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FROM VILLAGE CONCERNS TO NATIONAL BIOTECHNOLOGY PRIORITIES

Using the results of a case study with cassava farmers in the Tanzanian Lake Zone

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A. The context

1. CBN case study of cassava in the Lake Zone of Tanzania

A CBN case study explored the potential for obtaining the perspectives and opinions of cassava users directly, informally, and quickly, in a way that could be repeated at intervals or in different regions by any program like CBN whose main investment must be in research but which requires for its direction a practical method of current interaction with end-users.

The CBN case study was conducted in the Lake Zone of northern Tanzania, a cassava-dependent subsistence farming area. The approach known as Rapid Rural Appraisal (RRA) was chosen for its fit to CBN's needs for a cost-effective and relatively quick method of gathering information from cassava users about their needs and preferences. CBN case study participants were chosen to represent a range of expertise (Table 1) and knowledge of the local context. Participants divided into two smaller teams. At least one woman and not more than one international member were on each team. After a one-week planning meeting, the CBN teams spent two weeks in the field engaging in group discussions in villages.

Generally, men made up the majority of the village groups. Women's opinions were obtained because questions about cassava processing resulted in women being called or, often, in movement of the group to areas where women were processing cassava.

Summary of the findings

<u>A crop under stress</u> The Lake Zone region has experienced several successive years of delayed and inadequate rains. Mealybug, a recent arrival in the Lake Zone, has been a severe pest in most of the region and was said to have completely wiped out the cassava crop for two years in Mara. The mealybug is still present but cassava is making a come-back. Villagers said that the pest and the drought interact to cause greater damage than each one alone. Even varieties described as resistant are only tolerant, able to produce some yield even when infested with mealybugs. Scale insect and green mite were commonly observed.

Cassava yields in at least one village were declining. In this village, close to the Serengeti National Park, farmers said they did not have enough land to open new fields and that soil fertility was wearing out with continuous cropping.

<u>Varietal diversity to satisfy many needs</u> Lake Zone farmers grow many varieties, in separate fields, to satisfy a range of needs: early maturity for food in a hurry; long-term in-ground storage ability for food security; processing into the

staple ugali; for quick preparation as raw snacks or boiled; leaf production (an important green vegetable) and firewood. Some varieties were grown for extreme "bitterness" that repelled predation from wild pigs and rats, frequently-mentioned causes of crop loss. Most villages grew two or three "bitter" varieties on most of their cassava area, and two to five or more "sweet" varieties.

Lack of planting material, and desire to get planting material of new varieties, were both often mentioned by villagers. Stories told about the histories of variety names illustrated that the villagers were eager collectors and testers of new cassava varieties.

The designations "bitter" or "sweet" were in some cases used analogously to high and low cyanogen content. In other cases there are discrepancies between the reported uses and effects of "bitter" and "sweet" varieties, compared with uses and effects expected from high or low cyanogen varieties.

A variety of cassava uses In the Lake Zone, most of the cassava crop is processed into a storage form, generally "udaga", pieces of dry-fermented, sun-dried cassava ranging from the size of an egg to much smaller that is later pounded to flour and made into "ugali" (stiff porridge). Beer is commonly made. "Sweet" varieties are eaten boiled or raw. A packed-heap open-air dry fermentation process using prefermented inoculum, shown to the CBN team in two villages, was not previously known to any team member. Both women and men frequently asked how the speed, safety, and nutritional value of their village's cassava processing methods could be improved.

2. Cassava biotechnology research in Tanzania

Both of the national organizations charged with research for cassava production and utilization in Tanzania participated in the Lake Zone study. These are the Tanzania Ministry of Agriculture (MOA), which has responsibility for plant breeding and agricultural technology diffusion, and the Tanzania Food and Nutrition Centre (TFNC), which is responsible for cassava processing research including microbial biotechnologies.

Cassava biotechnology research in Tanzania has been concentrated in the area of microbial processing biotechnology at TFNC, and it is in this area where the present case study information will find immediate use. There had been no other biotechnology research on cassava in Tanzania at that time.

Discussions with other institutions in the Tanzanian research and policy community were not part of this CBN case study, because it was designed primarily as an experiment in obtaining farmers' perspectives for priority setting in an international biotechnology research network. Such discussion would be essential in a study for national planning purposes.

Tanzania has founded a Commission on Science and Technology (COSTECH) to assess potential research investments across institutions in Tanzania. COSTECH is participating in the present seminar, which gives us a welcome opportunity to learn from them about current plans for research capacity development, including biotechnology, and priority setting in Tanzania.

B. The issues

Issues in using the results of a village case study for setting research objectives

Using the results of the CBN case study (or any similar study) for setting research objectives requires a "translation" process (Lynam and Henry, 1995). Although there is a sequence to the process, it is not a one-time event. Any institution or country will re-iterate the process often, combining new information with existing experience.

Steps in the process include:

1 Problem identification: Learning the farmer/processor's expressed needs (e.g., the case study itself)
2 Distinguishing the subset of needs that can be solved via biological research, and "translating" those into their underlying biological causes
3 Determining the optimal research approach
4 Assigning a priority relative to other research needs

Step 1. Problem identification: Learning the farmer/processor's expressed needs

Considerations at this step include the methodology used for communicating with farmers and its shortcomings and advantages.

a. Methodology

Open questions. Like most RRAs, the CBN case study used the method of open questions. "We would like you to tell us about your cassava varieties." "Which one would you prefer to grow on most of your fields?" "Why?". Only toward the end of a conversation, if a potentially important topic had not been mentioned, would the team ask a more specific question such as, "What about intercropping? Are any cassava varieties better than others for intercropping?" "What would happen if you could leave cassava roots sitting in a basket for a month after harvesting instead of processing them the same day?"

Technology-independent. Beyond steering the village conversations to the general area of cassava varieties and processing, CBN chose not to try to focus the discussions on biotechnology or on a subset of problems for which biotechnology may have an advantage in finding solutions. We felt that could have complicated getting started hearing what the villagers had to say, and possibly caused us to miss important information. In consequence, some of our findings are not directly relevant to CBN, but many of these are useful input to other activities of the national programs and the NGO who collaborated with CBN in the field.

Crop specific. Although the CBN case study did not focus on a single technology, it did focus on a single crop. We sought farmer perceptions on cassava, because a prior international prioritization process established a global research priority for cassava. In setting national research priorities, there is the same need to decide first which crop(s) will be priority for research resources. Two sets of village or farm-level conversations might be conducted, the first set with the objective of learning farmers' perspectives on the relative importance of all the crops they grow and use.

b. Shortcomings and advantages of the methodology used by CBN

i. A major puzzle lies in knowing how to use case study/farmer perspective data at higher levels than a single village or farm. It is impossible to visit all villages or all farms, but equally impossible to average a perspective like a measurement. How to summarize a collection of non-uniform observations across many villages in a district, many districts in a nation? In combination with other types of data, such as national and international agricultural statistics? There are also problems with extrapolation to similar, unvisited, regions. Using information for national and international decision-making implies the ability to do all these things. CBN hopes to make a contribution to solving these methodological problems.

ii. The method was not satisfactory for obtaining farmer perspectives on novel solutions or opportunities.

In contrast to lively discussions on known production and processing factors, attempts at "brainstorming" about "what if ..." questions and "wild ideas" did not lead to much discussion. For example, no one expressed the need for cassava with longer post-harvest keeping quality, and no one responded to team members' questions about what it might imply for them. There is little variation for this characteristic in cassava; perhaps rapid perishability is seen as intrinsic. Another example: villagers mentioned the heaviness of planting stakes and the slow rate of multiplication of new varieties, but did not speculate about seed-propagated cassava.

Yet some things that seemed "part of the background" to villagers could in fact be altered by biotechnology, and would have consequences that farmers could evaluate as useful or not in their environment. In these examples, biotechnological tools may permit development of cassava varieties with keeping quality as much as several months, or varieties that could be planted by seed. Farmers and researchers would have different sets of knowledge providing complementary insights as to the effects of such changes on village life.

Other "wild ideas" would have consequences beyond those that a village group could assess. Cassava could be developed as an oilseed crop instead of a starch root crop, or to produce other compounds in its root "factories" instead of starch. The value of such innovations to a local community would depend on international factors as well as local ones. Novel ideas do have a place in priority setting. For example, the transformation of industrial rapeseed in Canada to the edible-oil crop "Canola" was not foreseen by farmers, and yet has provided the basis for new farm prosperity (Busch et al., 1994).

iii. Farmers are not working in controlled situations and consequently can miss important variables. Villagers in the Lake Zone did not mention green mite, which the team found frequently, nor African mosaic virus, which virologists later told us is known to be present in the Lake Zone. The devastating effects of mealybug and drought effectively masked the damage caused by mite and virus. To Lake Zone villagers, drought- and mealybug-resistant varieties appear the answer to most of their production problems. In fact mite and virus resistance are also needed.

Advantages of the methodology used by CBN

i. It is rapid and relatively inexpensive.

ii. It provides information on location-specific interactions and solutions, information that may be known only to those living in the situation. Local solutions provide clues for conditions that research must match or excel.

For example, Lake Zone farmers explained that the combination of drought and mealybug attack led to a requirement for varieties that matured early, to replenish the food supply quickly; and also for varieties that could be left long in the ground (2 or 3 years) for food security. But all their early varieties became inedible if left in the ground more than 12 months. They managed by growing several different varieties, some early maturing and others late. Because research on drought resistance is long term and mealybug resistance has not been found (biocontrol is being introduced instead), interim cassava improvement research for this region can follow the farmers' tactic and develop improved varieties of both early and late maturity types.

iii. It provides information on relative importance of specific issues to the crop users, which can differ from researchers' perspective.

This may be especially important when individuals involved in research planning for a specific target group come from a different region. For example, research planners from regions where the starch staple foods are grains (which are storable for several months to years after harvest) might easily fail to grasp the impact that research on cassava processing and products could have in the Lake Zone. Village conversations made clear to CBN teams that the best-targeted cassava production research, if it excluded post-harvest research, would still leave unanswered many questions important to villagers, and would miss good opportunities to improve village welfare.

iv. Not least, the results have a human face and thus a higher value than numerical data for influencing opinion and generating action leading to solutions.

> *Given problems expressed by farmers and processors in Step 1, Steps 2 and 3 involve assessment of which causes of a given problem are most important, which are accessible to technological improvement, and which technological interventions would be most sustainable for local conditions.*

Step 2. Distinguishing the subset of needs that can be solved via biological research, and "translating" those into their underlying biological causes

Any perceived problem may have more than one possible cause. For example, low yield on poor soils is a concern of Lake Zone villagers that may have several different causes, or several causes contributing at once, some socioeconomic, others material. Material causes could include soil erosion, absence of a functional mycorrhizal association, or low native potassium content.

At this step, CBN calls on experts in many disciplines for information on the global range of possible biological causes of a given problem. All of these network resources are also available to a national program. Another key resource for identifying underlying causes will be the local knowledge developed by the national program in its own work. Ideally, it will be possible for the national program to work with the target group to test the importance of various predicted causes.

Step 3. Choice of the optimal research approach

Deciding the optimal research approach is really several questions. Some of these are: If there is more than one technical solution, which is most suitable for the target beneficiaries? What research method is most likely to achieve the solution? Where should the research be conducted?

Solution and research method. Once a an expressed farmer concern has been examined as to its underlying causes, there may be multiple technical solutions. For example: A solution to a biotic constraint may consist of cultural practices, pesticides, biological control, or resistant varieties. If resistant varieties are the most practical solution for the users, then there are choices among crop improvement approaches for developing these. Some of these potentially applicable approaches will include use of biotechnological tools.

There are cases in which the biotech methods offer the only solution. For example, molecular markers will be essential for selecting ACMV-resistant varieties for South America and Asia to protect cassava agriculture there against the potentially devastating arrival of the virus. In other cases, however (for example, developing ACMV varieties for Africa), biotech tools may be an advantage but not essential, and a choice among methods is required. The choice involves an assessment of benefits and costs of biotechnology relative to other approaches to resolve the problem.

A network such as CBN provides sources of back-up expertise for such assessments. In many or most cases, international experts and national program scientists would work together to identify an optimum research approach. Where more than one type of solution is possible, cassava farmers, processors, or consumers will be involved to evaluate the suitability of different solutions in their conditions.

Research location In the case of cassava, research location is an important question because much of the research need is found in countries where there is presently little biotechnology capacity. If a biotech approach is indicated, options include developing biotechnology research capacity in the home country; collaborating with existing capacity in another country; or a planned phasing from collaboration to national research over the mid- or long-term future.

Each of the options has different costs and benefits to national technological development. They may also have different costs and benefits to the global cassava research effort, whose goals include building national research capacity, but also cost-effective use of available research funding and rapid research progress. Trade-offs in national vs. international benefits may be one of the factors in the decisions of Step Three. When international collaboration is indicated, a network can provide the opportunities to make contacts and develop action plans.

Step 4. Assigning priority relative to other research needs

This final step involves a synthesis of all the above considerations to reach a recommendation for research management purposes. National policy makers will be the chief decision makers, possibly calling on international consultants.

Additional considerations at this step include the effects of a problem and a given solution in the national farming system and in national and export marketing and consumption systems, and the need to evaluate trade-offs between farmers, processors, and consumers. At some point is will be necessary to prioritize among different sectors of national activity (agriculture, industry, health ...).

C. Biotechnology for cassava in Tanzania: Three selected topics[1]

1. Short term - can be done now

Micropropagation for cassava planting material

Rapid propagation of planting material is a critical link in the delivery system of any crop improvement program. Lake Zone villagers frequently mentioned lack of planting material of desired varieties. Cassava micropropagation using tissue culture is an established biotechnology that can dramatically speed up variety multiplication. It can be assessed for possible integration into the national technology transfer program to provide increased availability of desirable varieties.

One consideration will be the suitability and relative costs of other rapid propagation methods for cassava that do not involve in-vitro culture. These can be used either instead of in-vitro methods, or as a supplemental second stage between tissue culture lab and planting stake production. Another consideration is whether one tissue culture facility could serve more than one crop, e.g. sweet potatoes.

Steps 1 and 2 are completed for this farmer concern. Steps 3 and 4 are still needed before a decision is made on whether to proceed with tissue culture in a national variety distribution plan.

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[1] The three selected topics are not exhaustive of the possibilities for biotechnology research on cassava for Tanzania.

2. Medium term - 5 years

Molecular markers in the planning phases of a breeding program

Molecular markers could be used to help plan breeding programs by assessing existing genetic variability and heritability in cassava for any of the villager varietal criteria, i.e., early maturity, in-field storability, and their combined expression; drought tolerance, nutrient use efficiency, cooking quality, and insect and pest resistance.

Thus, in the mid-term, molecular markers would be used as a tool for accomplishing Step 2: understanding the biological basis of farmer concerns. Applicable molecular markers would have to be established through field experiments in the Lake Zone, or established in a similar environment elsewhere and then verified in the Lake Zone. The information gained could be used to refine identification of traits most amenable to improvement and to develop improved source populations or parental lines.

3. Long term - 10 years

a. Molecular markers-assisted selection as a breeding tool

b. Gene cloning and genetic transformation to understand complex traits

a. When used in the selection phases of a breeding program, molecular marker-assisted selection may permit faster and farther progress in cassava breeding for *all* villager concerns than is possible with present breeding tools. Molecular-marker assisted selection will make it possible to distinguish genetic from environmental variation and to identify specific desired genotypes in segregating populations. With this ability to monitor genotypes directly, breeders may be able to combine more favorable genetic factors in one variety than is possible using field measurements alone.

Based on results of the mid-term research with molecular markers, including development of information for Step 2 decisions, Steps 3 and 4 would be conducted to determine if molecular markers would be used for selection by given national breeding program, in its own lab or in a collaborating lab, and for what traits. Because of the cost of visualizing molecular markers with present methods, their use may be limited at first to the most important traits and those most difficult to select using other methods.

b. Genetic transformation may dramatically improve our knowledge of biological causes underlying villager concerns such as drought tolerance or improved nutrient use efficiency on poor soils. Genetic transformation will make it possible to create pairs of plants that differ only by a change in a single gene (isolines). The effect of that gene on the trait of interest can then be precisely measured. A series of such isolines can be used to trace biochemical pathways and pinpoint critical genes. Thus genetic transformation provides another new tool for Step 2, understanding the biological basis of farmer concerns.

Collaborative research at this strategic phase would be especially productive for traits that will be of concern to many countries, such as drought tolerance. Field research using the transgenic experimental materials would take place in the Lake Zone or a similar ecological region. Testing with the target farmers and processors would be preferred, to identify prototypes that perform best in their specific conditions. All field research will require that biosafety protocols be in place.

The information gained would be used in the long term to design strategies for creating and selecting superior genotypes. Genetic transformation might or might not be only approach to develop these genotypes. Use of genetic transformation to develop a solution, and the location of the research, would depend on the results of Steps 3 and 4 in any given situation.

D. Relevance to needs of developing country policy makers, financial advisors and research directors

Policy makers: Policy makers are responsible for the last step (Step 4) in the process of using village or farm-level case studies in priority setting. They will also consider the potential contribution of agriculture vs. other ways to achieve the same goals: industrialization, or perhaps tourism. They need reliable, broad-based information on needs and opportunities for food security and rural income and development through agriculture.

One information source will be the results of Step 1, the perspectives of people who grow and use national food staple crops. Policy makers need this information aggregated across the nation, and in the context of international agricultural trends: hence the need to solve some of the problems in combining farmer perspectives with other types of information.

Financial advisors. Once policy makers have made their decisions, financial advisors are asked to help calculate the costs and find the money. Financial advisors need to know costs and benefits (time and money) of alternative technical solutions, including costs of national vs. international collaborative execution of a given technical solution. They need information from Step 3.

Research directors. Research directors participate in Steps 2 and 3 (understanding biological causes, and selecting solutions and research approaches) and are responsible for the syntheses and recommendations/decisions of Step 4 at the institution level. They working within broad national policy outlines established by national policy makers. Participation in international networks with common goals can provide research directors with access to a global pool of collaborative expertise on these subjects.

Research directors combine knowledge of their own client's needs and opportunities, with national knowledge of local agroecosystems, and information on costs and benefits of various possible solutions and approaches. Their objective is to design relevant research with a high probability of realizing the benefits desired at the most reasonable cost.

E. Summary and conclusions

A. Methodology

1 Farmers are accessible and articulate on topics important to them, such as production, processing, and sale of a staple crop.

Novel innovations may difficult to evaluate with farmers until a prototype product is available for hands-on participatory research.

2 Village concerns, when input to a priority setting process, first require biological and socioeconomic assessment to identify which of the underlying causes may be susceptible to research solutions, and to evaluate interactions with factors that extend beyond village knowledge.

3 Next follows an examination of potential solutions for their suitability for target beneficiaries.

Both this step and the previous one are ideally conducted with participation of target farmers/processors, especially if the causes may be multiple or complex.

4 An assessment of potential research methods follows, to identify a method most likely to achieve the solution chosen, at a reasonable cost.

5 Participation in international networks with common interests can provide national experts with access to a global pool of collaborative expertise for assessments of biological causes and interactions, and comparative research methods and costs.

6 In deciding whether the research should be conducted nationally or with international collaboration, factors considered may include existing national capacity, national technology development plans, and costs and benefits to both national technological development and the global cassava research effort.

B. The Tanzanian context

1 Based on the results of the CBN case study, micropropagation (tissue culture) is a biotech applications that may contribute immediately to the welfare of Tanzanian Lake Zone farmers by increasing the rate and quantities of delivery of desired cassava varieties to farmers. It merits a cost-benefit analysis, to provide information for the research directors and policy makers who would decide whether or not the technology should be incorporated into the Tanzanian variety distribution scheme.

2 In the mid- and long term, molecular markers can assist progress in complex traits important to Tanzanian villagers. Also in the long term, gene cloning and genetic transformation can provide new knowledge of the biology of complex traits important to villagers.

3 Tanzanian cassava farmers, processors, and consumers will be target beneficiaries of research targeted at seasonally-dry areas where cassava is primarily for subsistence.

Consequently, Tanzanian national programs and Tanzanian villagers may have a key role in participatory testing of cassava innovations achieved via biotechnology.

Preparations for this role include strong national programs for cassava breeding, agronomy, processing; and national biosafety discussions

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F. References and suggested reading

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