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Market-oriented Crop Improvement Research and Outreach

Enhancing Financial Sustainability

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PREFACE

This report explores the potential for financial sustainability of agricultural research activities in Zaire, particularly those sponsored by the Agency for International Development. The study was entrusted by USAID/Kinshasa to Robert R. Nathan Associates, of Washington, D.C. under the AID Macroeconomic Indefinite Quantity Contract, IQC No.PDC-0000-I-23-6135-00.

The conclusions and recommendations presented here reflect analyses carried out in Zaire during a six week period in July-August 1988. Edgar J. Ariza-Nino, Principal Associate at RRNA, was the principal analyst, but many other scientists and officers contributed their ideas and suggestions to this effort.

Special recognition of the contributions by several individuals is gratefully acknowledged. Drs. Mahungu and Osiname of the Cassava research program, and Drs. Mulamba and Vogel of the maize research program were particularly helpful with their insights on the cost structure of agricultural research. At USAID/Kinshasa, Drs. J. Goodwin and D. Brown provided overall guidance in the identification of problems and issues. Numerous discussion with J. Mitchell, R. Griego, M. Jacob, and C. McCarthy provided a friendly and critical audience for most of the initiatives identified here. The principal author is, however, solely responsible for all remaining errors of fact or judgement.

CONCLUSIONS AND RECOMMENDATIONS

Survival Criterion. Make financial sustainability a priority criterion for the design of agricultural development projects in general and agricultural research activities in particular. This criterion forces designers to state clearly what the tangible outputs from the project are, to whom they are targeted, and whether the clientele is willing to pay for these outputs. Progress in regard to sustainability is also a good yardstick for measuring project progress.

Low Priority for Policy Makers. Accept the fact that agricultural research activities have a relatively low priority for Zairian policy makers. Investments in agricultural research have an uncertain and long-term payoff. Moreover, the performance of agricultural research efforts in tropical Africa has been very poor, with the sole exception of maize in southern Africa. Given the tight financial situation of the Government of Zaire, competing claims on public funds will have greater urgency. It is not likely that the priorities will change in the medium term or over the duration of the project.

High National Payoff. All previous agricultural revolutions have taken place only after great advances in the agricultural technology available to farmers. Expenditures in agricultural research have proven to be among the most productive forms of public investment in the long run. In Zaire, however, few important breakthroughs have been made in the past few decades, partly because of the institutional disruption of the agricultural research system since independence. As a result, Zaire has had two decades of production stagnation. Tropical African crops in Zaire have not benefited from the great advances in crop genetics in other parts of the world. Imported crop varieties have adapted poorly to the special environmental, economic, and

social conditions of the Zairian tropics. There is no alternative or shortcut to research to develop improved crop varieties adapted to the Zairian environment.

Market Policies Not Enough. Misguided policies have much to do with the agricultural stagnation, but even after the removal of some policy constraints and introduction of greater market orientation, traditional Zairian agriculture has not responded with the anticipated surge of vigor. This we attribute to the unavailability of appropriate improved varieties and technologies to farmers. Developing improved crop varieties is an integral part of the USAID agricultural development strategy for Zaire. Without better techniques and varieties, all other efforts to develop Zairian agriculture could prove futile.

Institutional Autonomy. Many of the operational deficiencies observed in the Zaire Applied Agricultural Research and Extension project (RAV) emanate from the rigidities imposed on it by its status as a state agency. More flexibility could be gained by giving the agricultural research institution as much autonomy as possible while ensuring that the objectives of the project are maintained.

Strive for Financial Independence. Minimize the agricultural research institution's dependence on financial support from the government's general budget. This support has proved feeble and unreliable. It cannot be counted upon to support research on food crop improvement in the near future. Special taxes to support research are also of doubtful use because they are subject to the same weaknesses of the public finance administration: collection, evasion, budgeting, and disbursement. More steady alternative sources of funding should be explored. Several alternatives are discussed below, from self-generated revenues through marketing of research results or doing contract research for other organizations.

Revenue Generation. There is increasing evidence that farmers are often willing and eager to pay for agricultural inputs of demonstrated advantage, provided they are priced reasonably and their delivery and quality are assured.

The progress made so far in Shaba in marketing maize seed is a good and encouraging example. Selling at competitive prices, the superior genetic materials coming out of the crop improvement research are underexploited sources of financial support. Agricultural research institutions should aim their activities to satisfy real and pressing needs of farmers. One of the best indicators of the usefulness of research is the farmers' willingness to pay for improved seeds or inputs embodying the results of genetic research. The name of the game is to produce a saleable product.

Research as a Public Good. Different crops have different prospects for self-generated revenues. Market mechanisms can fail to capture large and positive externalities emanating from research. The successful biological control of mealybugs on cassava is a good example. It has been shown to have a social benefit/cost ratio of 149 to 1. But there is no conceivable way that the research program could have been financed using marketing channels. Technical and social conditions for some crops are more conducive to financial self-sufficiency than for others. Cassava, for example, despite its nutritional and economic importance for a large portion of the population, does not lend itself to generating funds through the sale of improved materials. In such cases, A.I.D. needs to accept the idea that research in cassava must be financed externally.

Privatize Distribution. One way to reduce dependency on official funding is to allocate certain agricultural research activities to nongovernmental concerns. These concerns can be either private commercial operators or private voluntary organizations. Certain activities can be contracted to private firms. For example, the World Bank Seeds project subcontracts with private commercial farms for the production of commercial maize seed in Shaba. Another imaginative initiative is USAID's subcontract with another Shaba firm to commercialize the delivery of improved maize seed in Central and Southern Shaba.

Bypass Extension Service. Public extension services have not proved satisfactory as vehicles to deliver inputs and services to farmers in Zaire, as well as in many other countries. Alternative, parallel outreach mechanisms

need to be developed to ensure that the results of agricultural research in fact reach farmers. Several A.I.D. and World Bank agricultural development projects have already done that. Commercial dealer networks aimed at farmers should be encouraged. Private input delivery is viable, especially for commercial crops in the main agricultural production areas.

Special Parafiscal Taxes. Levies on particular products at critical points where either transport or processing takes place could be an effective means of generating funds for financing research on the product, on which farmers, processors, traders, and consumers might agree. In Zaire, however, the collection, transfer, and disbursement of similar special taxes has been subject to many irregularities. Their use to finance food crop research is not recommended.

High and Quick Payoffs. Efforts should concentrate initially in those regions and topics that promise more immediate results. As experience is gained and infrastructure improves, research should be expanded into new areas and new crops. The desire to help remote and poor areas should not preclude the development of seeds and technologies for more accessible farmers supplying consumption centers.

Independent Research. For some crops -- say export crops or perennial crops -- producers or traders already have organized themselves into associations. These organizations could carry out their own agricultural research activities for testing new varieties, selection, pests and diseases, and so forth. This is already taking place to some extent with oil palm and sugar, for example, and to a lesser extent with wheat in the Kivu region.

Open Borders for Seeds. Farmers should have equal access to varieties or materials developed outside Zaire. Success in the local generation of improved varieties can be measured in terms of how well they perform compared not just with traditional local varieties but also with varieties or hybrids developed elsewhere.

Crop Marketing and Research. The marketability of improved seeds depends on the marketability of the commodity in question. Agricultural markets in Zaire are bound by the severe limitation of its transport infrastructure. Product markets are regional at best, and costs increase rapidly with distances. Priority must be given, if self-financing is a concern, to those areas and those crops with a satisfactory system for marketing from farmers to consumers. Remote areas with inaccessible markets will be unable to generate the cash income to cover the price of seeds. Humanitarian criteria might still justify research in those regions to increase production for local consumption.

Manpower Planning. The extreme scarcity of adequately trained manpower in agricultural sciences makes it essential to base a national agricultural research strategy on realistic expectations about what can be accomplished. With only a handful of Ph.D.s in agricultural sciences in the country, and perhaps twice as many Master's, the expectations, scope, size, and complexity of the research program must perforce be kept modest.

Strengthening Management. Building a solid agricultural research institution requires more than technically qualified personnel. More of the difficulties encountered in RAV are attributable to management than to technical deficiencies. There is a dearth of well-trained Zairians in financial, manpower, stock, and production management. Using highly trained scientists for day-to-day project management is a misuse of their skills. The project needs to train for and strengthen its management.

Delivery is the Barrier. Most of the effort in agricultural research is concentrated on identifying an improved variety and multiplying its seed. The critical impediment for self-sufficiency, however, is marketing. Delivering seed and other farm inputs becomes prohibitively expensive in remote areas. Even seed obtained at no cost cannot be delivered at a profit to farmers in areas with poor access. The existence of a well-functioning product market for the commodity is a precondition for marketing the seeds.

Links with Other Inputs. For seed marketing to become commercially viable, seed delivery must be accompanied by the delivery of other physical inputs (fertilizers, tools, pesticides) and technical advice. Commercial enterprises are better suited to sales of inputs than government extension services. Nonprofit voluntary agencies can also get the job done, but maintaining continuity once they depart is difficult.

Adaptive Research. Given the limitations of trained manpower and geographical market size, agricultural research must concentrate at first on the simpler and less costly activities of testing for yields and adaptability of varieties brought in from other areas with similar climatic and soil conditions. More sophisticated crossing programs and selection to develop new varieties are costly and long-term undertakings that might not be justified for markets so limited.

Market Research for Seed. A market-oriented crop breeding program must develop its research agenda so that it satisfies the potential demands of its target clientele: farmers. Also, for commercial enterprises to invest in developing a distribution network for seeds and other inputs, it is essential to carry out preliminary surveys of the need for seeds of the main crops in well-defined regions. These surveys should determine the approximate demand to expect over time and should also identify bottlenecks and constraints encountered by farmers and distributors.

Financial Feedback. One effective means of making scientists who are engaged in crop improvement research responsive to the needs of farmers is to link their research budget to the proceeds from sales of the improved seeds. Crop programs that demonstrate good markets for their improved genetic materials should benefit from their success in the form of larger budgets. Programs that fail to show marketability after several years should be allowed to fade away.

Labor Constraints. It has been well established that in tropical Africa the most common limiting factor for agricultural production is the availability of labor, not land. In Zaire, especially, land pressure is not a serious concern.

RAV research usually has ignored the labor implications of the new varieties of maize and cassava. Implicitly, it is assumed that the improved varieties require the same amounts of labor. For cassava at least, this assumption is highly questionable. The farming systems components of the crop programs need to examine farm labor constraints and their implications for crop improvement research.

Outreach Stations Trials. Information from on-farm trials regarding the adaptability of the new varieties to the farming system of typical households has been rather uneven. It is inherent in the nature of on-farm trials that extraneous circumstances interfere with the trial and confuse the interpretation of results. An intermediate stage is to have outreach stations or village-level plots for adaptation and demonstration. The suitability of potential varieties to the soils of specific areas is tested more accurately in these plots. They will also show farmers the merits of the improved varieties relative to the traditional ones.

Experimental Farms. Potential savings in investment and recurrent costs could be realized by reducing the emphasis on establishing experimental stations. The level of infrastructure required to establish an experimental station and the associated maintenance are very high. Whenever possible, administrative offices, research laboratories, and housing for scientists could be placed in well-established cities or towns. Experiments could then be carried out in experimental farms not far from town. Greater mobility of researchers and field personnel also must be ensured.

I. MARKET-ORIENTED CROP IMPROVEMENT RESEARCH AND OUTREACH

Enhancing Financial Sustainability

The objective of this report is to examine the current financial situation of agricultural research in Zaire and to suggest possible ways to advance its eventual financial sustainability. To limit the scope of the assignment to manageable proportions, we shall concentrate our attention on the aspects concerning the USAID-financed National Applied Agricultural Research and Extension project, known by its French initials RAV (Recherche Agronomique Appliquee et Vulgarisation).

RAV consists of three main crop programs: PRONAM for cassava research, PNM for maize, and PNL for legumes. PRONAM is the oldest and most established program. PNM follows up an earlier CIMMYT project in the 1970s, but is still getting set up. PNL is the newest of the programs but is making big strides toward getting established.

USAID funds research on these three crops in keeping with its priorities to increase food production and to improve the welfare and nutrition of small farmers in the countryside. Research on other export and cash crops is left for other donors or private organizations to sponsor. In order to coordinate research on the three food crops, USAID and the Ministry of Agriculture established RAV as an umbrella program, separate from the nominal National Institute for Agricultural Research (INERA). Management difficulties and the fact that it is part of a separate ministry (Higher Education and Research) precluded the use of INERA as the coordinating body. (The Government of Zaire, with the support of the World Bank is defining a national long-term

strategy for agricultural research which includes the revitalization of INERA and several experimental research stations across the country.)

RAV depends completely on the financial support of USAID. During 1986-88, $2.5 million per year in foreign exchange was spent in technical assistance, training 35 scientists in the United States, and acquiring equipment and commodities. In addition, USAID uses the equivalent of nearly $2 million in counterpart funds to cover all annual expenses of the three subprojects in local currency. The actual value varies greatly because of the rapid inflation and devaluation of the zaire. For 1988 the total local currency budget for RAV was Z 225 million (see Tables 1 and 2 and graph).

Originally, in the project paper, the Government of Zaire was expected to contribute gradually greater shares of the local cost of the project; however, this has not happened. The critical economic situation of the country; the intractable problems of the government in collecting revenues, budgeting their use, and disbursing funds; and the lack of serious commitment to agricultural research have contributed to the non-performance of the national government.

So far USAID has been willing and able to increase the amount of counterpart funds to compensate for the shortage of government funds. But the question of the institutionalization and survivability of the program arises. If the program depends totally on USAID funds, it will surely fail if the funding stops. If funding is merely reduced, the issue is whether a viable program can be salvaged or whether projected objectives can be achieved by operating at a smaller scale. At any rate, USAID/Kinshasa has assigned great urgency to the sustainability criteria for agricultural projects. The Mission is particularly wary of creating projects that collapse at the end of the project life, when A.I.D. support is withdrawn and there is nothing to take its place. The sad experience of the North Shaba project is cited repeatedly as an example.

Table 1. 1988 R.A.V. Detailed Budget (Counterpart Funds)

	TOTAL	COORD	PRONAM	PNM	PNL
I. Personnel	121,709	9,440	55,257	24,800	32,212
a) Base salaries	27,685	1,366	13,208	5,488	7,623
b) Primes	86,475	6,322	38,844	17,836	23,473
c) Medical care	5,915	1,580	2,500	1,068	767
d) Social charges	1,634	172	705	408	349
II. Transport/Travel	27,079	8,355	5,600	7,412	5,712
a) Per diem	7,933	2,493	2,000	1,648	1,792
b) Travel tickets	4,221	1,673	0	1,288	1,260
c) Repairs/maintenance	6,846	2,236	900	2,600	1,110
d) Insurance	818	213	300	180	125
e) Provision accidents	249	249	0	0	0
f) Fuel	7,012	1,491	2,400	1,696	1,425
III. Office Expenses	16,639	10,764	2,444	1,756	1,675
a) Office equipment	1,589	0	350	604	635
b) Furniture	3,136	1,427	500	500	709
c) Bank charges	811	128	200	252	231
d) Printing	956	356	200	300	100
e) Maintenance	3,322	2,028	1,194	100	0
f) Rent	6,825	6,825	0	0	0
IV. Research Stations	22,638	0	7,650	9,312	5,676
a) Vehicle repair/maint	3,000	0	1,000	2,000	0
b) Vehicle insurance	548	0	400	148	0
c) Provision accidents	200	0	0	200	0
d) Fuel for vehicles	2,252	0	800	1,452	0
e) Tractors repair/maint	1,150	0	350	800	0
f) Fuel for tractors	3,190	0	2,000	752	438
g) Maintenance stations	3,200	0	1,450	600	1,150
h) Construction	500	0	0	500	0
i) Research equipment	2,970	0	500	1,324	1,146
j) Research furniture	4,528	0	900	1,436	2,192
k) Fuel for electricity	1,100	0	250	100	750
V. Public Relations	3,081	886	150	1,920	125
a) Receptions	2,111	586	100	1,300	125
b) MPR demonstrations	970	300	50	620	0
VI. Training and Forums	3,780	3,780	0	0	0
a) Training workshops	3,780	3,780	0	0	0
VII. IITA SUPPORT	29,093	29,093	0	0	0
VIII. Unforeseen Costs	800	0	800	0	0
TOTAL COSTS.....	224,819	62,318	71,901	45,200	45,400

Source: RAV

Table 2. Summary of 1988 R.A.V. Budget (Counterpart Funds)
(Thousands of Zaires)

	TOTAL	COORD	PRONAM	PNM	PNL
I. Personnel	121,709	9,440	55,257	24,800	32,212
II. Transport/Travel	27,079	8,355	5,600	7,412	5,712
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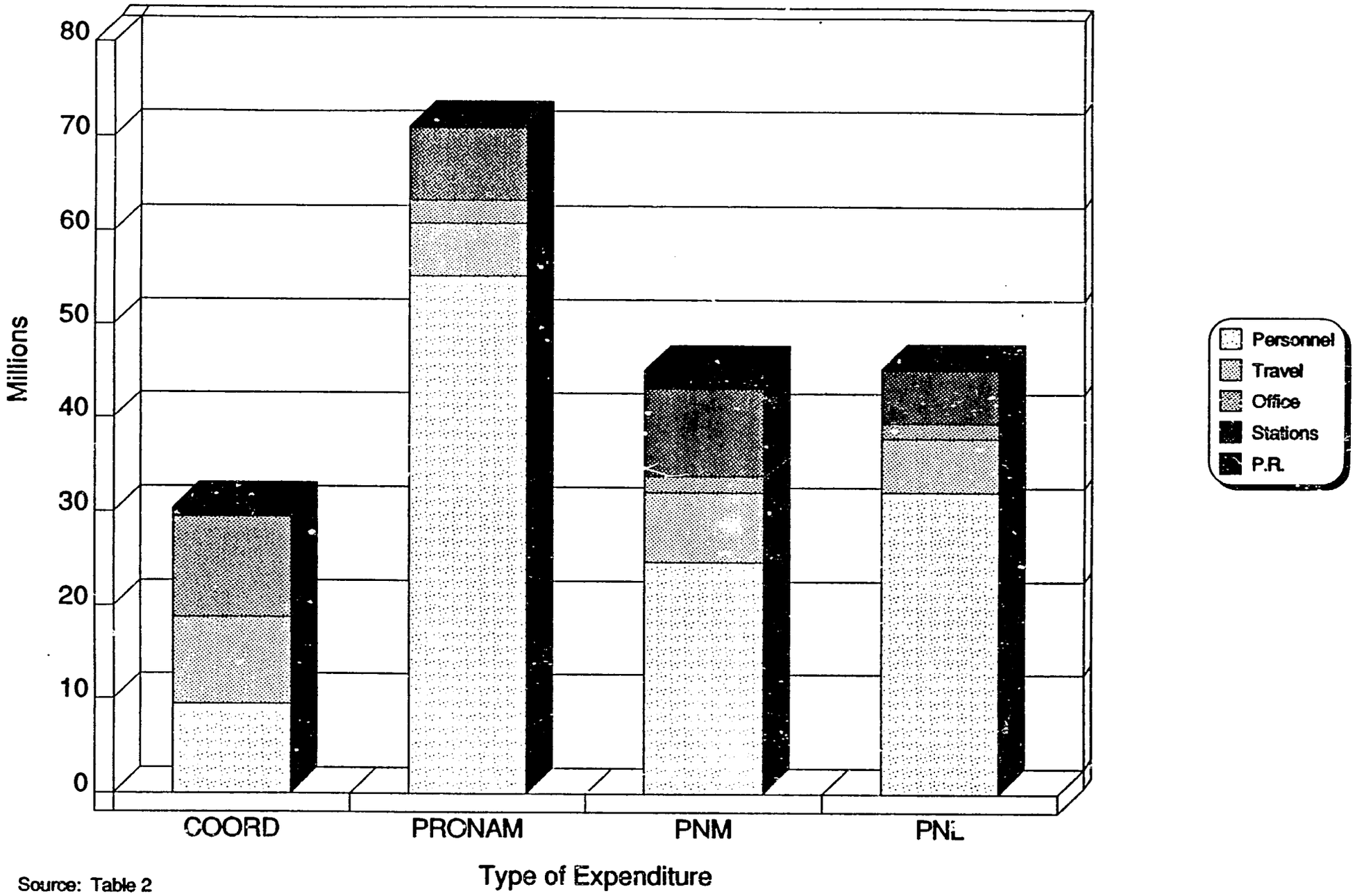
IV. Research Stations	22,638	0	7,650	9,312	5,676
V. Public Relations	3,081	886	150	1,920	125
VI. Training and Forums	3,780	3,780	0	0	0
VII. IITA Support	29,093	29,093	0	0	0
VIII. Unforeseen Costs	800	0	800	0	0
TOTAL COSTS.....	224,819	62,318	71,901	45,200	45,400

Source: RAV

1988 RAV Counterpart Fund Budget

(Millions of Zaires)



Source: Table 2

Alternatives for Financial Sustainability

At first we will focus on alternatives to the local currency budget, leaving aside the larger problem of foreign exchange support. The obvious first alternative to USAID financing of local currency expenses is for the Government of Zaire to accept this responsibility. Unfortunately, the prospects for government financing of agricultural research are nonexistent at present and dubious in the near future. Realistically, no program can be sustained financially by funding from the central government. The government has neither the resources nor the will to take over that responsibility. Several national and expatriate observers concur with this pessimistic assessment.

Government Support

Lack of government resources is the first impediment. Some rough figures help to put the problem into perspective. The 1988 budget for RAV was Z 225 million. The budget for the entire Ministry of Agriculture, nationwide, was a mere Z 145 million, and actual disbursements will surely be even less. Similarly, the national budget for the Ministry of Higher Education, Universities and Research is Z 140 million. Disbursements for certain dependencies of the government, however, notably those of defence, security, and police, consistently exceed their budgetary allocations greatly. In the opinion of one observer, the entire system of government expenditures is out of control. With the support of the IMF and the World Bank, the government is making valiant efforts to regain control, but the prospects for success are modest.

The low urgency or priority given to agricultural research within the overall structure of government priorities is another obstacle to state financing of crop improvement research. In 1987, the contribution of the government to RAV's local currency budget was Z 7.5 million, out of Z 196 million spent, or less than 4 percent of the total. In 1986 and 1985, the contributions were even lower. Given the long term nature and the

uncertainty of payoffs for research, it is only normal that other more immediately pressing needs receive the attention and funds of policy makers. Moreover, the recent performance and high cost of national research programs in tropical Africa do not encourage government officials to fund generously any research on food crops. With the exception of maize breeding and production in southern and eastern Africa, successful research programs have been few (Jahnke, *et al.*, pp. 103-5). The unavoidable conclusion is that the Government of Zaire probably will not be able to sustain the RAV project in the foreseeable future.

Special Taxes

Since general revenues cannot be counted on to finance agricultural research, can special taxes or levies be used instead? The use of special funds to finance research outside the regular budgetary process does not seem a viable option. For export crops such as coffee or industrial crops such as cotton, certain obvious marketing tools can be used to impose a levy that then can be channeled to fund research on those crops. Exports are shipped through ports, and cotton has to be ginned. Food crops for domestic consumption are not such easy targets. Few marketing channels can be monitored effectively for the imposition of levies. For cassava, for example, levies are out of the question since production, processing, and consumption are widely dispersed among thousands of households. Maize offers some possibilities, because a great portion of it goes through a few large mills that could be monitored and taxed to yield revenues to contribute toward the sustainability of agricultural research.

Basic administrative obstacles stand in the way of implementing a program of special taxes. The main one is the weak accountability of the funds collected. Independent funds based on parafiscal taxes already proliferate. The most important of these in the agricultural sector was the Fonds Agricole, raised as a tax on agricultural exports and administered by the Ministry of Agriculture to finance investment in the sector. Unfortunately, what happens to those funds is uncertain, and getting them disbursed by the

central government to the intended beneficiaries has proved difficult. Evasion of payments is also a serious problem that a parafiscal taxing program has to face. Inefficiencies in the public finance system and opportunities for graft and favoritism are unfortunate realities that must be taken into account. At any rate, under the structural adjustment program, the agricultural export tax that represented the revenue for the Fonds Agricole has been eliminated.

One promising instance of the use of special taxes for special purposes was the Office de Routes tax on fuel to finance road rehabilitation and maintenance. Since all fuel is imported, collecting and monitoring the tax is straightforward. Until recently, the Office de Routes was a beacon of hope in the public finance field. Unfortunately, recent economic developments, notably the devaluation of the zaire, have reduced the amount of funds, and disbursements by the central government have proven difficult. Right now, this promising route for development funding does not look hopeful.

The rural roads maintenance tax levied on the sales of motor fuel from the petroleum companies is similar to the fuel tax that was used to finance the activities of the Office de Routes and is going through the same difficulties. In general, the World Bank advises against special purpose taxes on the principle that all government resources should be subjected to the same performance and management criteria.

Auto-Financing

If agricultural research cannot count on funding from the general budget, and special taxes are also out of the question, are there any other alternatives? A crop improvement research program might try supporting itself. Seeds are the most cost-effective input available to a farmer, and improved seeds are the major product of the RAV program. If farmers in Zaire are going to pay for farm inputs, they will buy seeds first, before purchasing fertilizer, machinery, or pesticides. Seeds are small, of high value, and very productive in relation to their bulk. RAV estimates that the introduction of the improved varieties of cassava and corn can increase yields

at the farm level by about 30 percent. The financial question then is, can seeds generate enough money to pay for their own improvement? For some crops they can; for others, perhaps.

Next, we shall explore the prospects for auto-financing of crop improvement research in two contrasting crops, maize and cassava, and the implications for the future design of agricultural research programs.

Making a crop research operation self-supporting requires a considerable transformation of goals, structure, and procedures. Historically, agricultural research has been carried out by a state organization using station-based activities, financed by the central government or foreign donors, with vaguely defined outputs and objectives, and no worries about marketing its results. All these aspects need re-examining.

Reducing Program Costs:
Location of Experimental Stations

First, let us look at the need for remote, self-contained experimental stations. One telling contrast in the RAV program is the cost of operating two programs of comparable scope: PRONAM (Z 71 million) and PNM (Z 44 million). PRONAM has three times as many employees as PNM. One of the principal differences between the two programs is that PRONAM is based in a research station (Mvuazi), while PNM has only a research farm (Kaniameshi) near Lubumbashi. Most of the people employed by PRONAM at Mvuazi are not occupied in research at all, but in maintaining the entire infrastructure required for a handful of researchers to live comfortably. It required building a self-contained small town complete with electricity, water and sewage, streets, a school, a service station, a church, a hotel, and a clinic.

In contrast, the scientists for PNM live in Lubumbashi, also in relative comfort, and commute to the research farm 25 kilometers away whenever they need to supervise their experiments. At the farm, only modest structures are needed for shelter and for the guard. Since Lubumbashi provides all the urban

infrastructure and amenities needed, the maize research program is not burdened by the need to build an equivalent infrastructure or to maintain it afterwards.

The situation of maize researchers in Lubumbashi doing trials at the Kaniameshi farm is similar to the pattern of research in most U.S. land grant universities, where scientists work mainly on campus and the field tests are performed on research farms some distance away. One serious problem faced by PNM maize researchers, however, is that their offices and laboratory are on another farm out of town. This should be remedied by relocating them to a suitable building in town.

One undesirable result of setting up agricultural research around experimental stations is that when budgets are restricted, the normal reaction is to reduce funds for research while maintaining those for the upkeep of the station. Operational expenses for fuel and inputs are far easier to cut than personnel. The result is already evident in many research stations in Zaire: large populations of employees doing practically no research of value.

Experimental stations tend to be located in remote, inaccessible places far away from towns. Why? Most scientists would prefer to live in towns, and the great majority of farmers producing food crops for sale live around the major cities and towns where they can sell their products. Farmers producing for the market are the ones most likely to be interested in purchasing the superior seeds. Remote farmers who have no commercial outlets for their produce will have no means of paying back farm inputs, and the cost of making those inputs accessible to them becomes prohibitive.

Although farmers in remote and backward areas are more needy than those who living near towns and are hooked into the market economy, the issue is which farmers does the crop improvement research program want to reach. Where would the payoff from improved seeds be quicker and higher -- in the periphery of towns or in places accessible only by petit-porter?

Important national political considerations require that a proper balance of development resources be spent in the different regions of the country. Also, ecological differences require different research programs for different environments. These are valid factors influencing the location of experimental stations, and they should be recognized as such. The trade-offs between these factors and the objectives of quick-and-high payoff and sustainability of the crop research operation should be spelled out. While it is possible to have a self-supporting maize improvement program in the southern Shaba region, it may be impossible in Tanganyika or Equatoria.

High soil fertility in a particular site sometimes is given as a reason for locating an experimental station there. Unfortunately, the exceptionally good soils will also bias the research results, and might lead to recommendations unsuitable for farmers who do not have such good soils. Such an outcome is already reported for Mvuazi. The soils in the fertile valley where the station is located differ greatly from those of farmers who cultivate mainly hillsides. The cassava variety that performs best at the station, Kinuani, has not been accepted by farmers nearby; however, another variety that does not perform as well at the station, F-100, is reported to do well in farmers' fields.

Perhaps the greatest shortcoming of conducting crop improvement research in remote stations is that it hinders the delivery and marketing of research results. A good illustration of this is the problem of distributing cassava cuttings from the Mvuazi station. Since the station is in an isolated valley 30 kilometers from the paved road, most smallholders find it impossible to reach the station to procure cuttings. The net result is that large farmers able to hire large trucks are most able to get cuttings of the improved variety. The lack of dissemination of the cuttings among the general farming population has been disappointing.

Reducing Program Costs:
Number of Personnel

Another promising route for enhancing the financial self-sufficiency of a crop improvement program is trimming down the often bloated payrolls. In

July 1988, the RAV program had more than 1,000 employees distributed in the three crop programs throughout the country. Only three are Zairian scientists with doctorates and only five have master's degrees. There is also a contingent of about a dozen expatriate advisers provided by IITA. It is difficult to justify the need for so many laborers and support staff for so few researchers.

The program directors were aware that the number of employees was too high and interfered with research by taking away financial and managerial resources. Nevertheless, they did not trim personnel when the budget requested for 1988 was cut by half. The bureaucratic response to budget cuts is to sacrifice the output and keep the personnel. Public budget allocations are often based on how many employees an agency has, not on how many pounds of improved seeds or meters of cuttings are distributed. This lack of correspondence between output measurements and resources made available explains many of the inefficiencies observed. In the end, USAID demanded that the payroll be cut by 25 percent in an effort to free funds to pay for research, as well as to increase the salaries of those remaining. The project has accepted and is carrying out this directive without seemingly great disruption.

A sad consequence of the excessive manpower syndrome is the amount of time that scientists spend on administrative and personnel matters instead of on research. Both Zairian directors of PRONAM and PNM are eminent scientists in their own fields, but neither is left with enough time for research because of the continuous pressures and crises of managing the programs, an activity for which their technical training is of little help. Professional managers should be hired to take the administrative load off the crop program directors.

Insufficient attention to management requirements is a serious shortcoming common to many agricultural research organizations in Africa. The demise of INERA was largely the result of plans that were excessively ambitious in relation to the level of resources that the government or donors

could provide. Good financial management is essential both for internal control purposes and for maintaining confidence among donors that their monies are well spent. Problems of untimely disbursement of funds and procurement of equipment and vehicles have caused many delays and inefficiencies in the RAV program. In recognition of these weaknesses, USAID has moved to strengthen the central coordination office for RAV, but serious problems persist at the crop program and research station levels.

Flexibility in adjusting personnel numbers and remuneration rates to match the level of resources available is hampered by the public-agency status of the agricultural research program. When the national government contributes the bulk of the budget for the organization it is logical that the service should operate under the same rules and regulations as the rest of the government; however, the efficiency of a research organization can be hindered by bureaucratic procedures and the civil service rules. In the case of RAV, the contribution by the national government is modest, while the costs and rigidities arising from being a state agency are great. Civil service labor regulations, for example, make it extremely difficult to fire employees for cause, or to cut personnel when they are no longer needed. The crop research program might be better off if it shed its state-agency status -- saving the government some funds, but gaining greater operational discipline and flexibility by becoming an autonomous research institute. The economies gained from better management will probably compensate for the loss of government budgetary contributions. A national government interested in seeing viable and self-supporting crop improvement programs will probably be happy to liberate them from its tutelage. Conversely, USAID might prefer to create autonomous institutes with a decent chance of becoming viable concerns, rather than state agencies indefinitely dependent on its funding.

Increasing Program Revenues through Marketing

We have looked at ways to reduce the cost of crop improvement programs as a way to increase their future viability. Now, we turn to explore

options that contribute to revenues from either the sale of research outputs or the provision of technical services to other organizations.

A fundamental change would be required in the orientation of a crop improvement program in order to make it self-supporting: the outputs of the research must be marketable. That is, farmers must find it in their interest to purchase the improved genetic materials developed by the program, be they seeds or cuttings. Unfortunately, few agricultural research efforts in Africa have been aimed explicitly at developing marketable products. Historically, the results of research have simply been passed along to state-run extension services for dissemination to farmers. Researchers seldom concern themselves with the marketability of their results. However, if the survival of the crop research program itself depends on how well the outputs sell, scientists can no longer afford to disregard the market potential of the genetic materials they are working on.

Two separate questions arise in considering the market for seeds or other genetic materials: will farmers buy them and at what price, and how can the marketing system be most advantageously organized?

Both the maize and the cassava programs have identified varieties that perform better than the local varieties. PNM has successfully produced and distributed seeds of two improved varieties of high and middle altitude maize (Shaba I and Kasai I), especially in the Shaba regions. Enough new seeds of these varieties to plant 12,000 to 15,000 hectares are distributed yearly, but the impact is much greater since the resulting grain can be reused as seed for a couple of years.

PRONAM has been less successful in disseminating the two cassava varieties identified (Kinuani and F-100), especially around Mvuazi in the Bas Zaire region, where the program headquarters is located. Less than 5 percent of the cassava area in two monitoring villages is planted with the new varieties. In Bandundu region, however, F-100 has been disseminated more successfully. The contrast reflects in part the differences in the marketability

of the genetic materials for the two crops: seeds for maize, and cuttings for cassava.

Marketing Maize Seed

Commercial maize seed marketing is rapidly becoming a reality in Zaire, especially in Shaba, the main production and consumption area. This opens the door for the maize improvement program to develop new seeds that will generate enough funds directly from the sale of seed to contribute to its own financing. A few figures help put the possibilities into perspective.

The market for commercial maize seed in the Shaba region alone is estimated at about 400 tons, enough to plant 16,000 hectares producing 24,000 of the 180,000 tons of grain produced in the region. The current price of maize grain in southern Shaba is about Z 30 per kilogram. If commercial seed can be sold at five times the price of regular grain, a common rule of thumb, the price of seed would be Z 150 per kilogram. The 400 tons of seed could therefore generate a gross revenue of Z 60 million. Even if seed production costs reach Z 50 per kilogram, or Z 20 million total, Z 40 million would be left for the seed suppliers.

The budget in 1988 for PNM is just Z 44 million. A good portion of the recurrent costs of the PNM program could be covered if the program could share in the profits from the commercial production and sale of 400 tons of seed, the equivalent of 200 hectares of seed maize. True, marketing costs will reduce this figure substantially, but as the market expands in the future, the potential for seed sales to cover research in maize is a real possibility.

Two reservations are raised regarding production of seeds for sale. First, INERA reportedly attempted to raise revenue at its experimental stations by entering crop and livestock production, only to lose money and forget about research. It should be clear that what is being suggested is the <u>marketing of the results of research</u>, not the production and sale of products unrelated to

the research. PRONAM is already engaged in large-scale production of cassava for cuttings, and no one claims that the research has suffered as a result.

Second, it is feared that the pursuit of sales and profit will distort and pervert the social mission of research. This point is highly speculative, but we do not accept *a priori* that the search for marketable research outputs results somehow in socially undesirable outcomes.

Great strides are being made in establishing a commercial market for maize seed in Shaba. Both the World Bank and the USAID projects in the region emphasize the need to promote seed sales to farmers, private marketing of seeds, and private production of commercial seed. BUNASEM, the National Seed Bureau established with World Bank financing, is helping establish two seed farms in southern Shaba with credit, equipment, and technical assistance. One of the farms, Trabeza in Fungurume, has just produced 200 tons of seed for sale this coming season. The same company has a contract with USAID's Central Shaba project to establish and operate a commercial distribution center for seeds in the project area. A sliding-scale bonus system is designed to encourage Trabeza to maximize its sales. The coming planting season in October and November will see a lot of interesting activity in maize seed marketing. The financial sustainability of the maize improvement program may hinge on the success of the commercial channels.

In order for PNM to capture the potential revenues from maize seed sales, it is not essential for the program itself to engage in producing commercial seed and selling at competitive prices. Since, for practical purposes, it has a monopoly over the supply of foundation seed, it is in a position to extract a reasonable share of the rents that otherwise will go exclusively to the seed producers and distributors. Selling foundation seed to seed farmers at competitive prices (perhaps over Z 1,000 per kilogram) could contribute significantly to support PNM's annual research budget. Since other project units are already producing commercial seed, PNM could specialize in producing and selling high quality foundation seed to them. It is essential that PNM monitor the maize seed market carefully in the coming months in

order to get better estimates of the market potential for maize seeds and, accordingly, to decide on a pricing strategy for the foundation seed.

Marketing Cassava Cuttings

Marketing cassava cuttings in Shaba does not offer as optimistic a picture. Several factors make it extremely cumbersome and costly to market cassava cuttings. Cuttings are bulky (25 centimeters long and 5 centimeters thick). They are perishable, with a viable life of only three to four days before planting. A large volume is needed to plant one hectare (2,500 meters of cuttings). One hectare generates cuttings for only six new hectares, and only if harvested at planting time. Coordinating the delivery of cuttings with the time farmers are ready to plant presents insurmountable difficulties. Planting takes place during the rainy season, when farmers are least accessible by vehicle. Transporting cuttings is very costly and requires motorized transport for large enough amounts. There is no tradition of marketing cuttings (although frequent reports of stealing would indicate a ready market waiting to be satisfied).

PRONAM has made no attempt to market cuttings. The current dissemination strategy in the Bas Zaire region is to multiply the selected varieties in large areas -- 80 hectares in Mvuazi, for example -- and then distribute cuttings by the truckload, either to large commercial farmers or to collaborating organizations like Oxfam, for subsequent distribution in their areas of action. To judge by the low percentage of area cultivated with the improved varieties, even in well-located villages, it seems that this distribution strategy is not working.

In Bandundu, small multiplication centers were spread out over the region. The greater accessibility to farmers is reported to have resulted in far greater distribution of the F-100 variety cuttings.

The distribution problem is one of farmers' acceptance of the new varieties as well as of accessibility to cuttings. The two new varieties have

consistently better yields, more resistance to disease, and earlier maturation than the traditional varieties. The Kinuani variety, despite its higher yield in Mvuazi, is reported to have acceptance problems. Some of the problems are that it has a different flavor and higher water content, that it does not keep well in the ground past maturity, that its tubers are too large and take longer to dry, and that it does not yield as well in farmers' fields. Moreover, cuttings are inaccessible to farmers at the time they are planting their fields. Few farmers can afford to hire a truck to go to Mvuazi for a day. And the once-a-year distribution by voluntary organizations is very uncertain. Understandably, some farmers resort to stealing cuttings from neighbors' fields. Many farmers would probably be willing to pay for cuttings if they were available at the right time at an accessible place.

The difficulty in Bas Zaire arises out of PRONAM's decision to concentrate the multiplication of the improved varieties at the Mvuazi station, so inaccessible to most farmers. Given the transport difficulties, the cost, and the short life of the cuttings, dispersing multiplication to many lots spread throughout the region within reasonable distance of many farmers would seem more appropriate. Producing seed in one central place makes sense for maize because the seed amount needed per hectare is so much smaller, easier to transport, and longer lasting. But for cassava, the dispersal strategy makes more sense. The more successful effort in Bandundu along these lines corroborates this approach. Village lots of a few hectares each could be established under the care of a private farmer or extension agent, who could sell cuttings to farmers at whatever price they can fetch when the farmers are ready to plant. The revenue from cuttings and tubers would more than compensate for the costs of this method of distribution.

Some rough calculations indicate a high payoff for cassava cuttings: Z 96 per meter of cuttings. A farmer introducing a cassava variety producing 30 percent higher yield will produce 4 tons of cossettes instead of the usual 3 tons from the traditional varieties. At Z 40 per kilogram, the extra ton brings Z 40,000 per hectare. However, since one plant produces enough cuttings for five plants and more, the farmer needs to purchase one-fifth of a

hectare the first year, or 500 meters of cuttings. In two years, total revenue increases Z 48,000 or Z 96 per meter of original cuttings. To be sure, labor requirements for the improved cassava variety might be higher, and the benefit ratio would diminish accordingly. If the farmer is willing to share 25 percent of that gain with the supplier of the cuttings, a price of Z 12 per meter would be satisfactory to him. The current price PRONAM charges private farmers, Z 1 per meter, seems unjustifiably low.

Nevertheless, the prospects for recovering significant amounts of revenue for PRONAM from the sale of cassava cuttings are not promising. Not because farmers are not willing to pay a high price, but because the marketing costs to reach farmers away from the station would be equally high. The principle of pricing cuttings at competitive rates should still apply, especially since farmers are also able reuse and resell cuttings to other farmers.

Even if marketing cuttings does not generate funds to pay for research, the marketing task would be self-supporting by itself, and the wider impact would make it easier for donors like USAID to justify continued financing of research on the basis of its social benefits. As it is now, the impact is apparently so weak and the social benefits so small that a sponsor must question the wisdom of additional research work if the varieties do not leave the station in significant volume. The biggest challenge for cassava improvement is perhaps not in research, but in finding a cost-effective way to distribute the cuttings.

Great social benefits should be expected from the widespread adoption of improved cassava varieties. Not only does cassava contribute the bulk of calories in the Bas Zaire and Bandundu regions, it also contributes most cash income for farmers in both regions. That is to say, it is both the main cash crop and the main subsistence crop.

External financing of research on cassava improvement should be readily justifiable on the basis of these tangible social benefits and the difficulties the market mechanisms have in capturing a sufficient portion of these benefits.

In such a case, research in cassava has the characteristics of a public good with large positive externalities that justify public (donor) financing.

II. AUTO-FINANCING MAIZE RESEARCH IN ZAIRE

The National Maize Program (PNM) is the RAV component charged with selecting improved varieties of maize adapted to the conditions of the different regions of Zaire. Most maize consumption and production is concentrated in the Shaba region, so the PNM is headquartered near Lubumbashi. Branch units attached to experimental stations in other regions give the program a national scope: Mvuazi for Bas Zaire, Kiyaka for Bandundu, Gandajika for Kasai, and Kaniama for lower Shaba.

PNM receives roughly 20 percent of the RAV local currency budget, or Z 45 million out of Z 225 million for the entire RAV program for 1988. It employs a slightly smaller proportion of personnel. Out of roughly 1,000 employees in RAV, PNM accounts for only about 170 employees, 95 of which are based at headquarters in Lubumbashi. The rest are based in regional experiment stations: 33 in Kaniama, 29 in Gandajika, and so on. The low percentage of employees in Lubumbashi reflects the absence of a home-base experimental station. The beans program (PNL), a smaller and more recent program, accounts for 200 employees in its main base, Guandajika. (These personnel counts reflect the employment audit made in May 1988 by RAV. At the end of July 1988, A.I.D. requested a 25 percent cut in employment from RAV, resulting in the loss of 245 employees: 163 from PRONAM out of 537, 25 from PNM, and 57 from PNL).

In terms of output, PNM cultivates an estimated 10 hectares of maize in both scientific testing plots and multiplication plots for selected varieties. (This is my estimate, for lack of a more accurate figure. Total foundation seed production for 1988 was 3.5 tons; this corresponds to about 2 hectares of multiplication area. If testing and breeding plots occupy four times as much

land as the multiplication plots, this would add up to about 10 hectares.) This amounts roughly to 10 man-years per cultivated hectare, compared with an average of 140 man-days applied by ordinary farmers in Shaba. The comparison is not quite appropriate, since these are experimental plots that require far more careful work.

Research Stations and Off-base Research

The National Maize Program illustrates the serious financial consequences of placing all agricultural research activities in experimental stations. Unlike the other crop programs, PNM normally finishes the year with a surplus of local currency budget, which other components are ready to use. The main reason PNM is the cheapest RAV component is the absence of a central experimental station. Initially, the program was intended to set up an experimental station in Kaniameshi, a large property some 25 kilometers from Lubumbashi. Unfortunately, or fortunately depending on one's point of view, there were title difficulties; Gecamines claimed it belonged to them, and not to the Shaba regional government.

The lack of clear title prevented the project from building any infrastructure. Temporarily, housing for the scientists was provided in Lubumbashi, and office and laboratory space was established in Kasanga, a large farm belonging to the Presidency in the outskirts of Lubumbashi. For the past three years, PNM researchers have been living in Lubumbashi, going to the office or laboratory in Kisanga, and doing field work in Kaniameshi. PNM also maintains an office at the regional Ministry of Agriculture office.

This arrangement has been very unsatisfactory to the PNM researchers, particularly because the offices and laboratory in Kisanga are scattered in several modest farm buildings. Under the circumstances, it is remarkable that the scientific work on maize breeding and variety testing has proceeded without major interruptions. A shortage of vehicles is a serious problem, since office workers and field hands need to be moved to both the Kisanga and

Kaniameshi farms. The few vehicles available have been able to compensate with mobility for the absence of infrastructure at Kaniameshi.

Now that title to Kaniameshi has finally been ceded to the State, the question is whether the PNM experimental station should be built in Kaniameshi. There is no doubt that the agricultural scientists involved strongly prefer to have an experimental station of their own with all the small-town infrastructure that it entails. The proximity to Lubumbashi, only a half-hour drive, also makes life convenient for researchers and their families. Nevertheless, there are the questions of the cost of constructing all the required infrastructure and, more important for our case, of the sustainability of PNM activities if the support from A.I.D. were reduced. I argue that, given the proximity to Lubumbashi, PNM should think of Kaniameshi as an experimental farm (not station), and shift most of its office and laboratory to Lubumbashi.

The main argument for keeping the researchers housed in Lubumbashi is that moving them to Kaniameshi, a minimal distance, will require providing all the modern infrastructure for a small community (electric plant, garage, clinic, schools, sewage, radio-telephone, water supply). All this infrastructure is readily available now at Lubumbashi. Expatriate families with school children probably would commute to Lubumbashi for shopping and schooling anyway. Of course, rent and housing allowances would have to be paid to expatriate principal program officers, since housing at experimental stations is free. If the foreign financing were reduced, the Government of Zaire would be able to concentrate its resources on financing research activities, without the burden of maintaining an extensive and unused infrastructure.

Moving the administration and laboratory from Kisanga to Lubumbashi is also more advantageous than moving it to Kaniameshi, and for similar reasons. Communication by telephone, telex, radio, and courier are already well established. Utilities are reliable. Easy access to the airport facilitates traveling and receiving visitors. Established distributors can service office and other equipment more easily. Contacts with other projects, commercial

firms, and the government would also be facilitated. Office personnel and laboratory technicians would find their own housing and arrange for their own transportation, instead of being housed and transported at project expense.

These and other considerations have led other projects to establish their headquarters in Lubumbashi, even though their zones of operations are far from it. The World Bank's South Shaba project (Hinterland Minier) has recently set up offices in town, even though the principal areas of interest are around Likasi and Kolwezi. Similarly, USAID's Central Shaba project is commanded from the A.I.D. Shaba Area Development Office in Lubumbashi, although its zone of operation, Central Shaba, is at least three days away by road.

The experimental farm in Kaniameshi would still require the construction of some facilities to protect the machinery, store inputs and tools, house a guardian and a few permanent laborers, and shelter workers and researchers during the day. But the costs of these buildings and facilities are modest compared with what would be required by an experimental station.

We are well aware that tradition has it that agricultural research is carried out in experimental stations, and this is the norm in most developing countries. Most agricultural research in U.S. land-grant universities, however, takes place in experimental farms usually one hour or more away from campus, while professors and scientists, along with their research assistants, work most of the time at their offices or labs on campus.

The point is that experimental stations require a huge investment in infrastructure that is later very costly to maintain. If the same infrastructure is readily available in a nearby town, it makes sense to take advantage of it, and do only the field work at the station. This reduces the cost of agricultural research and improves its sustainability during hard financial times.

Fungurume

One more option for the location of PNM has appeared recently: an abandoned mining town built by an American consortium 10 years ago and never used. The town is complete, including street signs and bus stops. It was bought by an enterprising Belgian, who has established a farm and would like to make the town usable for other purposes. Fungurume, or more precisely, the Trabeza farm, is about a one-hour drive from both Likasi and Kolwezi, and three hours from Lubumbashi. Since all the housing and infrastructure needed is already in place, all PNM would need to do is rent it, probably for a good annual price.

PNM officials and scientists are cool to the idea of setting up headquarters in Fungurume, despite the realization that there is more maize production around the Likasi area. Their reluctance partly reflects their lack of involvement in the decision and their current attachment to Kaniameshi. But a valid objection to Fungurume is the isolation, compared with the cosmopolitan atmosphere in Lubumbashi. This is a particularly important factor for expatriate researchers with families, especially those with school age children, who might otherwise be happy to join the PNM program. Communication, transportation, and contacts with other projects and people are valid benefits that would be lost in Fungurume. Other projects, notably the South Shaba project and A.I.D.'s Central Shaba project are actively working with the Belgian owner in the production and distribution of maize seed. However, neither of these projects would consider setting up headquarters in Fungurume, even though the same locational advantages would apply.

Fungurume offers many possibilities for PNM to do research away from the Kaniameshi farm. There is much to be said for doing varietal testing and demonstration plots in areas closer to the major zones of maize production. Such possibilities of joint work should be explored regardless of the site selection for the headquarters of PNM. Mr. Coutenier, the Belgian farmer, is most agreeable to cooperate in any way.

South Shaba Project

The South Shaba project (Projet Hinterland Minier de Shaba) is financed by the World Bank mainly to promote maize production along the Kolwezi-Likasi-Lubumbashi corridor. Part of the activities of the SSP include a program of applied research at the field level. Included in such a program would be the establishment of at least 10 adaptation and demonstration sites at the sites of cooperating organizations spread out over the project area. Some of these sites are in commercial farms like Gecamines Developpement at several sites, Trabeza in Fungurume, and Sodimiza in Tshinsenda. Other sites are located in development projects of religious organizations: Catholic Missions in Kanzenze and in Bunkeya, the Protestant Mission in Mulungwishi, the Orthodox Church in Kolwezi.

RAV has been approached by the South Shaba project to provide the technical expertise needed to establish and conduct these village-level tests, since the cooperating organizations are poorly prepared to do this type of technical work. Specifically, PNM is being asked to organize the varietal adaptation and demonstration tests.

Each test and demonstration site will consist of a plot of 2.5 hectares, of which 0.10 hectares (33 square meters) will be dedicated to maize. The remaining area will be used for cassava and legume crops. The maize tests will include both varietal and fertilizer tests. Ten varieties thought promising for the southern Shaba area will be tested in each site, including PNM's Shaba I, PNM 1, SR-52, TZMSR, and SEED COOP varieties. Three replications of each variety will be made, and fields will be fertilized and treated with herbicide at planting and weeded manually thereafter. In each site, the 30 plots will occupy a space of 30 meters by 20 meters.

PNM has responded positively to the request from the South Shaba project and has provided a technical proposal indicating how it intends to carry out the tests. The two principal scientists responsible will be Dr. Mulamba and Dr. Johnson. A budget for a five-year joint program has

been prepared, for a total of Z 12 million, including Z 5.5 million for the purchase of a four-wheel drive vehicle. (See Annex A for a set of documents concerning the SSP-RAV joint program.)

The proposed joint testing and demonstration program in the South Shaba project area represents a promising mechanism for contributing to the support of agricultural research. It is mutually advantageous to PNM and the development projects that are primarily interested in the results of its research. At the same time, these joint plots contribute to the PNM's efforts in field testing promising varieties and reaching out to farmers.

The budget presented by PNM to the South Shaba project covers only part of the resources needed to carry out the task. For example, it includes the salary for a new full-time agronomist in charge of supervising the 10 plots and a half-time laborer, but leaves out charges for the time Dr. Mulamba, Dr. Johnson, and other PNM scientists and technicians will surely spend on the sites. They are excluded on the grounds that their salaries are already being paid by A.I.D. or the Government of Zaire. Of course, charging for their time does not mean that they personally will get double pay. It means that what PNM can get for their time and services will help finance PNM activities, including research activities, equipment, and facilities.

Another major omission in the PNM budget to the South Shaba project is an overhead and administrative charge. Any autonomous or private institution, even non-profit institutions, normally includes substantial overhead charges over and above its costs. If the project were to ask a private research outfit to provide the same technical assistance that PNM will provide, a charge of 100 percent over the salaries and fringe benefits of personnel would be expected. Overhead charges cover the cost of the physical, administrative, and institutional infrastructure necessary to carry out the tasks. For agricultural research institutions, the establishment and maintenance of this infrastructure constitutes the major expenditure in their budget.

PNM's omission of billing for the time of its experts and for overhead charges makes the joint testing program advantageous for the South Shaba project and disadvantageous for PNM. The project is getting a bargain compared with what it would have to pay for the same services from any commercial or non-profit but self-sustaining institution. PNM is engaging in a deal that covers part of its recurrent costs (fuel and inputs) but none of its considerable overhead costs. Moreover, it will add to the demands upon the time of its researchers. As a result, the joint testing program will constitute a net drain on PNM resources. Time and dedication to the program will then be kept to a minimum, and performance will suffer. Undercharging for research services, as many consulting firms have found out, is a sure prescription for eventual failure.

One final observation: the budget as presented covers a five-year commitment and all monetary figures are in zaires. Only a 15 percent contingency for unforeseen expenses is included. No allowance for inflation or devaluation is made. Given the current rate of inflation of more than 50 percent, PNM is bound to short-change itself severely. To protect its interests, PNM could make a budget for only the first year, leaving subsequent years to be negotiated later, and present figures in dollars to allow for depreciation of the zaire. One justification for the five-year budget is that the South Shaba project is willing to pay for the acquisition of a Land Rover, which it might not be willing to do for a one-year contract; however, PNM could simply charge for the use of a Land Rover for, say, eight months at US$ 60 per day (US$ 10,500 per year) and US$ 0.20 per kilometer (US$ 2,000 for 10,000 kilometers), and get US$ 12,500 in just the first year. At Z 200 per dollar, PNM would get Z 2.5 million. This is exactly what the current PNM budget charges the South Shaba project for one entire year of operations (Z 12 million for five years).

Discussions in Lubumbashi with officials at the South Shaba project regarding the principle of PNM billing the project as if it were an independent research entity received a favorable and understanding hearing. Unfortunately, the opinion of the project director, Dr. Mateso, was not

obtained; he was away on business. The project officials suggested that the matter be referred for discussion and agreement between the South Shaba project, RAV, PNM, and the Ministry of Agriculture. In principle, the South Shaba project does not seem to object to paying another project for services rendered, as long as the performance is satisfactory.

We acknowledge, however, that PNM itself has expressed reservations about the correctness of charging another official organization for PNM's cooperation. Their view is that since PNM is a state institution, it should lend its help to other government bodies, at the request of the proper authorities, without seeking any financial benefit. Only charges for those resources not at hand would appear legitimate. (That is, it could charge for the additional laborer, but not for the staff scientists.) The cost of financing agricultural research is then viewed as a separate matter that the central government must decide to fund. Besides, PNM says, what is the use of taking money from one government project to give it to another project? It is equivalent to taking money from one pocket to put in another.

Two commendable attitudes seem to be at the core of PNM's reservations: (1) agricultural research scientists should pursue more noble goals such as the advancement of knowledge or the betterment of people and reject the more mundane concerns of monetary matters; and (2) PNM, as an institution supported by the State or foreign aid donors, should be above being run on business criteria like daily rates and overhead charges. Its scientists have a mission, and they should be supported as necessary to fulfill it, without the pressure of budgets and bottom lines. Another way this view is expressed is that researchers should be given well-defined guidelines and then left alone to follow them, isolated from considerations about marketing their output.

I will not attempt at this moment to address these reservations. It suffices to recognize that it is not altogether evident to everyone that an agricultural research institution should contribute to its own funding by charging competitive rates for its technical assistance.

Seeds Marketing and Pricing

In the final analysis, the sustainability of agricultural research (on varietal selection) in maize will be determined by the capability to market its output -- improved seeds -- at a price sufficient to cover costs; therefore, it is essential not only to orient the maize improvement program toward satisfying a real market, but to design it to match the prospective market growth potential for improved seeds.

Farmers are the ultimate clientele of the agricultural research program. Their decision to adopt the improved varieties generated by breeders and other scientists of the agricultural research program is the best indicator of the success or failure of the program. Their decision is primarily based on the expected gains and risks of changing to the new varieties, and on how well the new cultural practices blend with the rest of the household economy.

Unfortunately, the scientists doing the research and the farmers getting the seeds are far removed by physical as well as cultural, economic, and institutional barriers. In a well-functioning commercial agricultural subsector, market mechanisms eventually establish a communications system informing the breeders whether farmers accept their output. If farmers buy the seed, their job is well done; if farmers do not buy, no matter how many virtues the new varieties have, the breeders' efforts are useless.

There is, however, no established seed market in Zaire, although several organizations are trying to develop a viable market for maize. A delivery system for getting seeds to the farmer does exist, through a variety of programs and projects. But a delivery system does not constitute a market, because the agents involved are acting in accordance with motivations other than economic criteria. A missionary distributing seeds among his parishioner farmers is not likely to give much consideration to commercial gains and losses.

Maize farmers in Shaba have already been well exposed to the new maize varieties. Maize production in Shaba has shown an astounding performance during the 1980s; farmers have responded to improved marketing opportunities for maize by raising their output enough to make Shaba not only self-sufficient in maize but also a net exporter to the neighboring Kasai province. Higher prices, improved roads, new varieties, and a good extension service combined to induce expansion of maize production at remarkable rates. In this sense, the story of maize in Shaba is one of remarkable achievement. The success of the North Shaba project is matched by few other A.I.D. agricultural projects in Africa.

Marketing opportunities appeared partly as a result of the economic measures adopted by the Zairian government in the early 1980s under its economic adjustment program. The devaluation of the zaire, for example, made it prohibitively expensive to import maize, and increased domestic prices. The North Shaba project built feeder roads linking a fertile zone to the rail line that made it possible to transport the maize cheaply to the large urban centers in Southern Shaba. Introducing improved varieties through a well-motivated extension service provided the means for farmers to take advantage of the new market opportunities.

Now that farmers are conscious of the benefits of the improved varieties over the traditional ones, the project is shifting gradually toward making farmers pay for the improved seeds, in order to transform seed distribution into a self-sustaining commercial delivery system. Most maize farmers in Shaba are now cognizant of the maize market, and marketing considerations have become part of their economic calculations; therefore, decisions to purchase seeds of the improved variety reflect more careful consideration of the economic advantages of doing so, whereas the initial credit for such purchases could be given to the persuasive powers of extension agents.

Table 3 illustrates the sort of calculation that a farmer must make to evaluate the advantage of using improved seeds for maize. The table is taken out of the World Bank's *Staff Appraisal Report for the Zaire Seeds Project*

Table 3. Return to Farmers' Family Labor from Improved Maize Seed

(Area: 1 hectare)

Item	With Local Seeds Priced at 7 Z/kg	With Improved Seeds Priced at 20 Z/kg 1/	30 Z/kg	35 Z/kg 2/	20 Z/kg 3/
Labor days	143	160	160	180	160
Seeding rate (kg/ha)	35	25	25	25	25
Yield (kg/ha)	900	1,300	1,300	2,000	1,040
Producer price (Z/kg)	7	7	7	7	7
Production cost (Z) 4/	525	900	1,130	3,170	900
Gross income (Z/ha)	6,300	9,100	9,100	14,000	7,280
Net income (Z/ha)	5,775	8,200	7,970	10,830	6,400
Income to family labor (Z/man day)	40	51	50	60	40
Improvement ratio of income to family labor	1.00	1.28	1.25	1.50	1.00
	Using F1 of controlled composite maize seed 5/				
Income to family labor (Z/man days)	46	51	49	60	n.a.
Improvement ratio	1.00	1.11	1.07	1.30	n.a.

1/ Average seed price in year 1 estimated at about 25 Z/kg.

2/ Model with use of fertilizers: 50 kg at 20 Z/kg, pesticides 25 Z, hire spray equipment 20 Z and construction cribs 1, 250 Z.

3/ At a yield of 1,040 kg/ha the return to family labor with controlled and local seeds is the same.

4/ Other costs for models without fertilizer are: bags (20 Z/bag) and tools (80 Z/ha).

5/ Farmers could buy from neighbors the F1 or F2 of controlled composite maize, which would give yields of about 1,100 kg/ha. He would pay for such seeds a price of about 10 Z/kg. In that case the profit from controlled seeds should be sought in better husbandry and the use of fertilizer.

Note 1: The switchpoint for seed price is about 50 Z/kg for the respective returns to family labor to be equal. However, the farmer using controlled seeds expects in general the yield and the income return to family labor to increase by at least 25%. In that case the maximum seed price would be about 30 Z/kg.

Note 2: If increased production lowers producer prices the price can drop to 4 Z/kg, at which level the maximum price will be 25 Z/kg, which is the projected sales price.

Note 3: The income return to family labor is considerably above the average cost of hired labor, about 14 Z/kg.

Source: Zaire Seeds Project, 1985.

(BUNASEM) (May 1985). The monetary values are in 1985 zaires but illustrate the basic procedure. Using traditional varieties, one hectare of maize requires 35 kilograms of seed, 143 days of labor, and Z 525 in inputs (including seed), and the expected yield is 900 kilograms. With improved seed, more labor is required (160 days) but less seed (25 kilograms). The expected yield is 1,300 kilograms (a 44 percent increase), but production costs increase to Z 900. Assuming a uniform price for both traditional and improved maize grain, gross revenue per hectare increases from Z 6,300 to Z 9,100. Net revenue increases from Z 5,775 to Z 8,200 per hectare or from Z 40 to Z 51 per labor day. That is, the improved varieties increase net revenue per hectare by 42 percent and per labor input by 27 percent -- a definite advantage.

The improved varieties promoted were open-pollinated varieties developed in the late 1970s by a CIMMYT maize improvement program: Kasai I for the lower altitude (500 to 100 meters) areas of Shaba and Kasai, and Shaba I for farmers in higher elevations (above 1,000 meters). An earlier variety, Salongo II, also performs well in the lower altitude areas. (PNM is currently working on several new varieties and crosses, but will not release them until they have been field tested further).

Open-pollinated composite varieties, rather than hybrid crosses, were chosen for dissemination because they perform as well as hybrids when no fertilizer is added, and because they hold their yield advantage over traditional varieties for two or three years. Thus, farmers can use their maize production for seed for a couple of years, and need to renew only every three or four years. It was taken as a given that farmers, at least in the North and Central Shaba areas, cannot count on having fertilizer available. As a general rule, both hybrids and composite varieties perform better than the traditional varieties, even with no fertilizer application, but hybrids outperform the composites when fertilizers are applied. There is a general belief that without fertilizers, improved varieties give lower yields than traditional varieties, but this belief is usually wrong, as the experience in Shaba shows. (See Lipton and Longhurst in *Modern Varieties, International Agricultural Research, and the Poor*, CGIR Study Paper No. 2, The World Bank, 1985).

In Southern Shaba, however, where the transport network is much better, the availability of fertilizer on a regular and economical basis cannot be ruled out. Farmers in those areas could be better off using appropriate hybrids instead of the composite varieties. Unfortunately, neither CIMMYT nor PNM have identified or selected a hybrid for these zones, although some imported hybrid varieties from Zambia and Zimbabwe are being tested. Identifying a suitable hybrid for Southern Shaba is a priority task for the PNM program.

Little is known about the market potential for maize seeds nationwide, or in the important Shaba and Kasai regions. Although demand estimates based on the current area planted to maize would seem very optimistic (800,000 hectares planted in maize in 1983 in Zaire would require 23,000 tons of seeds), the actual commercial demand would be far more modest. Much of the area planted in maize is in remote areas not reached by current agricultural marketing channels. Farmers in those areas offer a negligible effective demand for commercial seed production.

For the Shaba region, which is the area most developed in terms of maize production and marketing, it is possible to arrive at a crude estimate. The commercial maize marketing system in Shaba, including Mbuji-Mayi, handles an estimated total of 240 kilotons, of which some 180 kilotons are produced in Shaba, 30 in Kasai, and 30 imported mainly from Zambia. (See "Market Prospects for Maize in Shaba," USAID/Kinshasa, December 1987.) If the Shaba quantity were produced using improved seeds, it would require roughly 1,200 tons of seeds. One hectare of improved maize needs 25 kilograms of seeds and produces 1,300 kilograms of commercial grain, a ratio of 1:50. Since open-pollinated varieties can be reused for three to four years, we can assume that sufficient seeds are required for only one-third of the total production or 60,000 kilotons. At a ratio of 1:50, we need 1,200 tons of seed at most. This is an upper limit. Of course, since maize consumption and the population are expanding, the needs for the future will expand accordingly.

Current demand for improved varieties of commercial maize seeds in Shaba is much less than 1,200 tons, since most maize is still being produced using traditional varieties. We have no indication of what proportion of maize production uses traditional seeds, but if it is two-thirds to one-half, the demand for improved seeds in Shaba in 1988 might reach 400 to 600 tons.

In order to produce commercial seeds, seed farms need to obtain the base or foundation seeds from PNM. PNM is the sole source of foundation seeds for the main maize varieties: Shaba I, Kasai I, and Salongo II. It produces the foundation seed for Shaba I at the Kaniameshi farm near Lubumbashi, and for Kasai I and Salongo II at the Kaniama and the Gandajika experimental stations.

Information on actual quantities of foundation seeds produced, processed, sold, and otherwise distributed is incomplete. None of the PNM reports contains either a total or a breakdown of such basic information. Considering the small volumes involved, it seems that proper recording and accounting of these data would be a simple matter.

Incomplete information is available for the distribution of foundation seeds for the 1987-88 season. PNM reports having delivered 1.25 tons of Shaba I to Trabeza, 1 ton to Sagricim, and 1 ton to the Lubudi project, for a total of 3.25 tons. The PNS project got 150 kilograms of Kasai I from the Kaniama experimental station. There were other small deliveries of foundation maize seeds to Prodalu (Kananga) and BUNASEM in Kasai and Bas Zaire, but the varieties and quantities are not known.

The PNM quarterly report for January-March 1988 reports collaborating in the production of 352 hectares of commercial maize seed with several organizations in Shaba:

Trabeza	157 hectares
Lubudi Project	102 hectares
Sagricim	52 hectares
PNS	35 hectares
A.I.D.-105 Project	6 hectares

Gecamines Dev	0 hectares

In addition, PNM reports the area planted for commercial seed production in the following stations in the 1987-88 season:

Kaniameshi (Shaba)	5 hectares of Shaba I
Kaniama (Shaba)	5 hectares of Kasai I
Kiyaka (Bandundu)	3 hectares of Bandundu I
Kiyaka (Bandundu)	3 hectares of Kasai I
Gandajika (Kasai)	2 hectares of Salongo II
Mvuazi (Bas Zaire)	3.5 hectares of Bandundu I
Mvuazi (Bas Zaire)	3 hectares of Salongo II

The area planted for commercial seed seems to be fairly accurate, since Trabeza reported exactly the same number, 157 hectares planted. (This much area would require close to 4 tons of foundation seeds, in contrast to the 1.25 reportedly sold by PNM.) To plant the nearly 400 hectares of commercial seeds, it is necessary to have 10 tons of foundation seeds. PNM reports selling only 3.25 tons. The source of the remaining foundation seeds is not known.

Yields of commercial seeds, however, were not very encouraging. Trabeza reports obtaining barely 200 tons of commercial seeds, or 1,300 kilograms per hectare. The Lubudi project (French aid financing) has reported especially poor germination resulting in very low yields. Trabeza did not complain about low germination.

The quality of the foundation seeds received from PNM has been questioned. First, the characteristics of the current Shaba I variety are not the same as those of the original variety identified in 1979. The same is claimed for the Kasai I identified in 1976. Both of these varieties date to the CIMMYT project on maize in Zaire. Apparently the genetic purity of the original variety has been compromised over the years, and it now exhibits great heterogeneity, including the coloration and shape of grains. Unfortunately, it is not practical to reconstruct the original variety from the progenitor lines. Since then, CIMMYT has made much progress in other

family lines, and it seems more advisable to start anew using some of the more advanced lines.

The genetic contamination of the Shaba I and Kasai I varieties can be attributed in part to the lack of proper pollination bags. The bags currently in use are manufactured locally and come unglued after a few days. Imported pollination bags were ordered more than two years ago but have not yet arrived. The bags have been delayed by procurement procedure mixups, together with hundreds of laboratory equipment items included in the same order.

Conditioning of the foundation seeds sold by PNM is also criticized, and probably with good reason, since PNM does not have equipment appropriate for the purpose. In fact, PNM does not even have a seed analysis laboratory to perform basic tests on the foundation seeds it distributes. Since the installation by BUNASEM of the seed analysis laboratory and conditioning facility at Fungurume (at the Trabeza farm), PNM should be able to provide better quality seeds.

Trabeza is quickly becoming the central point for the production, conditioning, and marketing of commercial seeds in Shaba. Its farm in Fungurume has been the beneficiary of support from many organizations. It was a bargain, bought from a defunct mining consortium. The World Bank's National Seed project, creating BUNASEM, has provided financing (nearly US$ 750,000, according to BUNASEM) and technical assistance to establish a full-fledged commercial seed farm. FAO is in the process of installing a turnkey operation of a seed conditioning facility due to start operations at the end of July 1988. Expatriate experts are in place for testing the equipment and training operators. BUNASEM has also installed a well-equipped seed analysis laboratory in the same farm, at no charge. USAID has signed a US$ 400,000 contract for the distribution of the seeds in the North and Central Shaba zones of the Project-105 area, above any revenues from the sale of seeds. The same contract includes US$ 700,000 for the cost of technical assistance to Trabeza by a Zimbabwean company, Seed Co-op, on the

production and processing of maize seeds. Finally, the World Bank's South Shaba project is negotiating to place a testing and demonstration field in the same farm, with the technical support of PNM, to help select the most suitable varieties for the Likasi area.

For the 1987 harvest, PNM reports collecting Z 1.2 million in revenue from the sale of both commercial and foundation seeds. It sold Shaba I foundation seed to Trabeza at Z 250 per kilogram. Trabeza has not yet decided on a price for its commercial seeds, but a rough ratio of six times the price of regular maize grain was being discussed. Since the current price is close to Z 30 around the Likasi area, Trabeza will probably charge about Z 180 per kilogram of commercial seeds. This is the first year Trabeza has sold commercial seeds, so it has no previous sales record.

PNM also sold commercial seeds last year. Commercial production at Kaniameshi was mainly to satisfy the small requests of influential individuals within and outside the government. The price charged for commercial seeds was Z 65 per kilogram. Unfortunately, many of the buyers have not yet paid. For 1988, PNM reportedly did not produce commercial seeds to avoid duplicating the efforts of Trabeza and other producers. (The latest quarterly report, however, records 5 hectares each in Kaniameshi and Kaniama for commercial purposes. Unfortunately, there was no opportunity to reconcile this apparent discrepancy.)

Several PNM scientists expressed reluctance to expand the production of commercial seeds. In the past, they felt it was necessary to produce commercial seeds for sale to complement the poor financial situation of PNM. But given the choice, they would rather concentrate their efforts on breeding and leave the commercial considerations aside. As a potential source of financial sustainability, they felt that it would detract from the scientific vocation of PNM. The financial support for PNM research activities, it was felt, is a responsibility that the Government of Zaire or foreign donors must assume.

Pricing of foundation seeds by PNM should receive serious consideration, however. At the current price of Z 250 per kilogram, the 3,500 kilograms reportedly sold in 1987 only brought Z 875,000, or US$ 4,375 at the July 1988 exchange rate. This barely covers one month's rent of the houses for the PNM expatriate scientists in Lubumbashi. Trabeza would seem to be getting another bargain by buying foundation seeds from PNM at Z 250 and selling commercial seeds at Z 180 per kilogram. If the same ratio of 6:1 that Trabeza uses were applied to foundation seeds, the appropriate price would be more than Z 1,000 per kilogram. And, if PNM could sell the entire 10 tons of foundation seeds required by the seed multiplication farms, it would receive Z 10 million per year. This is roughly one-fourth of the annual local currency budget for the entire PNM program. To produce 10 tons of foundation seeds, it will be necessary to cultivate 5 to 7 hectares, not an excessive burden for such a highly competent team of technicians. Trabeza produces 157 hectares of commercial seeds on four separate farms, and they have only one young agronomist.

To conclude, selling foundation seeds at a competitive price could enable PNM to contribute significantly to its own financing. Producing commercial seeds and selling them at competitive prices could also generate additional supporting funds for PNM. Both of these options would represent significant contributions toward the self-sustainability of maize research financing.

Input Marketing and Extension

Weakness of the Extension Service. One of the major impediments to the effectiveness and the sustainability of agricultural research in Zaire is the present weakness of the system for delivering inputs to farmers. Traditionally, responsibility for the diffusion of information regarding new varieties and cultural practices has been entrusted to the extension service. In Zaire in general, and Shaba in particular, the extension service dependent on the Ministry of Agriculture is completely unable to perform this task. Agriculture agents in each zone and district serve mainly as reporters to regional headquarters on the extent and status of agricultural production in their

respective areas; however, they have neither the training nor the resources to transmit technological improvements to farmers. Devoid of any mobility, even bicycles, they are barely able to maintain contact with a few nearby farmers. Inputs delivered through the extension service are never adequate, are of poor quality, and are seldom available on time.

Parallel Extension Networks. The rather successful distribution of improved maize varieties in Shaba has primarily been the result of parallel extension networks established independently by various foreign aid projects. A.I.D.'s North Shaba project, for example, had its own cadre of trained extension agents and supported them with mobility, prompt delivery of inputs, and close supervision. In addition, the project worked with many of the established private voluntary organizations in the region, including religious missionaries. Similarly, the South Shaba project financed by the World Bank is directing its extension efforts and the provision of inputs through a series of private voluntary organization and commercial enterprises in the area.

Separate Extension from Input Delivery. A novel initiative is being introduced in the A.I.D. Central Shaba project, which covers the area around the rail line north of Bukama, including the former North Shaba area. Here, A.I.D. will attempt to separate the extension activities from the task of delivering seeds and other inputs. Trabeza, a private company, is being contracted to establish an independent network able to distribute maize seeds commercially to farmers in the region. The extension service and private voluntary organizations working in the region will continue promoting the improved seeds and advising farmers on new cultural practices. But farmers must obtain the seeds from the local distributors from Trabeza. These distributors could be anyone, including private individuals, extension agents, public officials, traders, or the private voluntary organizations themselves.

Great Expectations. This year will be the first opportunity to try the A.I.D. private seed marketing initiative. Trabeza has already moved 30 tons of commercial seeds to Nyembo, in the center of the Central Shaba area, and is in the process of establishing an informal network of dealers in the different

localities. USAID has lent a truck to move the maize, 5 tons at a time, from Fungurume to Nyembo, a two-day trip each way. Planting will begin in October and November, but sales will begin much earlier. Initially, Trabeza had expected to exchange seeds for regular maize at a ratio of 6 to 1 shortly after harvest, before farmers had sold it to traders. Now, close to August, it is no longer certain that farmers can pay for seed in kind, so Trabeza must decide on a monetary price per bag of seed. The actual price charged is not as important in the first year, since Trabeza's income will be coming mainly from USAID, under a sliding scale arrangement: US$ 48,000 for the first 10 tons sold, US$ 27,000 for the next 10 tons, US$ 23,000 for the next 10 tons, and so on (see Table 4). This is in addition to what Trabeza gets from the farmers. The amounts contributed by USAID will diminish in the second and subsequent years (see the accompanying graphs). The rationale behind this arrangement is to encourage Trabeza to establish a private network of dealers in the first few years, on the expectation that once established, it will generate enough self-interest to remain in business by itself. Both Trabeza and A.I.D. are confident that the formula provides sufficient incentives for everyone concerned. The contract is designed so that Trabeza is gradually weaned from A.I.D.'s support, and in five years it is expected to be not just financially self-sustaining, but profitable.

Implications for Maize. If successful, the experiment with private seed distribution could have important implications for the financing of maize research in the future. It will provide, at least, a vehicle for the dissemination of results of research that does not depend on the government budget, donations from foreign donors, or gifts from charitable organizations. Moreover, by tapping farmers' willingness to pay for the improved varieties, it will provide a measure of the success or failure of the breeding research effort. It also poses a challenge for PNM breeders: Trabeza could use the same marketing channels to introduce imported maize seeds, (e.g. hybrids from Zambia), which could outperform the improved PNM seeds. If farmers in Central Shaba accept the principle of paying for improved seeds, it will prove once more that farmers, even those in areas remote from commercial markets,

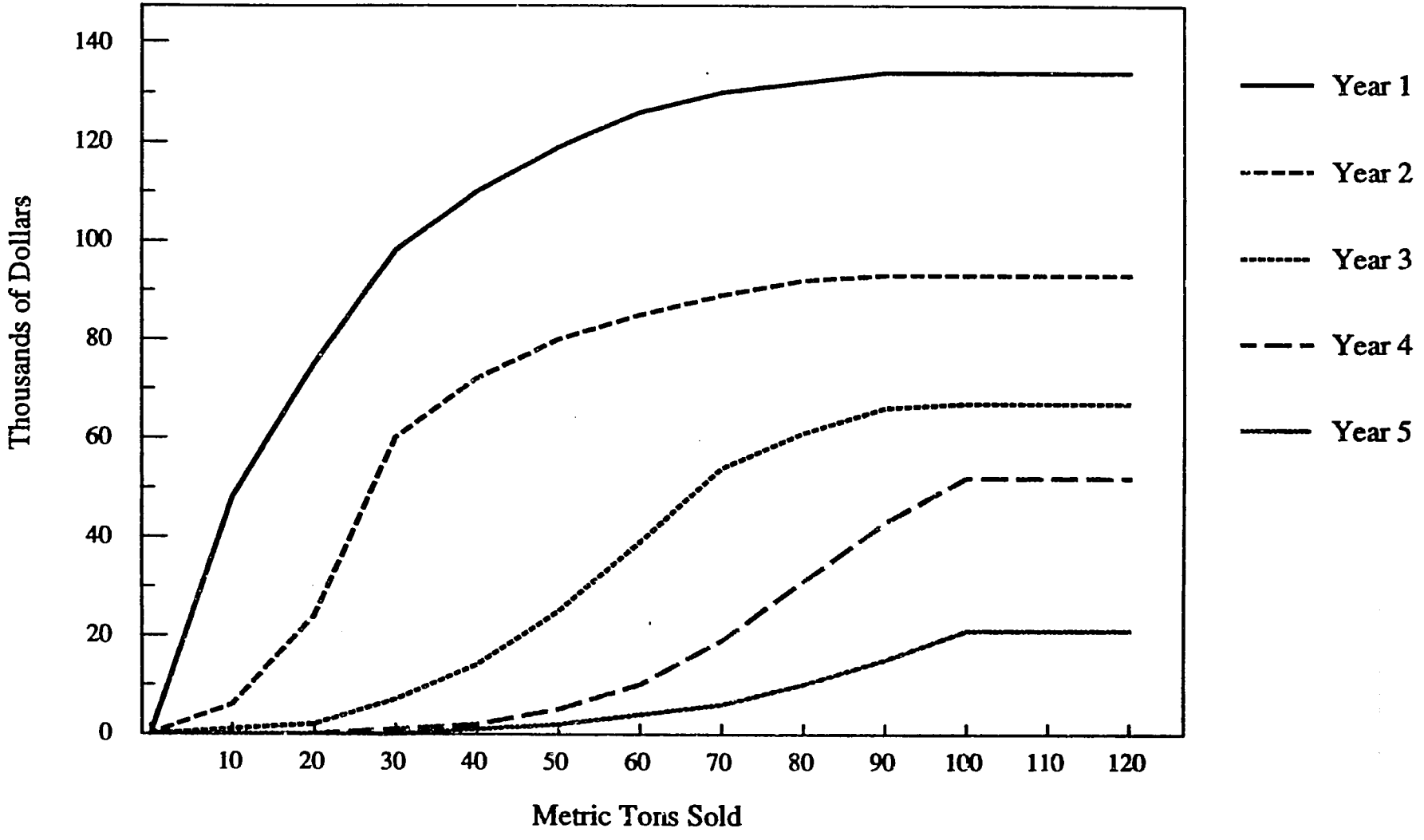
Table 4. Central Shaba Maize Seed Marketing Project

(Thousands of dollars)

Year	10	20	30	40	50	60	70	80	90	100	110	120
1	48	75	98	110	119	126	130	132	134	134	134	134
2	6	24	60	72	80	85	89	92	93	93	93	93
3	1	2	7	14	25	39	54	61	66	67	67	67
4	0	0	1	2	5	10	19	31	43	52	52	52
5	0	0	0	1	2	4	6	10	15	21	21	21

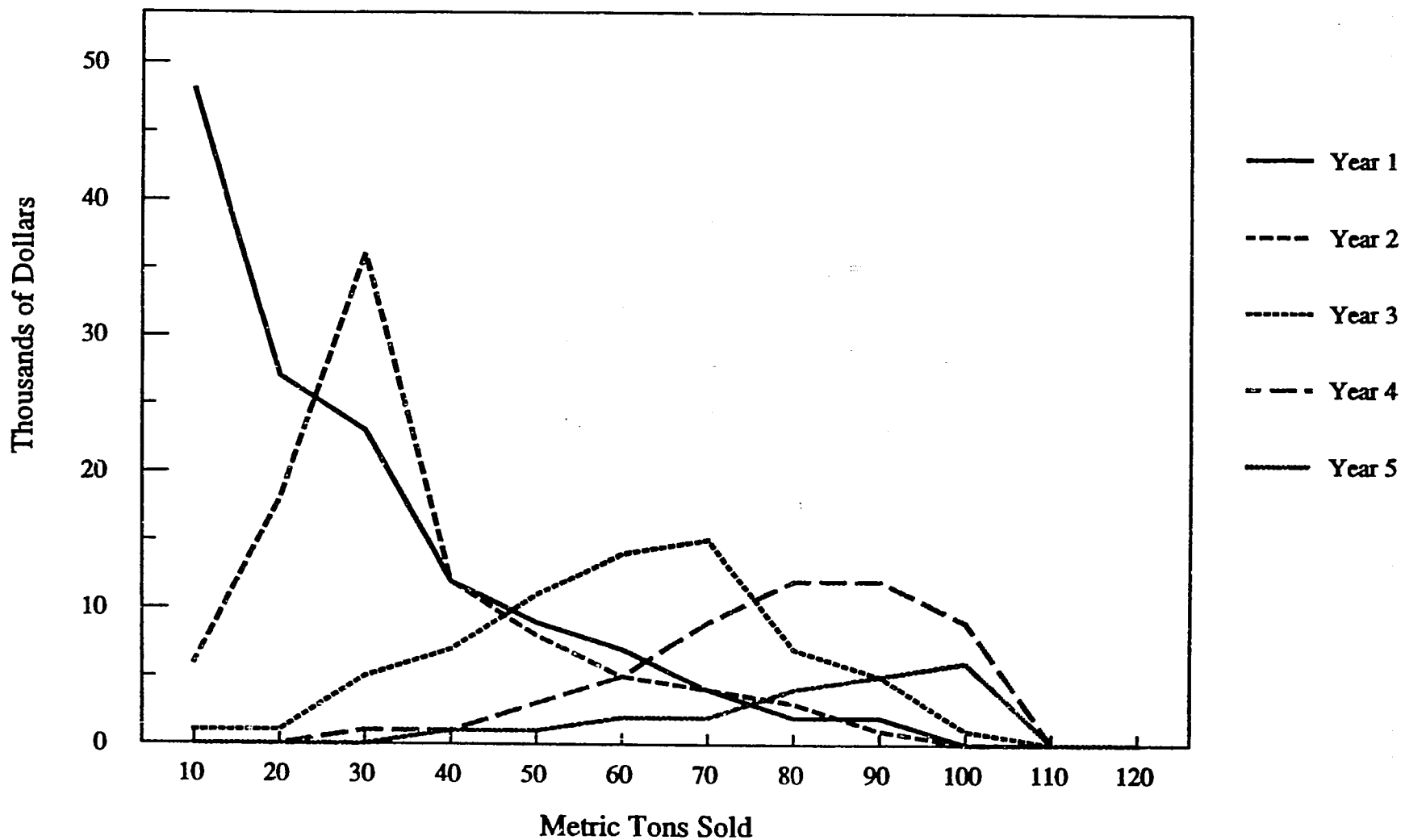
Cumulative Market and Risk Payments

Seed Enterprise Project 105



Incremental Market and Risk Payments

Seed Enterprise Project 105



are willing and able to invest hard cash in inputs if they are available on time and at reasonable prices.

Parallel Moves. Several other organizations are also moving in the same direction. In particular, two of the World Bank's projects are acting in concert to privatize gradually the trade in improved maize seeds. The National Seed Bureau, BUNASEM, is investing heavily in establishing Trabeza as a viable commercial seed producer and seed processor. The installation of BUNASEM's seed laboratory, also at Trabeza, will establish some quality control standards for maize seeds. The South Shaba project is promoting agricultural development through a network of private voluntary organizations and commercial companies. These organizations will obtain commercial maize seeds from Trabeza also, purchased at a competitive price yet to be decided. Whether these organizations in turn will charge farmers for the seed or distribute it to them free is their decision, but it is likely that they will charge something.

Market Feedback. The most important result from the point of view of maize breeding research is that the establishment of a market for improved seeds will allow PNM itself to charge competitive prices for its foundation seeds. Such a move will generate funds to offset part of the cost of PNM research activities. Also, it will remove the element of arbitrariness and favoritism that a system of administered prices entails.

BUNASEM

The National Seed Bureau (Bureau National de Semences, BUNASEM) is a semi-autonomous entity attached to the Ministry of Agriculture, charged with the production and certification of seeds in Zaire. BUNASEM was created in 1985 as part of the seeds project financed by the World Bank. Its goal is to develop a self-sustaining and commercially viable seed industry with increasing participation by the private sector. Seed production is contracted to private seed farms, or in their absence to regional development organizations. In Shaba, for example, BUNASEM contracted in 1987 with Trabeza for the

production of 40 tons of maize seeds in a Fungurume farm. Seed farms obtain base seeds for the major varieties of food crops from research centers or from National Commodity Programs.

The private sector remains reluctant to invest in seed production farms, since the market and profit potential of such ventures are uncertain. Moreover, there is limited expertise in seed production technology; therefore, BUNASEM has to provide close supervision and technical assistance to the seed farms in the early years of the project. Several intermediate alternatives include organizing state-owned seed farms or developing management agreements with subsidiaries of commercial enterprises. BUNASEM supervises the production and distribution of quality seeds to the farming population.

A major investment made by BUNASEM is the complex of offices and the seed laboratory in its headquarters in Kinshasa, including radio communication systems with seed farms, audiovisual training equipment, and a fleet of vehicles. Technical assistance is provided by a team of FAO agronomists and seed technology specialists.

In addition to establishing BUNASEM, the World Bank's seeds project is also active in (1) assisting research stations in the production of base seeds, (2) establishing and operating seed farms for later transfer to private hands, (3) developing a seed quality control system, (4) training, and (5) special studies, pilot projects, and technical assistance.

The total cost of the seeds project was estimated at US$ 21.3 million, of which US$ 12.5 million is foreign exchange and US$ 8.8 million is local currency.

Maize Seed Pricing and Farmers' Willingness to Pay

Several alternative approaches have been suggested for pricing commercial maize seeds by the seed farms. The most frequently mentioned is the cost of production (the costs incurred by the seed farms or the project in

producing the seed). Unfortunately, production costs are not easy to establish and vary greatly from year to year with the vagaries of the weather, and from farmer to farmer, and from zone to zone. Moreover, producing the seeds is only part of the total cost, and a small part at that. In the case of Central and North Shaba, the cost of marketing -- transporting, stocking, financing, distributing, and promoting -- would be far higher than the cost of producing the seed in the first place. Finally, cost of production ignores the demand side of the market -- what farmers are willing to pay to get the seeds.

Some rules of thumb have also been suggested. PNM and BUNASEM mentioned the 25:5:1 ratios among prices for foundation seeds, commercial seeds, and regular grain seeds. Trabeza has tentatively decided on a 6:1 seed exchange ratio for regular grain in the Central Shaba subregion. These ratios reflect earlier experiences by seed producers elsewhere, but it is not evident that under the peculiar situations of Shaba the same ratios would apply. Since prices received by farmers for maize grain vary greatly depending on the distance to Lubumbashi and the distance from farm to railhead, one town must become the reference point. A ratio of 5:1 in Lubumbashi could result in a 10:1 ratio for a farmer in Kongolo, for example, living far from town.

A better technique, which takes into account both the price received by farmers for maize and the expected yield, is used in the project paper of the Central Shaba project, using the formula

$$\frac{\text{Expected Yield} \times \text{Farm Price} \times \text{Percent Return}}{\text{Seeding Rate}}$$

where the percent return can range from, say 5 to 15 percent. In other words, farmers are willing to pay a given percentage of their total gross revenue per hectare for seeds. The ratio will give the price per kilogram of seeds.

For example, a farmer in North Shaba using Kasai I and expecting a yield of 1,500 kilograms per hectare to be sold at Z 20 per kilogram will gross Z 30,000 per hectare. If his return is 10 percent, he is willing to pay Z 3,000 for seeds, and if the seeding rate is 25 kilograms per hectare, this amounts to Z 120 per kilogram of seeds. Using the formula above we have

$$(1{,}500 \times 20 \times 0.10) / 25 = Z\ 120/\text{kg seed}$$

or a ratio of 6:1. If the rate had been set at only 5 percent, the price would be only half and the ratio only 3:1.

The World Bank's seeds project appraisal report introduces another consideration: The farmers' willingness to pay for improved seeds is conditioned by how much better the improved seeds are relative to the traditional varieties. If they are just as good as what he already has, he will not pay anything, in spite of the formula.

The same farmer, when using the local variety gets, for example, 1,000 kilograms per hectare, which at Z 20 per kilogram results in a gross income per hectare of Z 20,000. Suppose that with both traditional and improved varieties the farmers spends Z 2,000 in cash per hectare (not counting the cost of the seeds). Then, net revenues per hectare are Z 28,000 for the improved variety compared with Z 18,000 for the local variety, a difference of Z 10,000 per hectare.

Other things being equal, this farmer might be willing to share his additional income, Z 10,000, with the seed supplier. How much of his income? One-third? One-fifth? Your guess is as good as mine. If it is one-fourth, 25 percent of Z 10,000 equals Z 2,500 that he is willing to give to the seed dealer for the 25 kilograms of seeds needed to plant one hectare. That is, the farmer is willing to pay Z 100 per kilogram when the price for grain is Z 20, a ratio of 5:1.

Two additional factors were introduced in the calculation above, namely the yield of the traditional variety and the cash expenses under both cases. In order to estimate what farmers are willing to pay for improved seed, it is net cash revenue that matters, not gross revenues.

One final issue needs to be raised. Labor is usually recognized as the limiting factor in typical African peasant production conditions. Land is usually not a binding constraint, especially in the vast expanses of Shaba. New, improved varieties often require more labor inputs per hectare than the traditional varieties. If labor is the limiting factor, the farmers will not be able to cultivate as many hectares of the improved variety as of the traditional one.

Suppose, for example, the North Shaba farmer uses 20 percent more labor with the improved variety. Then for the same amount of effort he can cultivate less land than before, 17 percent less. That means that the Z 100 per kilogram of seeds needs to be adjusted downward by 17 percent. Moreover, in the smaller area not as much seed is needed. After making the necessary adjustments, the same farmer is now willing to pay only Z 64 per kilogram of seed, while still sharing one-fourth of his net revenue gain with the seed supplier (see Table 5). The ratio of seed to grain has dropped to 3:1.

The following table provides a series of prices that farmers would be willing to pay for maize seed depending on the price of grain received and the relative labor requirements of the improved variety compared with the local one. Obviously, if the labor needs are the same, the price is the same as above, Z 100 per kilogram of seed when the price of grain was Z 20 per kilogram. However, if labor needs are 10 percent higher, the farmer is not willing to pay more than Z 82 per kilogram if he is to retain 75 percent of his increase in net revenue.

There is some constancy to the ratios of the prices of seed relative to grain. When labor requirements are the same as for the local variety, farmers are willing to pay five times the price of grain, regardless of the price of

Table 5. Prices Farmers are Willing to Pay for Maize Seed When Labor is the Main Limiting Factor of Production

Grain price Z/kg	Labor same 150	Days Relative to Local Variety		
		10 percent 165	20 percent 180	30 percent 195
10	50	42	34	26
12	60	50	40	30
14	70	58	46	34
16	80	66	52	38
18	90	74	58	42
20	100	82	64	46
22	110	90	70	50
24	120	98	76	54
26	130	106	82	58
28	140	114	88	62
30	150	122	94	66
32	160	130	100	70
34	170	138	106	74
36	180	146	112	78
38	190	154	118	82
40	200	162	124	86
42	210	170	130	90
44	220	178	136	94
46	230	186	142	98
48	240	194	148	102
50	250	202	154	106

Note: Given the yields for local and improved varieties, and other data as described in text.

grain (hence the rule of thumb of five to one). Similarly, when labor increases by 20 percent, the ratio drops to 3:1 over the whole range of prices. For 30 percent more labor, the ratio becomes only 2:1.

We have no field information on how the improved varieties that are being promoted relate to the traditional varieties in terms of labor demands. Judging by the sensitivity of the willingness-to-pay prices to the labor requirements, determining these labor relationships should be a priority item for the PNM component on farming systems research.

These preliminary calculations seem to indicate that the rule of thumb of exchanging five units of grain for one unit of seed holds for a wide range of farm prices for grain. This assumes a 50 percent increase in yield and no additional labor requirements with the improved variety. Trabeza's proposed exchange ratio of 6:1 might be higher than warranted, especially if the expected yield increase is below 50 percent, and labor requirements are slightly higher. The 5:1 ratio allows farmers to keep 75 percent of the additional net revenue, and pass along 25 percent to the seed supplier.

Appendix to Chapter II:
Calculating Farmer's Willingness to Pay for Seeds

The formula used to calculate the price farmers are willing to pay when labor is the main production factor constraint is

$$\left[\left(\frac{Y_X * P_g - C_X}{L_X}\right) - \left(\frac{Y_O * P_g - C_O}{L_O}\right)\right] * \frac{\%W}{100} * \frac{L_X}{S_X} = Px$$

where

P_g = Price of grain received by farmer
Y_O = Yield of local variety
Y_X = Yield of improved variety
C_O = Cash expenses on local variety (other than seed)
C_X = Cash expenses on improved variety (other than seed)
L_O = Labor requirement for local variety
L_X = Labor requirement for improved variety
%W = Percent of net revenue farmer is willing to share
S_X = Seeding rate for improved variety

The constancy of the ratio of the price of seed to the price of grain is explained most easily when cash expenses, C_X and C_O, are the same for both local and improved varieties.

$$\frac{P_x}{P_g} = \frac{1}{P_g}\left[\left(\frac{Y_x * P_g - C_x}{L_x}\right) - \left(\frac{Y_o * P_g - C_o}{L_o}\right)\right] * \frac{\%W}{100} * \frac{L_x}{S_x}$$

$$= \left[\frac{Y_x * P_g - C_x}{P_g * L_x} - \frac{Y_o * P_g - C_o}{P_g * L_o}\right] * \frac{\%W}{100} * \frac{L_x}{S_x}$$

$$= \left[\frac{Y_x}{L_x} - \frac{Y_o}{L_o} - \underbrace{\frac{1}{P_g}\left(\frac{C_x}{L_x} - \frac{C_o}{L_o}\right)}_{\approx 0}\right] * \frac{\%W}{100} * \frac{L_x}{S_x}$$

Note that the third term is very small and close to zero, especially if C_x and C_o are nearly equal. The term would be zero if cash expenses increase in the same proportion as labor requirements. Dropping the term from the expression, the ratio becomes

$$\frac{P_x}{P_g} = \left[\frac{Y_x}{L_x} - \frac{Y_o}{L_o}\right] * \frac{\%W}{100} * \frac{L_x}{S_x}$$

Note that the right-hand side does not contain any prices. It is purely determined by technical parameters for yields, labor use, and seeding rate, plus the percentage of net revenue the farmer is willing to share with the seed supplier.

III. AUTO-FINANCING CASSAVA RESEARCH IN ZAIRE

This chapter explores ways to develop the eventual financial sustainability of the cassava research program, PRONAM; and looks at the institutionalization of cassava research in an ongoing program supported independently of A.I.D.

For the moment, we are primarily concerned with the sustainability of the local currency costs of the program (those costs incurred in-country), which in the original conception of the project were to be covered by contributions from the central government. The more sizeable foreign exchange amounts being spent in RAV on technical assistance and training of Zairian agricultural scientists in U.S. universities will be addressed separately.

Government support of the cassava research program is not considered an alternative. The current contributions of the government toward the costs of RAV are less than 3 percent of the total local currency budget (Z 7 million out of a Z 224 million budget for 1988). It is unlikely that the GOZ will be able to make a more significant contribution in the future.

To reach financial sustainability, the only realistic strategy for PRONAM is to restructure its program to operate within the limitations of funds generated by its research output and contributions by independent sponsors. Two alternative approaches are explored here: we need to look at the structure of costs and locate possible reductions, and PRONAM needs to explore ways to generate its own funds through the monetization of its output and services.

Cost of Mvuazi

PRONAM's budget is nearly double that of PNM, even though the number of scientists, expatriate and national, is roughly equivalent for both programs. For 1988, PRONAM's budget was Z 71 million compared with Z 45 million for PNM and about the same for PNL. In previous years, PNM has also distinguished itself by finishing the year with funds left over from their budget, while PRONAM usually ends up short. Many reasons can be adduced to explain why the PRONAM program is more expensive than PNM. For example, one hectare of cassava produces enough cuttings to plant only 5 to 7 hectares, while 1 hectare of seed maize produces about 2 tons of seed, enough for about 80 hectares. So, for the same area impact, cassava requires 12 to 15 times more seeded land than maize.

The main reason for PRONAM's high cost is the much larger staffing required by the research stations where it operates, particularly Mvuazi, the main center. Mvuazi is practically a self-contained community, shared by INERA and PRONAM. In addition to the offices and laboratories, the station has modern housing for each scientist and his family. It has its own electricity generating system, water supply, radio communication, fuel storage, garage and mechanical shop, clinic, schools for the workers' children, housing for the field workers and their families, and housing for the support staff and their families. A guest house and recreation center add to the amenities. All together, it is a comfortable and idyllic environment.

There is a cost, however, for the high level of infrastructural support required in a research station. The cook and the gardener serving each scientist have to be housed, and the scientists' children must be educated. These costs would be marginal if the scientist were living in a city, but in the isolated environment of a research station, they have to be absorbed by the agricultural research program. In a research station, the number of people required to support a small number of scientists balloons to the size of a small town that depends totally on the agricultural research budget. The high local currency cost of agricultural research in Zaire is primarily a reflection of the

isolated location of the experimental stations and the need to provide all the modern infrastructure to the adjoining community.

Are there alternatives to the dependence on station-based research and multiplication in cassava? An interesting possibility is described below. It is already in operation under PRONAM's direction but its possibilities are not fully recognized.

Off-station Testing

Half way to Mvuazi one encounters a PRONAM sign by the road side for a demonstration plot of different varieties of cassava. This plot turns out to be a 20-hectare cassava field. It is kept very clean. A single house overlooks the field, and no other infrastructure is visible. The different cassava varieties are well marked with painted stakes. They could be made more visible and easier to read and photograph; right now they are hidden by the fully grown cassava plants.

This is one of the PRONAM outreach efforts. The plot is rented and is maintained with a minimum of labor and infrastructure. An agronomist from PRONAM is charged with running the Kavuaya plot. He lives in the nearby town of Kisantu, and using a pick-up truck (an old Chevy left over from an earlier A.I.D. project), he commutes daily with six laborers from the same town to keep the plot running. Two guards living nearby take turns watching over the plot. The house in the field serves as a shelter for the guards as well as a warehouse for inputs and tools.

The Kavuaya field offers an interesting alternative to the experimental station approach. It is a better testing ground for different cassava varieties. It presents a quite different soils environment than the fertile Mvuazi valley. Kavuaya is on the side of a large hill, closer to the hilly conditions where most farmers operate. Mvuazi has an exceptional soil, all alluvial with a permanent source of water (even in the middle of the dry season there are natural ponds with 2 feet of water).

What is remarkable about Kavuaya is the low cost of operation. With a minimal amount of manpower, it is possible to operate a farm of 20 hectares planted with more than 300 varieties of cassava. The key to this low cost is the proximity to a town and the availability of a pick-up, which means housing is the responsibility of the individuals themselves, rather than the responsibility of the research station; therefore, all the infrastructure needed for making a livable and comfortable community is unnecessary.

The only unusual thing we observed was the presence of some white hunters shooting pigeons with shotguns while we were visiting the field with Dr. Osiname. Although there was not even a fence to protect the 20 hectares of cassava, no problem with stolen plants was observed. A peasant family living 100 meters uphill probably provided some of the security needed.

One additional note on this issue: There is not enough land in Mvuazi. As large as Mvuazi is in terms of building infrastructure and personnel, the area available for research plots of cassava is rather limited. PRONAM has had to rent land outside the station for multiplication plots. In return, landlords receive rent and a certain number of hectares inside the station, planted and cultivated at PRONAM expense for the landlords to harvest when ready. So, some of the fields in the station really belong to private farmers, while the cassava fields are outside the station. This exchange of land makes it hard to account for station output, and results in irregularities. The land shortage problem is aggravated by the large number of station employees; each family must have a private plot of station land to raise its own crops, including cassava.

We now turn our focus to the market potential for the improved cultivars of cassava that have been identified and are being developed by PRONAM. Such market potential must exist, because PRONAM has selected cassava varieties that respond to the needs of farmers, in keeping with the farming system research orientation of the program.

On-farm Testing

The farming systems approach to agricultural research emphasizes on-farm testing as a preliminary stage before full release of a promising variety. PRONAM has attempted to do some on-farm testing by providing cuttings to a few selected farmers in villages spread out over the Bas Zaire region. In general, these tests have not been very effective in providing solid information on the merits, or lack thereof, of the varieties in question.

Supervision of the test seems to be the major drawback to on-farm testing. For cassava, it requires at least one year of follow-up, as opposed to 90 to 120 days for maize. Farmers do not harvest cassava all at once, but gradually over the dry season, which makes comparisons difficult. Since planting and harvesting seasons are not well defined, there is no specific date when yield comparisons can be performed. Many extraneous factors interfere with the results. Test fields are small and subject to many uncontrolled events such as goats eating the plants, passersby helping themselves to plants or cuttings, and families eating the output before it is recorded. Quantitative analysis of the data from on-farm tests is not deemed appropriate. Qualitative assessment of results becomes anecdotal and case-specific.

The farming systems economist, Dr. Barlett, has been following-up on 50 farmers in two villages to assess the relative importance of cassava in the household economy of the region. Results from these year-long surveys will become available in the coming months. Preliminary indications confirm the general assumption that cassava is by far the main crop, contributing more than half of the cash income for farms. It is produced for both consumption and commercial (cash) purposes. Virtually all of it is processed into cossettes for household consumption and for sale. Sales of cassava leaves also constitute a major revenue for households. Processing imposes the major claim on labor demand for cassava. Improvements in cassava yields will likely lead to more than proportional increases in cash income, because family consumption is already well covered.

In Dr. Barlett's opinion, however, improved varieties of cassava occupy barely 5 percent of total cassava area. This low adoption rate is even more surprising since the villages are along the main paved road connecting Mvuazi to Kinshasa. The difficulty of diffusing cuttings of improved cassava varieties poses the greatest challenge to the cassava research program.

Farmers' Willingness to Pay

Both the agricultural economist and the extension specialist in the PRONAM project are cautious about farmers' willingness to pay. So far, PRONAM has little experience distributing cassava cuttings directly to farmers. It has sold cuttings by the truckload to some prominent farmers at extremely low prices (Z 1 per meter of cuttings), but most cuttings of released varieties are given away to "collaborator" organizations such as the Programme National d'Engrais, Oxfam, and the French development project PRODERIM. These programs in turn distribute cuttings to farmers free of charge. To save costs, PRONAM intends to ask the collaborating programs to pick up the cuttings in Mvuazi, rather than transporting them itself to the different sites.

PRONAM outreach staff view sales of cassava cuttings to farmers with some skepticism for several reasons:

1. No Market for Cassava Cuttings. Farmers obtain new cuttings from their own fields or from neighbors. Even the free distribution efforts by collaborators require elaborate coordination with farmers to get them to prepare fields for planting when the cuttings arrive.

2. No Proven Superior Varieties. The best varieties released by PRONAM, Kinuani and F100, have proven slightly superior to traditional varieties in terms of yield. Consistent improvement of only 25-30 percent has been confirmed in station tests. Actual yield differences on the farm have been hard to document, although researchers are confident that the difference is significant.

3. Charity is the Tradition. Farmers are accustomed to receiving cuttings free of charge from charitable organizations or from the government extension services and development projects. They probably will resent being asked to pay something now,

and many will refuse. The same organizations, however, apparently have little difficulty selling beans and vegetable seeds to the same farmers. Could the reason be that these "collaborator" agencies have to pay for seeds but get cuttings free from PRONAM?

4. Marketing Cuttings is Difficult. Compared with seeds for maize or beans, cassava cuttings are bulky and heavy. A cutting is a stick about 25 centimeters long and 3 centimeters thick with protruding nodes distributed through its length. After cutting, it maintains its vitality only for a few days (four at most); its viability can be extended if kept in a properly moist and healthy medium, but this is costly and bulky.

5. Money-losing Delivery. Transporting, storing, and delivering perishable cuttings can reach a considerable cost. I don't know of any estimate of such a cost, however. Since cuttings are being given away free, the distributing organizations are incurring heavy losses every time they distribute. There is a strong financial disincentive for any organization to engage in cassava cutting delivery. Since PRONAM is producing and transporting cuttings, every shipment reduces their budget. Given a fixed budget, PRONAM likely will try to limit cutting deliveries to conserve money.

6. Low Heritability. Cassava genetics are rather unpredictable. Desirable traits for selection have low replication ability. Even though daughter plants are genetically identical to the original plant, they will exhibit widely different characteristics depending on soil and environment conditions. For example, F100 is classified as a sweet variety in the Mvuazi station, but in many farmers' fields not far from Mvuazi it produces bitter tubers. Soil differences are probably responsible for this change, but since PRONAM does not have even a rudimentary soils analysis capability, this possible association has not been established. (Ironically, the senior cassava technical adviser has a Ph.D. in soil sciences from a Big-10 American university.)

7. Planting in Rainy Season. For a cutting to survive, generate roots, and evolve into a viable plant, it requires moist soils; however, planting can be stretched over several weeks. The implication is that cuttings cannot be marketed in the dry season, when most of the harvesting is done. For a particular region there is no well-defined marketing season once the rains start. Farmers who harvest in the dry season cannot use or store their own cuttings. If they harvest their fields in the rainy season, it is difficult to dry and process the tubers when their labor demand is already great. Farmers might be amenable to buying cuttings if they are available at the right time, simply to reduce the labor at planting time. PRONAM might try different methods of preserving cuttings, so that

extension agents could have them in stock when farmers come to buy. Alternatively, PRONAM could try small nursery plots at the village level to save on transport and storage -- just cut, cash, and carry.

Output Selling

Most of the cuttings of the improved varieties (F100 and Kinuani mainly) are distributed by PRONAM free of charge to various "collaborating institutions." PRONAM has a weak outreach and extension program and has opted to work through intermediary organizations. These agencies, being in closer contact with farmers, may be better able to carry out the diffusion. These agencies view PRONAM as a benefactor and expect it not only to provide cuttings at no charge, but to deliver the cuttings to their places of operation.

Large private requests from influential individuals have also been received and honored by PRONAM, charging a token price of Z 1 per meter (four cuttings of 25 centimeters each). Thus, a truck load of cuttings with enough material for 6 hectares (15 kilometers of cuttings) generates Z 15,000 (US$ 75 in July 1988).

Once the cassava plant has been cut for cuttings, the tubers must be harvested immediately or they will rot in the ground. PRONAM is then faced with the problem of disposing 10 tons of fresh tubers from each hectare harvested. Because PRONAM has no processing or drying capabilities, it sells the tubers to local villagers or traders for another token amount, Z 4 per kilogram, or about one-fifth of what PRONAM could generate from selling them as dried chips (cossettes). In total, PRONAM receives Z 55,000 per hectare planted for cuttings. A farmer's gross revenue on cassava tubers can reach Z 120,000 (3 tons of cossettes at Z 40 per kilogram).

For reasons difficult to understand, PRONAM considers the price of Z 1 per meter of cuttings already high and fears that if the price were raised, private farmers would not be interested. Similarly, PRONAM fears that if it

charges the "collaborating institutions" for the cuttings, they will refuse to distribute the cuttings among their farmers.

The mere fact that influential farmers are willing to hire a truck to go to Mvuazi to pick up the cuttings reflects a higher value for the cuttings. Hiring a truck for one day can easily cost Z 60,000, already four times the amount paid for the cuttings alone.

A conservative estimate of potential benefits to a farmer from the improved variety yields substantial gains. Assuming that in the second year a farmer can generate enough cuttings of his own to plant five hectares, he needs to plant only one-fifth of a hectare with new cuttings the first year. This requires 500 meters of cuttings, at 2.5 kilometers per hectare. Assume further that the improved variety only increases yields by 30 percent (4 tons of cossettes instead of 3 from traditional varieties). In the first year, gross revenue would increase by only Z 8,000 from the one-fifth hectare (one-fifth of Z 40,000); however, in the second year, using his own new cuttings, gross revenue would increase by Z 40,000. In the first two years alone, the farmer would realize a gross revenue of Z 48,000 from the original investment on 500 meters of cuttings, a ratio of Z 96 per meter. Even after allowing for the additional labor requirements of the improved variety, the gain remains substantial; therefore, we conclude that benefits to farmers from improved varieties justify charging a much higher price for cassava cuttings.

Accounting for Revenues

The accounting system established for RAV is designed to monitor the disbursement of funds. Money flows from the central coordination unit to the different programs and research stations. Little or no attention is given to accounting for funds generated by the different programs through the sale of seeds or commodities. This inattention could lead to unwarranted suspicions about both the amount of funds collected and the disposition of those monies. Accounting should be transparent for commodities produced by the different units and for their distribution. When these commodities are transferred,

either to outside entities or to other dependencies within the project, clear written records of those transfers must be kept. Sales to private or public concerns should be duly recorded and accompanied by proper receipts.

The one-way accounting flow is not peculiar to the RAV project. Most A.I.D.-funded projects share this problem. For example, it is practically impossible to return monies into an A.I.D. project from the sale of vehicles at the end of a project. It is easier to give away commodities in ways that do not involve the generation of cash. (I do not know A.I.D.'s accounting procedures well, but they do not make it easy to have currency coming in the reverse direction. In a couple of instances in other countries, it was easier to give the commodities away than to transfer the cash back to A.I.D. or the national government.)

Who Controls Revenues?

As much as possible, the unit generating the revenues from the sale of seeds or commodities should control the use of those funds. It would be self-defeating to reduce the budget allocation of the unit by the amount of revenue generated. Doing so would remove the motivation for each unit to seek ways to finance its own operations. PRONAM, for example, might fear that RAV-Coordination would reduce their allocations to the program by the amounts of sales of cuttings and tubers. If this were true, the tendency would be for programs either to hide those funds or to eliminate sales altogether.

Mistrust is Prevalent

Unfortunately, mistrust permeates the manipulation of funds at all stages of management. This results in the excessive centralization of accounting and the removal of authority for expenditures at the unit or station level. At the extreme, revenue generation at the unit level is frowned upon or eliminated to avoid the problems of keeping track of those funds. Safeguards to ensure the integrity of public funds are necessary. It is also necessary to reconcile the

need for public safeguards with the flexibility expected from an autonomous or private institution.

Alternative Financing

PRONAM has long advocated setting up mechanisms for generating revenues as a way of contributing to their own financing. In addition to selling products from the research station, initiatives have also been made to obtain research grants from other sponsors.

Given the high caliber of the technical assistance personnel in some specialized fields, it is possible for PRONAM to attract research funding from outside organizations dedicated to the promotion of research on certain topics in Africa. Both private foundations and international research organizations are likely sources. The Rockefeller and Kellogg Foundations, for example, allocate funds to sponsor research of promising quality in the United States and in developing countries. Several international research programs require a national counterpart research organization to cooperate in studying a particular topic.

Provided that the subject matter can be related reasonably to the mission of PRONAM, the core scientists should try to attract research sponsored by outside sources. For sponsored research to contribute to the financial support of PRONAM, the sponsoring organization should be willing to fund a reasonable margin above costs, including appropriate overhead rates. A research organization that conducts sponsored research satisfactory will accumulate a portfolio of ongoing research projects after a few years, which will bring credit to itself and the country. A reliable measure of the quality of research being done by an organization is the amount of sponsored research it manages to attract from outside organizations. A.I.D. could be one of the main sources of such research.

PRONAM has obtained at least one small research grant thanks to the presence of one its senior scientists. However, a second research grant

obtained by another scientist met serious objections from USAID and RAV-Coordination. As a result, scientists at PRONAM have the impression that A.I.D. frowns on outside sources of financing and prefers to maintain the program solely on A.I.D. funding and working exclusively toward the original project objectives. The nature of the grant and the merits of the issues are known only vaguely. The potential importance of this type of financial mechanism, however, requires that a favorable climate be established for PRONAM scientists to seek outside funding.

An example of profitable sponsored research is the request by IITA for PRONAM to collaborate on the mealybug biological control program that IITA has for all of Africa. PRONAM is interested in doing research on mealybug control on cassava, and additional funding from IITA will help to accomplish that task. Of course, credit for the results should be shared by both organizations, and both organizations would benefit from working together on the subject. Appropriate charges by PRONAM to IITA to cover its costs, including technicians' time and overhead, can be calculated. To a limited extent, this collaborative research is taking place, but without any formal contract or agreement and with a minimal contribution by IITA to PRONAM's financing.

Conclusion

The general enthusiasm for market solutions to the problem of financing agricultural research needs to be tempered with the acknowledgement that some research is desirable, even necessary, despite the absence of any market mechanism to recover costs. The biological control of the cassava mealybug offers a good counter-example to illustrate this point. In this particular case, the appearance of mealybugs in Africa resulted in the disappearance of cassava from some regions of Africa, including the Shaba region in Zaire. It threatens large portions of the continent with the devastating prospect of wiping out the staple crop. In response to the threat, PRONAM initiated a program of varietal selection for resistance to the mealybug. Unfortunately, genetic selection in cassava progresses very slowly and even now, a decade

after the bug surfaced, we are far from identifying varieties that are tolerant to mealybugs.

The successful solution was developed by entomologists at IITA who identified a natural predator of the mealybug, a wasp, in its original South American habitat. They successfully multiplied it and introduced it in Africa, releasing it from airplanes over affected areas. Today, the mealybug is reported controlled, and attempts are being made to reintroduce cassava in the Shaba area. Given the importance of cassava in Africa and the impact of the biological control compared with its relatively modest cost, the social benefit/cost analysis of the program has been reported as an unheard-of 149 to 1. (See Annex B for further details.)

It is significant that the successful solution to the cassava mealybug, although highly desirable socially, would probably not have been viable if market criteria had been used to pay for its costs. The main impediment is the difficulty of convincing a farmer to pay for the predatory wasps. Once released, they would be of as much benefit to the neighbors' fields as to his own, so farmers may tend to wait for someone else to pay for them.

Moreover, even if it had been possible to package the wasps for sale, the distribution costs of doing so would have been far greater than those of production. It is far cheaper just to spray the wasps for free from airplanes, than to attempt any cost recovery. Needless to say, it is almost certain that no private research company would have been attracted to finding a solution to the problem.

The mealybug counter-example illustrates that private commercial calculations alone will not suffice to induce the development of solutions to important agricultural research problems. Public action, including national and international cooperation, is needed and can be successful.

Clearly, financial self-sufficiency cannot be the sole criteria to measure the desirability of agricultural research activities. Social impact assessments

will also be needed in most cases. This is the case with crops like cassava which, despite its importance as a commercial crop and as a diet staple for the entire population, presents serious marketing difficulties. It is especially true for marketing cassava cuttings, which are more expensive to distribute than to produce. The amount of costs recovered through the sale of cuttings cannot be expected to contribute significantly to amortizing the cost of the development.

Maize has a large and expanding market that presents realistic prospects for the sale of seeds to generate sufficient revenues to support continual research and the development of new varieties. Unlike maize, cassava varietal research in Zaire is likely to remain dependent on outside financing. The challenge is to make the program more cost effective than it has been.

ANNEX A.
NATIONAL MAIZE PROGRAM (PNM):

Proposed Joint Program of Adaptive Varietal Research with the South Shaba Project

Mouvement Populaire de la Révolution
REPUBLIQUE DU ZAIRE
Département l'Agriculture et du Développement Rural
Projet de Recherche Agronomique
Appliquée et Vulgarisation

P. N. M.
B.P. 3673 — Lubumbashi

Projet Hinterland Minier - IFAD

Introduction :

Le projet RAV fonctionne grâce aux budgets reçus du Conseil Exécutif et l'US-AID. Le but du PNM consiste à développer des variétés à haut rendement, résistantes aux insectes et aux maladies. Les données collationnées jusqu'ici sont éparses et limitées dans quelques sites du Haut-Shaba. Pour le nouveau projet, il y a lieu d'intensifier les essais d'amélioration et d'agronomie sur toute l'aire du projet afin de confirmer ou infirmer les résultats du passé.

A l'aube de la création du PNM, l'argent et les moyens ne faisaient plus défaut et il n'était que normal que le personnel du PNM se déplace de Sakania jusqu'à Dilolo-Kapanga pour l'installation des champs de démonstrations et quelques essais. Avec la collapse de l'économie en 1975 - 1976, ces efforts n'ont fait que s'amenuiser avec le temps, à tel enseigne que les champs de démonstrations ont été éliminés, la vulgarisation se limite à coopérer avec les ONG existants et les essais en dehors de la station se font de plus en plus rares.

La coopération avec l'Hinterland Minier ne pourra que faciliter l'extension des essais du RAV en dehors de la station et rendre la Vulgarisation plus efficace. Ceci est d'autant plus vrai lorsqu'il s'agit des nouvelles variétés qui sont appelées à remplacer le Shaba-1 réputé susceptible à la virose et les essais de fertilité des sols pouvant conduire à des recommandations diversifiées d'une zone à l'autre.

...2/...

N° Cpte Banque du Peuple : 0465038 N
N° Cpte Banque de Kinshasa : 60007818

Budget :

Afin de permettre au PNM d'être actif et coopérer avec le Projet Hinterland Minier, une certaine assistance est requise en ce qui concerne l l'équipement, les fournitures et le personnel. Un véhicule tout terrain est nécessaire pour assurer le transport des chercheurs, le matériel de semis et de récolte. La couverture des frais de mission et de déplacement est aussi indispensable.

Coût du budget : (PNM)

	Zaïres x 1.000
1. Coût d'investissement :	
a) Véhicule tout terrain 4 x 4 (Toyota ou L/R)	5.500 (à recevoir exécution)
b) Equipement (balances, humidimètres, pulvérisateurs...) Manuel d'exécution ; guéé - Adresse.	180
2. Coût recurrent :	
a) Salaire (Agronome A1 ou A2)	
120.000 Z/an x 5 ans	600
60.000 Z/2,5 ans Main d'oeuvre temporaire	150
b) Fournitures bureau (livres de champs, calculatrices,...) à recevoir	120
c) Maintenance véhicule :	
- Carburant (2500 l/an x 70 Z/l x 5 ans)	875
- Lubrifiant (2 fûts/an x 40.000Z/fût x 5 ans)	400
- Pièces de réchange à recevoir	800
d) Frais de mission et déplacement :	
- Supérvision (30j./an x 5 ans x 5000 Z/j.)	750
- Techniciens (45j./an x 5 ans X 3000 Z/j.)	675
3. Intrants :	
- Engrais (DAP, Urée, K_2O, P_2O_5, CaO)	
5 has x 12 sacs/ha x 2000 Z/sac	120
- Herbicides :	
5 has x 7 l /ha x 1200 Z/l	42
- Insecticides : 2 Kg x 5000Z/kg x 5 ans	50
f) Imprévus (15% du coût)	1.540
TOTAL (5 ans)	11.802

Nous disons : ONZE MILLEBS HUIT CENTS ET DEUX MILLE ZAIRES

N.B. : Ce coût ne concerne que le PNM. Le RAV étant composé de PRUNAM et PNL, un supplément est à prévoir en ce qui concerne les frais de mission et de déplacement, le personnel, les intrants et le carburant.

Programme National Maïs

Proposé de l'essai variétal de maïs à installer avec la coopération du Projet Hinterland Minier (saison 1988-89)

1. objectif : Evaluer l'adaptation et la performance des variétés en iffusion comparativement aux variétés en amélioration.

2. Nombre de sites : 10 sites ont été retenus en collaboration avec la Direction de l'Hinterland Minier (Tshinsenda, Mubindu, Mangombo, Kando, Fungurume (Kamibamba), Mulunguishi, Kolwezi (Orthodoxe).

3. Collaborateurs : Dr. MULAMBA, Dr. Johnson, Ir. Kembe, Cit. MUNGANZA.

4. Dispositif expérimental : Blocs complètement randomisés en trois répétitions avec des parcelles de quatre lignes de cinq mètres de long, espacées de 75 cm entre les lignes et 0,25 m entre poquets, semis à 2 grains par poquet.

5. Doses d'engrais : 64 - 46 - 0 répartis en 18 - 46 - 0 au semis et 46 - 0 - 0 après ± 40 jours.

6. Contrôle de maumaises herbes : 7 l/ha de primagram à pulvériser après le semis et sarclage manuel.

. Liste d'entrées et randomisation :

	Rep. I	Rep. II	Rep III
1. Shaba 1	103	206	304
2. PNM 1	109	207	309
3. Babungo	107	202	303
4. Ikenne	105	204	305
5. SR - 52	102	203	307
6. HYB 8321 - 21	110	209	302
7. HYB IK x BAB	108	201	308
8. TZMSR (W)	101	208	301
9. GWEBI 8443	104	205	310
10. SEED COOP	106	210	306

SCHEMA DU CHAMP

Rep III	8 301	6 302	3 303	1 304	4 305	10 306	5 307	7 308	2 309	9 310

Sentier de 2 m

Rep II	7 201	3 202	5 203	4 204	9 205	1 206	2 207	8 208	6 209	10 210

Sentier de 2 m

Rep I	8 101	5 102	1 103	9 104	4 105	10 106	3 107	7 108	2 109	6 110

5 m
2 m
5 m
2 m
5 m
19 m

30 m

COLLECTE DES DONNEES

Recueillir pour chaque parcelle de chaque répétition les données concerant les différentes observations indiquées ci-dessous et les noter dans la colonne appropriée du livre de champ.
Toutes les données concernant les aspects non mentionnés dans ce cahier d'observation doivent être notées dans la rubrique : "remarques personnelles".

01. Levée : Nombre de pieds dans les deux lignes centrales de chaque parcelle après demarriage (environ trois semaines après le semis).

02. Nombre de jours à la floraison : (Days to flower) :

Compter les jours entre la date de semis et le jour ou 50 % des plantes ont visiblement leurs soies.

03. Taille des plantes (Plant heigt) :

Au moyen d'une regle graduée placée au centre de la ligne, mesure la hauteur du plant (en cm) de la base du plant a la base de la panicule. Cette mesure permet d'indiquer la hauteur moyenne de la parcelle.

04. Hauteur d'insertion de l'épi (ear heigt) : M

Mesurer la position moyenne des épis (en cm) de la base de la plante jusqu'au noeud portant l'epi superieur.

05. Maladies :

L'evaluation des maladies devra avoir lieu 2 a 4 semaines après la date moyenne de l'emission des soies. Chaque maladie sera evaluée sur base d'une echelle 1 à 5 soit 1 : Bonne et 5 : mauvaise. Les anotations se font seulement en nombre entier.

06. Aspect de la plante (plant aspect) :

paramètre à reveler entre la floraison et la recolte (au stade soies brunes ou seches) lorsque les plantes sont encore vertes et que les épis ont achevé leur développement. Il s'agit d'une évaluation visuelle globale portant sur la taille et la hauteur d'insertion des épis, l'uniformité des plantes, le comportement à l'égard des maladies et des insectes, la verse etc... de toute la parcelle. Echelle : 1 à 5 (1 : excellent ; 5 : mediocre) en nombre entier seulement.

07. Dechaussement : (Root lodding) : Nombre de pieds inclinés (à partir de la base à plus de 45 par rapport a la verticale. Cette observation est à prélever avant la recolte.

08. Verse de la tige (stalk lodging) : nombre de pieds dont la tige est inclinée à plus de 45° à partir de la portion de la tige située au dessous de l'épi. (Observation à prendre avant la recolte).

09. Recouvrement des spathes (Husk cover) : Noter les épis sur base du recouvrement assuré par la spathe à l'aide d'une échelle de 1 à 5. (1 : Bonne c-à-d spathes serrés ; 5 : Mauvaise c-à-d spathe lache exposant le sommet de l'épis.

10. Nombre de pieds à la recolte (Plant harvested) : Cette opération doit être effectuée juste avant la recolte. Ces renseignements nous sont necessaires pour determiner le degre de compétition dont la parcelle a fait l'objet de la part des parcelles voisines et estimer ainsi le nombre d'épis par plant.

11. Epis recoltés (Ear harvested) Nombre d'épis recoltés.

12. poids au champ : (Field wight) Relever le poids en kilos (au dixième près) de la totalité des épis de la parcelle.

13. Aspect des épis (Ear aspect) : Attribuer une note comprise entre 1 et 5 (1 : excellent ; 5 : mediocre) sur base de l'aspect des épis recoltés après étalement de la pile devant la parcelle. Il faut tenir compte en effet, de la taille des épis, de l'uniformité de la taille, de l'homogeineite de la couleur et de la texture, du degre de remplissage des graines des dégats dus aux maladies et aux insectes.

14. Pourriture des épis (Ear rot) : la pile étalée devant la parcelle, noter le pourcentage d'épis présentant des traces de pourriture. Echelle de 1 à 5.
(1 : peu ou pas de pourriture ; 5 : la majorité des épis sont gravement atteint.

15. Pourcentage d'humidité : Teneur en eau (%) mesurée au moyen d'un humidimètre à la recolte.

Dans le cadre de préparation du programme de la recherche appliquée sur financement du P.H.M.S. pour la campagne 88/89, une équipe P.H.M.S/R.A.V. dont la liste en annexe a effectué une tournée d'identification des sites qui devront abriter les essais variétaux du Maïs (P.N.M.), de Soja (P.N.L.), d'Arachide (P.N.L.), de Haricot (P.N.L.) ; essai clônal du Manioc (PRONAM) ; essai des doses d'engrais (P.N.M.) et les parcs à bois de Manioc (PRONAM). La mission a eu lieu le 24/05/1988 et la période du 26/05/1988 au 29/05/1988.

Les sites visités se présentent de la manière suivante :

- Ferme SODIMIZA à TSHINSENDA
- GECAMINES-DEVELOPPEMENT - Siège de MANGOBO
- GECAMINES-DEVELOPPEMENT - Siège de KANDO
- Projet de Développement - Eglise Protestante MULUNGWISHI
- Ferme Semencière - TRABEZA à FUNGURUME (MBEKO-SHABA)
- Projet de Développement - Eglise Orthodoxe à Kolwezi
- Projet de Développement - Eglise Catholique de KANZENZE
- Projet de Développement - Eglise Catholique de BUNKEYA

2. RESULTATS DE LA TOURNEE

Après plusieurs séances de travail et l'analyse des contraintes liées à la faisabilité de l'opération dont notamment, la disponibilité du terrain, des tracteurs pour le labour-hersage, de la main d'oeuvre pour les travaux agricoles ainsi que le suivi des essais, les résultats suivants ont été enregistrés avec la satisfaction de toutes les parties impliquées au dit programme.

UNITES VISITEES	ESSAIS PREVUS	SUPERFICIE PREVUE (HA)	OBSERVATIONS ENREGISTREES
1. Ferme - SODIMIZA	Essai variétal et dose d'engrais-P.N.M. Essais variétaux-P.N.L. Essai clonal-PRONAM Parc à Bois-PRONAM TOTAL	0,10 0,20 0,20 2,00 2,50	- Possibilité d'utiliser le BULDOZER pour Labour-Hersage - 2è rencontre en Août pour le suivi.
2. GECAMINES-Développement siège de MANGOBO	Essai variétal et dose d'engrais-P.N.M. Essais variétaux-P.N.L. Essai clonal-PRONAM Parc à Bois TOTAL	0,10 0,20 0,20 2,00 2,5	- Collaboration acquise avec la hiérarchie. - Rencontre en mi-juillet pour le suivi

.../...

UNITES VISITEES	ESSAIS PREVUS	SUPERFICIE PREVUE (HA)	OBSERVATIONS ENREGISTREES
3. Mission Protestante de MULINGWISHI	Essais P.N.M. Essais P.N.L. Essai PRONAM Parc à Bois - PRONAM TOTAL	0,10 0,20 0,20 2,00 2,50	Accord du Comité agricole obtenu - Rendez-vous en mi-juillet pour le suivi
4. Ferme TRABEZA à FUNGURUME	Essais P.N.M. Essais P.N.L. Essais PRONAM Parc à Bois PRONAM TOTAL	0,10 0,20 0,20 2,00 2,50	- Accord de principe - Rendez-vous mi-juillet pour le suivi
5. GECAMINES-Développement siège de KANDO	Essais P.N.M. Essais P.N.L. Essai PRONAM Parc à Bois TOTAL	0,10 0,20 0,20 2,00 2,50	- Collaboration acquise - Rendez-vous en mi-juillet pour le suivi
6. Mission Catholique KANZENZE	Essais P.N.M. Essais P.N.L. Essai PRONAM Parc à Bois TOTAL	0,10 0,20 0,20 2,00 2,50	- Abbé curé en congé - Accord de principe - Rendez-vous en juillet pour la confirmation disponibilité de terrain.
7. Mission Orthodoxe de Kolwezi	Essais P.N.M. Essais P.N.L. Essai PRONAM Parc à Bois TOTAL	0,10 0,20 0,20 2,00 2,50	- Accord de principe - Difficulté de tracteur - Sollicite un don de tracteur - Rendez-vous en juillet pour le suivi
8. Mission BUNKEYA	Essais P.N.M. Essais P.N.L. Essai PRONAM Parc à Bois TOTAL	0,10 0,20 0,20 2,00 2,50	- Accord de principe - Nécessité d'affecter un A_3 de R.A.V pour le suivi - Rendez-vous en juillet
9. Ferme MUBINDU	Essais P.N.M. Essais P.N.L. Essais PRONAM Parc à Bois TOTAL	0,10 0,20 0,20 2,00 2,50	- Identifiée par le P.H.M.S. le 21/05/1988 sur route Kasenga

UNITES VISITEES	ESSAIS PREVUS	SUPERFICIE PREVUE (HA)	OBSERVATIONS ENREGISTREES
10. Ferme KALALA	Essais P.N.M.	0,10	- Située dans la ceinture verte de Likasi
	Essais P.N.L.	0,20	
	Essais PRONAM	0,20	- Non encore identifiée
	Parc à Bois	2,00	
	TOTAL	2,50	
TOTAL GENERAL	Essais P.N.M.	1,00	
	Essais P.N.L.	2,00	
	Essais PRONAM	2,00	
	Parc à bois	20,00	
	TOTAL	25,00	

3. CONCLUSION

Comme on peut bien le constater, la réaction de tous les responsables des Unités de production contactés a été largement positive.

Le total des superficies prévues par Programme de recherche se présente comme suit :

- Essai variétal et des doses d'engrais / P.N.M : 1 ha pour 10 sites
- Essai variétal / P.N.L. : 2 ha pour 10 sites
- Essai clonal / PRONAM : 2 ha pour 10 sites
- Parcs à Bois / PRONAM :20 ha pour 10 sites

T O T A L 25 ha pour 10 sites

Lors de la tournée de suivi-préparation des sites en juillet et août prochain, les deux fermes MUBINDU et KALALA pourront être visitées par l'équipe R.A.V./P.H.M.S.

Nous avons maintenue la même superficie des essais par site pour une meilleure programmation ainsi que pour une gestion et contrôle efficaces.

Signalons qu'à l'Intitut KITABATABA (Mission Protestante de MULUNGWISHI) 3 variétés de manioc sont déjà en multiplication, variétés obtenues de KAMINA ; il s'agit des variétés LWENYI, M.S.B. et 85/28/10.

KABWE-MUTAMBA MULAJA — OYOKOTO LUMENA

Adjoint Suivi-Evaluation.- — Adjoint Technique-Formation.

MULAMBA NYINDU	RAV/PNM
KALOMBO MUEMBELA	RAV/PNL
KAPONGU LUKANDA	RAV/PRONAM
OYOKOLOLO LOMENA	P.H.M.S.
KABWE-MUTAMBA	P.H.M.S.

ANNEX B.
BIOLOGICAL CONTROL OF CASSAVA MEALYBUG IN AFRICA

Wasps Help Stave Off Starvation in Africa

Airlifted Insects Blunt Invasion of Crop-Ravaging Mealybugs

By Boyce Rensberger
Washington Post Staff Writer

Every few weeks, an airplane carrying thousands of wasps takes off from an airport in Nigeria, heads across Africa and eventually swoops low to scatter the insects over the scraggly, pest-ridden cassava fields of unsuspecting and impoverished farmers.

Some 200 million of the poorest people in 35 African countries rely on cassava's starchy tubers for more than half their dietary calories, but starvation has threatened many because of one of the worst, although least publicized, modern threats to Africa's food supply. An obscure species of Latin American mealybug, which turned up in Zaire 10 years ago and has spread to 31 countries, is stunting the plants and cutting yields by as much as 80 percent. Within months after the wasps fall from the plane, however, the farmers' economic plight and nutritional status improve dramatically. The wasps, a rapidly multiplying species no bigger than a fruit fly, feed only on the mealybug, destroying them in vast numbers. Villages step back from the brink of starvation, aware only that the ravaging pests have mostly gone and cassava yields are soaring.

Since 1981, when the wasp flights were begun, the effort has become the world's largest biological pest control program. This form of pest control, an ancient strategy revived in recent years, avoids hazardous or costly chemicals and relies instead on cleverness to find and encourage insect species that are the natural enemies of the pest species.

See PEST, A20, Col. 1

The Washington Post, Monday, June 20, 1988

Africa Pest-Control Program Saves Lives, Lifts Productivity

PEST, From A1

According to experts in international agriculture, the cassava mealybug control program, designed and operated by the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, is among the world's most successful biological pest control programs. Countless lives have been saved and untold miseries banished.

A leading American economist has calculated that for every dollar spent on the effort, African farmers have reaped $149 in increased food productivity—a spectacularly favorable cost-benefit ratio.

Yet, according to Hans R. Herren, the Swiss-born director of the Africa-wide Biological Control Programme, he is having trouble attracting funds needed to continue toward the goal of establishing enough wasps to keep the mealybug under long-term control throughout Africa's vast cassava belt, an area 1½ times the size of the United States.

"If there's a fruit fly problem in the California citrus crop, nobody objects to spending $100 million to fight it," said Herren, who is in the United States to raise money to keep the program going. "But here we have 200 million people at risk in Africa and it has been a struggle to beg for $15 million," the cost of the financially hobbled program so far.

In the 1970s, when the mealybug appeared in Africa, Herren and his colleagues at IITA asked the international donor community for $30 million over five years to create the huge biological control program he thought would be needed. Pesticides, Herren reasoned, were out of the question because cassava farmers could never afford them and the bug has a defense in its waxy body coating.

Such a massive biological control program, however, had never been attempted and scientists dispatched by the U.S. Agency for International Development pronounced the plan unworkable. The United States refused to help support it. The program went ahead with funds from Germany, Switzerland and, to a lesser extent, several other European countries.

Herren's first job was to find an insect that killed the particular species of cassava mealybug plaguing Africa but which attacked no other species, especially not beneficial insects such as bees. It could only be found in a place where the mealybug already was established.

Since the mealybug fed only on cassava, Latin America was an obvious place to look, because the plant is grown over much of the area and South America was the source of the cassava that Portugese traders took to Africa about 500 years ago. Many Latin Americans call the tuber manioc. In the United States, cassava is known chiefly as the source of tapioca.

Also, there was reason to believe that the mealybug reached Africa aboard cassava cuttings imported from South America in an effort to breed new varieties. The imports apparently were not quarantined to detect pests before being planted in open fields.

This particular species of mealybug, however, was new to entomologists. No one knew where in Latin America it came from.

"I thought the only way to find it was by traveling around, checking cassava plants for mealybugs," Herren said. "I will tell you, it is very hard to find mealybugs in Latin America."

The reason, it is now clear, is that the mealybug's natural enemies are already present in Latin America, keeping its numbers low. Africa's problem was the result of introducing the pest without its natural control. If the control could be found and introduced into Africa, the natural balance would be restored.

After 30,000 luckless miles of driving and checking, starting in Mexico and working down through Central America, Herren heard

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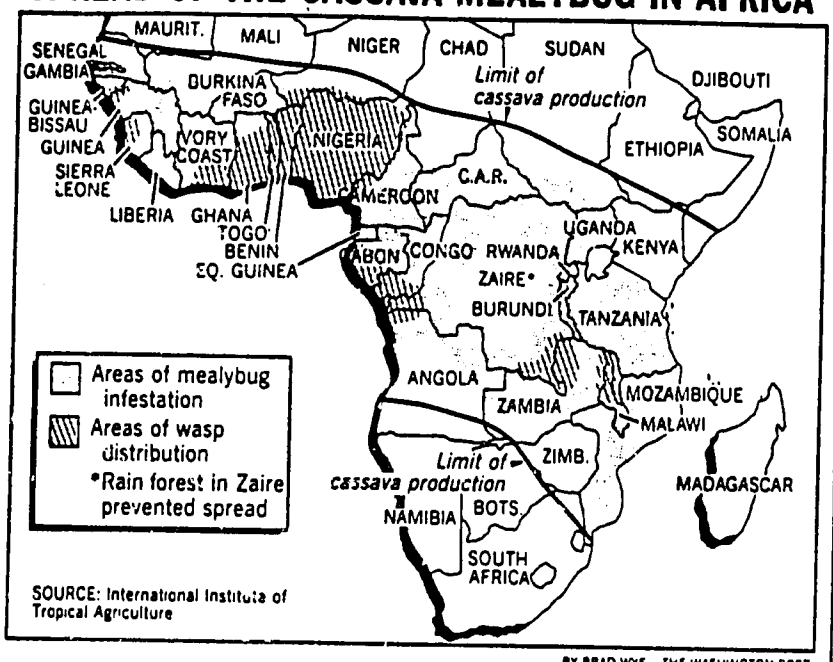
SPREAD OF THE CASSAVA MEALYBUG IN AFRICA



SOURCE: International Institute of Tropical Agriculture

BY BRAD WYE—THE WASHINGTON POST

from a colleague at IITA's sister institution in Colombia, the International Center for Tropical Agriculture, or CIAT. He just happened to run across the right species of mealybug in Paraguay.

Live specimens were flown to London's Commonwealth Institute for Biological Control for study in special chambers. While there, some of the mealybugs died, their exoskeletons dried and cracked open and out came tiny wasps, hardly bigger than a fruit fly. They were the product of eggs that female wasps had injected into live mealybugs. When the wasp eggs hatched, the larvae fed on the mealybug's internal organs, turning it into a "mummy" from which one adult wasp would emerge.

The newly emerged wasps looked for mates. Within two weeks, each female would lay another generation of about 40 eggs in 40 cassava mealybugs.

The wasps were tested many times to be sure they would not harm other insects. Exposed only to bees, silkworms and many other insects, female wasps simply refused to lay any eggs and died.

Once it was clear that the wasps were a threat only to mealybugs, they were sent to Herren's lab at IITA in Ibadan. Millions would have to be raised to begin the assault in the cassava fields.

Herren and his colleagues invented a variety of mechanized contraptions for growing cassava hydroponically, establishing mealybugs on them and, finally, rearing millions of wasps on the mealybugs.

The next step was to disperse the wasps. Scattering them from planes seemed the most reasonable way to cover vast areas of nearly roadless countryside. The solution was to invent an automatic bug-scattering machine that could fit into a light plane. It holds hundreds of plastic vials, each containing a number of wasps. The device can drop 1,000 wasps per second of flight.

Studies show the wasps soon establish themselves on the ground and spread from field to field. As the mealybug numbers decline, so does the wasp population. Eventually, they reach an equilibrium at low levels for each.

That's when cassava yields go up, and life for some of the world's poorest farmers gets significantly better.

The Biological Control of Cassava Mealybug in Africa

Richard B. Norgaard

Cassava, brought from South America 300 years ago free of its pests, became a major subsistence crop in Africa. A mealybug was mistakenly introduced in the early 1970s. By the 1980s the mealybug was a major pest. The International Institute of Tropical Agriculture found a parasitic wasp in South America and reared and released it in Africa. Conservatively estimated, the benefit-cost ratio for this program is 149 to 1. This success indicates that biological control can play an important role in pest management.

Key words: Africa, benefit-cost analysis, biological control, cassava, pest management.

Cassava was brought to Africa some 300 years ago without the herbivorous pests and diseases with which it had coevolved in South America. Numerous minor pests, grasshoppers, and mosaic disease plague cassava in Africa; nevertheless, it has been easier to manage and a more secure source of calories than other crops. For this reason and the convenience of being harvestable when needed, cassava accounts for approximately one-third of the calories consumed in tropical Africa (Barker and Dorosh).

In the early 1970s two pests were inadvertently introduced from South America, cassava mealybug and cassava green spider mite. These pests are relatively minor nuisances in South America where predators and parasites have coevolved to keep them in check. In Africa, however, these pests spread rapidly and devastated cassava fields in the absence of their natural enemies. Walker, Heydon, and Guthrie describe the losses as follows:

> Yield losses of tubers, as reported by farmers, averaged 65 percent during the 1983 (cassava mealybug) outbreak, but good rains in 1984 resulted in losses being reduced to 43 percent of the 1979/80 (pre-infestation) levels. . . . The economic cost of such crop losses to Ghana, valued in maize equivalents . . . , indicate overall costs in the range of $58 to $106 million at 1983/84 average prices. . . . The price of Gari (made from cassava) rose nine times after the 1983 (mealybug) outbreaks, equivalent to a rise of 2.3 times in real terms. The price of planting material rose 21 times, or 5.5 times in real terms. Double the area of cassava now gives the same yields as before the 1983 outbreak. The area of maize has also increased. (page 1)

In the mid-1970s, biologists began to search in South America for natural enemies of the cassava mealybug and the cassava green mite that would control their population outbreak. A classical biological control solution, in particular the reuniting of predators and parasites with their previously dislocated prey and hosts, was deemed the best solution because subsistence farmers in Africa do not use chemicals. *Epidinocarsis lopezi*, a small wasp, was found to be a parasite of, as well as a host feeder on, cassava mealybug. With support primarily from the International Fund for Agricultural Development, mass rearing and distribution techniques were deveioped at the International Institute of Tropical Agriculture (IITA) in Nigeria in the early 1980s. By 1987 *E. lopezi* was established in 90% of the

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Giannini Foundation Paper No. 863 (for identification purposes only).

The author served as a member of a team to evaluate the biological control program on behalf of the International Fund for Agricultural Development. The full report (Winrock International), prepared by Michael Arnold with the assistance of the other team members—Jean-Paul Aeschlimann, Thomas Coaker, Hugh Murphy, and Kenneth Rachie—provides further details. Paul Dorosh, S. K. Hahn, Hans Herren, and Winfred Hammond of the International Institute of Tropical Agriculture and Abbas Kasseba of the International Fund for Agricultural Development provided background information during the evaluation. This analysis stems from extensive conversations with all of the above, interviews with agricultural officials in Nigeria, Benin, Togo, and Ghana, and field observations. Tim Brown, Clifford Gold, and Laurel Prevetti provided suggestions which improved the manuscript.

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cassava-growing region of Africa, and losses from mealybug were brought under control.

Ecologists and environmental economists have stressed the value of nature's services to agricultural production and the maintenance of a viable environment (Westman, Fisher and Ellis). The cassava-mealybug-*E. lopezi* episode documents the advantages of working with nature's services. Many crop species have been transplanted to new environments without their indigenous pests and predators and have shown increased productivity (Anderson). Strong arguments have also been made in support of the quarantine laws and inspection systems that are necessary to maintain the separation (McGregor, Eden et al.). It is unrealistic, however, to expect that separation can be maintained forever: hence there is value to biological control knowledge and implementation capability (Marsden et al.). The following benefit-cost analysis documents the value of maintaining biological diversity and the ability to work with biological systems.

Methodology

Appropriate methodologies depend on the circumstances (Johnson). The following analysis was undertaken by the author as a member of an evaluation team which had agreed to prepare a report on the biological control program in a matter of weeks. The author had unusual access to the expertise of program and review team personnel and to all the reports and data that existed. The data and time available, however, were insufficient to estimate how the program had shifted the supply curve for cassava. Indeed, official production data are questionable, and price data are nearly nonexistent. When data are poor and how the future might unfold is uncertain, the effect of alternative assumptions on the benefit-cost ratio can be explored. Sensitivity analyses produce an array of benefit-cost ratios which give insight into the likelihood of the project's success. A preliminary analysis for the control of cassava mealybug resulted in a benefit-cost ratio greater than 400. It was clear that a sensitivity analysis would result in an array of ratios, each of which indicated that the project was a great success. For this reason, the analysis was limited to a "reasonable, least favorable" case that incorporated the features which the experts felt might threaten the success of the project.

Good estimates of total production are not available because cassava is interplanted with other crops and harvested after variable periods of growth, frequently a little at a time as needed for subsistence consumption. FAO estimates of total cassava production are used even though many analysts believe they significantly underestimate the production of subsistence crops.

Putting a value on cassava is especially difficult. Cassava is the preferred source of calories in some parts of Africa. In others it is eaten last. Yet it is grown on an estimated 7.2 million hectares across Sub-Saharan Africa because it thrives in poor soils, requires little labor, can be left in the ground until needed, and tolerates drought. Thus, in bountiful years, cassava has a very low price and much is left in the field to rot. In years when other crops do poorly, the price of cassava is very high and represents life itself (Walker et al.).

Estimates of the portion of potential yield lost to cassava mealybug range from 10% to 100%, differing between nations and years. The estimates also differ, however, because yield losses from mealybug vary substantially from field to field and are difficult to distinguish from those of other pests, diseases, and drought (Schultheis et al.). Controlled field experiments have nearly reproduced this range of losses due simply to varying planting dates and weather (Schultheis et al.). There is little agreement among researchers or extension agents about average losses under average conditions or even on what these terms mean. There is also disagreement as to the level of control that *E. lopezi* provides. Some argue that it reduces losses by 90%, while others think control is closer to 50%.

There is the possibility that losses from mealybug may be declining for reasons in addition to parasitization by *E. lopezi*. To some extent, the most susceptible strains of cassava are being wiped out by the mealybug or are being selected out by farmers. New resistant strains are being adopted by a few farmers. Planting and harvest dates are being modified to reduce damage. Several indigenous species of insects behave as predators during peak infestations, and perhaps natural selection is occurring so that some populations are becoming more effective as predators during the critical period earlier in the plant's growth. While these and other adjustments are possibly taking place, there are no data to document their existence, let alone their extent.

Table 1. The Derivation of the Benefit-Cost Ratio

Year	T-Value (1)	Percent Loss (2)	Percent Saved (3)	S-Value (4)	D-Value (5)	Expenditures (6)	(7)	(8)	(9)	(10)
					($US millions)					
1977/78	3100	5	0	0	0	0.0	0.1	0.0	0.1	0.1
1978/79	3200	10	0	0	0	0.0	0.1	0.0	0.1	0.1
1979/80	3300	15	0	0	0	0.1	0.2	0.0	0.3	0.4
1980/81	3400	20	0	0	0	0.3	0.4	0.0	0.7	0.8
1981/82	3500	20	1	7	7	1.0	0.6	0.0	1.6	1.6
1982/83	3600	20	10	72	66	1.5	0.6	0.1	2.2	2.0
1983/84	3700	20	20	148	123	1.6	0.4	0.2	2.2	1.8
1984/85	3800	19	35	253	190	1.6	0.4	0.3	2.3	1.7
1985/86	3900	18	50	351	239	1.4	0.3	0.4	2.1	1.4
1986/87	4000	17	60	408	253	1.0	0.2	0.5	1.7	1.1
1987/88	4100	16	60	394	221	0.6	0.1	0.6	1.3	0.7
1988/89	4200	15	60	378	193	0.3	0.0	0.7	1.0	0.5
1989/90	4300	14	60	361	170	0.2	0.0	0.8	1.0	0.5
1990/91	4400	13	60	343	144	0.1	0.0	0.9	1.0	0.4
1991/92	4500	12	60	324	126	0.1	0.0	0.9	1.0	0.4
1992/93	4600	11	60	297	104	0.1	0.0	0.8	0.9	0.3
1993/94	4700	10	60	282	90	0.1	0.0	0.7	0.8	0.3
1994/95	4800	9	60	259	75	0.1	0.0	0.6	0.7	0.2
1995/96	4900	8	60	235	61	0.1	0.0	0.5	0.6	0.2
1996/97	5000	7	60	210	50	0.1	0.0	0.4	0.5	0.1
1997/98	5100	6	60	184	40	0.1	0.0	0.3	0.4	0.1
1998/99	5200	5	50	130	26	0.1	0.0	0.2	0.3	0.1
1999/2000	5300	4	40	85	15	0.1	0.0	0.1	0.2	0.0
2000/2001	5400	3	30	49	8	0.1	0.0	0.0	0.1	0.0
2001/2002	5500	2	20	22	3	0.0	0.0	0.0	0.0	0.0
2002/2003	5600	1	10	6	1	0.0	0.0	0.0	0.0	0.0
Totals					2.205					14.8
					Benefits/Costs = 149					

The benefit-cost ratio for the "reasonable, least-favorable case" is derived in table 1 using the following assumptions. Total value of production (column 1) is based on FAO production figures for the latter 1970s before cassava mealybug had a significant impact. Barker and Dorosh's estimate of the price of processed cassava at the farmgate, $60 per ton, was used for all years. Fresh cassava brings a higher price and much is consumed fresh on the farm. Hence, this is a conservative estimate. The value of production is assumed to increase $100 million per year, roughly in proportion to projected population increases. These are estimates of production without losses due to cassava mealybug.

The percent loss (column 2) due to cassava mealybug if *E. lopezi* had not been introduced builds to a maximum of 20% in 1984/85 and reduces linearly by 1% per year to 0% in 2003/04, terminating the analysis. The decline in losses is attributed to the adoption of resistant or tolerant varieties, cultural practices, changes in the location of planting, and evolution of indigenous predators and parasites that would have occurred if *E. lopezi* had not been introduced. *E. lopezi* will surely play a significant role in the control of cassava mealybug for many more decades and perhaps forever. This assumption, more than any other, makes this a "reasonable, least favorable" case.

The percent saved (column 3) because of the presence of *E. lopezi* rises to a maximum of only 60% as the parasite becomes established in the early 1980s, and then declines to zero at the end of the period as the presence of cassava mealybug is reduced through other controls. The decline in effectiveness at the end of the period is attributed to the lower likelihood that *E. lopezi* will be established wherever cassava mealybug outbreaks happen to occur as outbreaks become fewer and fewer. The value saved (column 4) is simply the product of the first three factors. The discounted value saved (column 5) is derived using an interest rate of 10% and setting 81/82 as year zero. A relatively high interest rate was selected to assure that the case was "reasonable, least

favorable" from an economic perspective.

The expenditures through the IITA (column 6) on exploration, research, rearing, and distribution of biologicals for the control of cassava mealybug include expenditures by other international centers and organizations and national programs funded through the IITA budget. Expenditures by other international agencies (column 7) include, for example, the early exploration by the Commonwealth Institute of Biological Control. Expenditures by national programs (column 8) include expenditures financed directly through national programs. Hans Herren, director of the IITA biological control program, assisted in the allocation of IITA expenditues between work on the mealybug and the green spider mite, the estimation of early exploration expenditures, and the projection of national expenditures. To be conservative, generous numbers were used, especially for national programs. Expenditures in the 1970s were inflated approximately to early 1980 price levels, the period during which the IITA program was officially initiated and the price of cassava was estimated. Total expenditures (column 9) is the sum of columns 6 through 8. The present value of total expenditures (column 10) was derived using the 10% interest rate.

The analysis indicates that this "reasonable, least favorable" case has a benefit-cost ratio of 149 to 1.

The framework of the analysis has been kept simple deliberately. Going into more detail would not improve the analysis. For example, country-by-country data on production, losses, and control are not available on a yearly basis, and the numbers that are available were not determined systematically between countries. Hence, a more detailed, country-by-country analysis would suffer from logical inconsistencies, could produce spurious numbers for each country, and may not produce a better estimate overall. It would have been illogical to match a more elaborate framework of analysis with the existing data and the range of the experts' perceptions of how the future might unfold.

On the other hand, 149 is a very large number for a benefit-cost ratio, especially in light of the conservative derivation procedure. A sensitivity analysis using alternative combinations of the experts' judgments would produce many benefit-cost ratios much higher than 149 and very few less than 100. The biological control of cassava mealybug by *E. Lopezi* has been unusually successful. The level of success and unusual nature of this project have several implications.

Interpretation and Conclusions

The benefit-cost ratio for the establishment of *E. lopezi* is high in part because the analysis only considers the most successful part of the biological control program of IITA. Classical biological control is most likely to work well when an exotic predator or parasite is introduced into a previously introduced plant-pest system. It is easier to put coevolved species back together again than to match species which have not evolved together. This program in particular has been unusually successful because *E. lopezi* (*a*) was discovered quite quickly and inexpensively, (*b*) could be mass reared by relatively simple techniques, (*c*) appears capable of permanent establishment over nearly all, if not all, of the cassava region, (*d*) disperses effectively and rapidly, and (*e*) provides good control under a wide variety of conditions. In addition, cassava is an extremely important crop. This combination of factors means the very high benefit-cost ratio for the biological control of cassava mealybug cannot be extrapolated to biocontrol projects in general. Yet, a conservatively estimated benefit-cost ratio of 149 to 1 must have some broader implications.

First, the analysis documents the advantages of working with nature. The destruction that occurred as the mealybug multiplied in the absence of natural controls illustrates the value of the "checks and balances" that have evolved in natural systems. The use of pesticides in the developed world has not only eliminated nature's beneficial services for many crops but reduced our options for switching back to biological control in the future. This analysis documents the value of maintaining biological diversity, of maintaining our options for working with nature by saving her parts.

Second, the analysis documents the value of maintaining the knowledge and capability to implement biological control. Since the advent of pesticides, farmers' experiential knowledge of how to work with nature has seriously eroded. Furthermore, little has been invested in the science of biological control. This analysis indicates the value of maintaining this knowledge and capability.

Third, the project is an unusual success for

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the very reasons that most development projects perform so poorly. Farmers do not have to decide to adopt the "technology"; the dynamics of populations with which they work are simply changed. The technology requires neither investment nor maintenance expenditures by farmers. Thus, no credit programs, extension services, or subsidies are needed. Since *E. lopezi* reproduces and disperses itself, no manufacturing or distribution system beyond those of the initial "research" project are necessary. Because almost no institutional, economic, or technological developments are required, successful classical biological control is very inexpensive and spreads very rapidly.

Fourth, while biological control provides development options without bureaucratic entanglements in agricultural production, it raises extremely challenging social and ecological questions with respect to optimal quarantine areas, the thoroughness of inspection, and freedom of travel and exchange of materials (McGregor, Eden et al.).

Fifth, the high ratio of benefits to costs on this project suggests that there likely are other opportunities for classical biological control. These projects may have benefit-cost ratios a magnitude lower than that for cassava mealybug control, but such ratios are still a magnitude greater than other good development projects. Africa is likely to have additional opportunities because so many key crops have been introduced from other continents, the number of introduced pests and likelihood of additional introductions are quite high, and very little has been invested in the biological control of pests (Greathead). Hence, the very high benefit-cost ratio for the establishment of *E. lopezi* indicates: (*a*) a substantial increase in the exploration for native predators, parasites, and diseases of introduced pests in Africa is justified; (*b*) the technical capability to quarantine, rear, and introduce predators, parasites, and diseases of introduced pests should be enhanced; and (*c*) African nations should collectively develop screening criteria and appropriate institutions to promote the safe and timely introduction of predators, parasites, and diseases.

Sixth, many opportunities for biological control do not fit the classical ideal, the situation where the introduced biological requires little or no further introductions or special cultural practices to remain established. The exceedingly high benefit-cost ratio for the biological control of cassava mealybug indicates that the additional expenditures associated with biological controls within an integrated pest management (IPM) approach likely are justified. Additional expenditures may be required for continual rearing and release of predators and parasites, the maintenance and use of resistant varieties, and cultural practices.

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ANNEX C

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