and to assess the importance of this co-operation in different areas.
3. More formal surveys to test hypotheses in areas of interest identified during the reconnaissance survey.
4. Village experiments in pastoralist-farmer co-operation.

Analysis

Methods 2 and 3 will use standard analytical methods for farm management/rural sociological surveys. Method 4 will require a twofold analysis: (a) technical analysis to determine the performance of the legumes and (b) estimation of the quantities exchanged in pastoralist-farmer co-operation and socio-economic to assign values to these and monitor the reaction of the co-operating farmers and pastoralists.

Tentative Timetable

October, November 1984: Literature search.
December 1984 to March 1985: Field surveys.
April 1985: Design of 'experimental' studies.
May 1985 to April 1987: 'Experiments' running.
May-June 1987: Evaluation and reporting.

Further plans will depend on the results obtained in this and other components of the co-operative program.

Division of Labour

The Australian input proposed is a sociologist or economist with previous experience in a developing country, to work for 6 months on literature and field surveys, 1 month on design, and to visit annually during the experimental phase and at final evaluation. Some assistance on vehicle provision, transport, and travel etc. is envisaged.

IAR and NAPRI senior staff will work alongside the visitor during the survey and design stage and will supervise the experimental phase. Enumerators and interpreters will come from the Institutes.

Potential Users

This is one essential component in a much broader study on forage legumes in Nigerian farming systems and the knowledge gained will be essential for designing an extension program for using forage legumes, assuming that parallel studies indicate that the technical performance is adequate. The essential thrust of the project is to ensure that crop farmers benefit as well as the pastoralists.

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Summary of Potential Fields for Collaboration with ACIAR

J.G. Ryan*

The meetings in Nigeria went well and were very productive. The Nigerian institutions represented at the initial two-day meeting in Zaria presented a comprehensive list of priorities for consideration. They were subsequently narrowed down to four or five that could form the basis of the ACIAR program in Nigeria. These priorities received the endorsement of those attending the final meeting that was held in Lagos on 23 November 1983 at the Federal Ministry of Education, Science and Technology (FMEST). The meeting was chaired by Dr D.E. Iyamabo, Director of Agricultural Sciences of FMEST.

The areas agreed for possible collaboration include:

1. Soil, Crop, Pasture, and Livestock Improvement in the Savannah Region of Northern Nigeria

This is based upon proposals in the McCown-Jones paper and it received strong endorsement. The main participants from Nigeria would be the Institute of Agricultural Research (IAR), Samaru; the National Animal Production Research Institute, (NAPRI), Shika; with interaction of the Institute for Agricultural Research and Training (IAR&T) at Ibadan; and the Lake Chad Research Institute (LCRI).

The project was divided into the following components:

- Legume-crop interactions.
- Legume-livestock interactions.
- Legume nutrition (N, P, S, and micro-nutrients).
- Soil surface management.
- Integration of crop and livestock production via a farming systems approach using the above technology components.

2. Animal Health

There was considerable interest in this topic, especially from the National Veterinary Research Institute (NVRI) at Vom, near Jos in eastern central Nigeria. Amongst the topics that may be considered by ACIAR are:

- Tick-borne diseases.
- Epidemiology and economics of diseases, employing the ELISA technique.
- Parasites, including their biology and control.
- Technology of vaccine production in hot, dry and humid environments.

3. Animal Production

(1) By-product utilization:

This includes crop residues (cereal and legume), brewers grain, and coconut waste. On the cereal/legume side it would be desirable to establish a close link with any project arising from the McCown-Jones proposals in item 1 above. Consideration could be given to a project in this area that is formulated around the McCown-Jones proposals primarily, but with provision for some input into utilization research in other commodities, including straw by-products from river basin schemes in the north.

(2) Breed evaluation:

ACIAR suggested beef breed evaluation while Professor Saka Nuru of NAPRI and others placed a higher priority on dairy cattle breed evaluation. It was pointed out that ACIAR was currently reviewing the priority to be accorded to dairying. The interest in dairy breed evaluation would be conveyed to ACIAR.

4. Management of Vertisols

This matter is a major concern of the scientists in the Lake Chad region, where Nigeria's Vertisols occur. ACIAR could facilitate the

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interaction of these scientists with Vertisol researchers in Australia, ICRISAT (India), and in the Sudan.

In conclusion, the discussions at the seminar

established a solid foundation and the consultations were highly appreciated by the administrators in Lagos, the scientists in the field, and staff from ACIAR.

Appendix 1

List of Participants

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E.A. Lufadeju	NAPRI, Shika		
J. MacFarlane	ICRISAT, Nigeria		

Appendix 2

Acronyms and Abbreviations

ABU	Ahmadu Bello University, Zaria
ACIAR	Australian Centre for International Agricultural Research, Canberra
ADAB	Australian Development Assistance Bureau
AERLS	Agricultural Extension and Research Liaison Services, Zaria
AI	Artificial Insemination
ASEAN	Association of South East Asian Nations
AUIDP	Australian Universities International Development Program
CBDA	Chad Basin Development Authority
CBPP	Contagious Bovine Pleuro-Pneumonia
CGIAR	Consultative Group on International Agricultural Research
CSIRO	Commonwealth Scientific and Industrial Research Organization, Australia
ELISA	Enzyme Linked Immuno Sorbent Assay
FLD	Federal Livestock Department, Lagos
FMEST	Federal Ministry of Education, Science and Technology
HYV	High Yielding Variety
IAR	Institute for Agricultural Research, Zaria
IAR&T	Institute for Agricultural Research and Training, Ibadan
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
IITA	International Institute for Tropical Agriculture, Nigeria
ILCA	International Livestock Centre for Africa, Kaduna, Nigeria
IRRI	International Rice Research Institute, Los Baños, Philippines
KLRI	Kainji Lake Research Institute
LCB	Lake Chad Basin
LCRI	Lake Chad Research Institute, Maiduguri
NAPRI	National Animal Production Research Institute, Shika
NITR	Nigerian Institute for Trypanosomiasis Research, Kaduna
NVRI	National Veterinary Research Institute, Vom
SAT	Semi-Arid Tropics
SSA	Sub-Saharan Africa

ACIAR PROCEEDINGS SERIES

- No. 1. Proceedings of the Eastern Africa—ACIAR Consultation on Agricultural Research, Nairobi, Kenya, 19-22 July 1983. J.G. Ryan (ed.), 241p., 1984.
- No. 2. Proceedings of the International Workshop on Soils, Townsville, Qld, Australia, 12-16 September 1983. E.T. Craswell and R.F. Isbell (ed.), 189p., 1984.
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