A New Future for Cassava in Asia:

Its Use as Food, Feed and Fuel to benefit the Poor

Proceedings of the Eighth Regional Workshop
held in Vientiane, Lao PDR. Oct 20-24, 2008

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ENHANCING THE ADOPTION OF IMPROVED CASSAVA PRODUCTION AND UTILIZATION SYSTEMS IN INDONESIA (The ACIAR Cassava Project in Indonesia)

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ABSTRACT

In order to improve food security, protect the soil from degradation and contribute to poverty alleviation, a research project was implemented by CIAT in close collaboration with several government and non-government agencies in Indonesia, and funded by ACIAR in Australia. The project was part of a larger project entitled "Enhancing the Adoption of Improved Cassava Production and Utilization Systems in Indonesia and East Timor". The general objective of the project was to increase the productivity of cassava-based cropping systems through the widespread adoption of higher yielding cassava varieties and improved cultural practices that increase yields and protect the soil from erosion and nutrient depletion.

This was achieved by conducting collaborative experiments on varieties and some agronomic aspects in experiment stations and on-farm. The project was executed in East Java, Central Java,Yogyakarta, West Java, and Lampung provinces. A farmer participatory approach was used with the objective to include farmers in all the project activities in order to enhance adoption of improved practices. Both on-station and on-farm trials were conducted on appropriate and economic fertilizer and manure inputs, on cassava leaf production, and on the effect of supplementing the diet of sheep and dairy cattle with cassava leaf silage. To increase the market demand for cassava, in Malang district of East Java farmers were also encouraged to develop simple tools and methods for on-farm processing of fresh cassava roots into a variety of products. These groups visited similar processing groups in Kediri, Gunung Kidul and Pati districts to learn to make more cassava-based dishes and products for sale.

The main achievements of this 3-year project were the identification of several high-yielding, high-starches and/or tasty cassava varieties, that are suitable for industrial processing, animal feeding and for human consumption, respectively, as well as more economic and sustainable cassava production practices. Highly promising varieties identified and preferred by farmers include UJ-5, UJ-3, Markonah, Malang 6, UB 447-2, UB ½, Faroka, Bandung, Manggu and Adira 1. The last three varieties, i.e. Bandung, Manggu and Adira 1, are mainly used for direct human consumption or processing into snacks such as *kripik* or *krupuk*.

Many new varieties and improved technologies were tested in FPR trials by farmers. Some of these have now been adopted commercially by the collaborating farmers. In Malang district of East Java, three farmer groups of cassava processors have been established. They are now producing and selling a variety of products, such as *kripik, krupuk,* wafers and cakes made from fresh cassava roots. They have produced a recipe book for 32 different cassava-based products or dishes.

It is still too early to have achieved widespread adoption and impact. However, observing the enthusiasm of the collaborating farmers and some of their neighbors in the village, it is likely that the dissemination methodology used in this project has a good prospect to be continued in order to enhance more widespread adoption and achieve real impact in the future.

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1. INTRODUCTION

Together with Nigeria, Brazil and Thailand, Indonesia is one of the largest cassava producing countries in the world. In Indonesia cassava is the third most important food crop, after rice and maize. From about 1.6 million tones of fresh roots produced, about 53% is used for food and the other 47% for the production of starch, modified starch, sorbitol, fuel-ethanol and other industries based on cassava (CBS, 2007). However, cassava has never been considered a high priority crop, either by the government or by researchers. National responsibility for cassava research rests with the Indonesian Legume and Tuber Crops Research Institute (ILETRI) in Malang, E. Java, but very few researchers are actually working full-time on the crop. Brawijaya University used to have an active cassava breeding and agronomy program, but both have practically disappeared. Similarly, the national, provincial and district extension offices concentrate their limited resources mainly on rice, maize and soybean, with very little attention paid to cassava. With a population of over 200 million people and an estimated 5-10 million cassava producing households, Indonesia has now only 2-3 full-time cassava researchers and no more than ten part-time researchers.

Most varieties presently grown are local cultivars developed and selected by farmers. An exception is Lampung province in the southern part of Sumatra island where cassava is grown mainly as a commercial crop for starch processing. Here the private sector, particularly the Great Giant Pineapple Co., has conducted it own research at Umas Jaya Farm, and has first selected and widely disseminated the high-yielding variety Adira 4, which was later replaced by two varieties introduced from Thailand, which have now been officially released as UJ-3 (= Rayong 60, locally known as “Thai”) and UJ-5 (= KU 50, locally known as “Kasetsart”). The latter variety is now estimated to be grown in about 65% of the cassava area or 160,000 ha in Lampung province. Locally developed and officially released varieties such as Adira 1, Adira 4, Malang 1, Malang 4, Malang 6 and Kaspro, and some highly promising breeding lines such as UB ½ and UB 477-2, are not yet widely adopted, as many farmers are not even aware of their existence, and no planting material has ever been widely distributed.

During the 1970s and 80s Indonesia made a major effort to upgrade its cassava research. At least 19 researchers received training in CIAT-Colombia, and since the establishment of the CIAT Cassava Office in Asia in 1983 there has been a close working relationship between researchers in various Indonesian institutions, notably Brawijaya University, ILETRI, CRIFC and Umas Jaya Farm, with the CIAT breeder and agronomists stationed in Bangkok. Being the second largest cassava growing country in Asia, Indonesia has actively participated in the Asian Cassava Research Network, especially in the seven Regional Cassava Workshops that have been held every three years in different countries in the region. Unfortunately, during the 1990s and the first decade of the 21 century, economic crises and budget cuts resulted in a marked reduction in funding for cassava research, both at CIAT and in the Indonesian institutions.

In spite of these reduced efforts, Indonesia has made steady progress in cassava research and development, partially driven by increasing demand for cheap food, especially since the economic crisis of 1987, as well as for starch and starch-derived products, such as instant noodles, MSG, sorbitol, and modified starches; the latter is used mainly in the paper and textile industry. During the past ten years the cassava area in Indonesia declined, especially in Java, due to competition from other, more valuable, crops, but total production increased at an annual rate of 1.4% due to a steady increase in yield, from 12.0 t/ha in 1996 to 15.9 t/ha in 2005, corresponding to a remarkable annual increase of 3.2%. Increases in yields were greatest in Lampung province where many farmers started planting the two high-yielding Thai varieties, "Kasetsart" and "Thai", while also intensifying production by planting cassava more and more in monoculture and with increasing use of chemical fertilizers. Average yields in Lampung have now reached 19 t/ha, which is similar to yields in Thailand, but still much below the yields of 26-28 t/ha obtained on average on 2,000-3,000 ha of cassava at Umas Jaya Farm in Lampung.

Because cassava has many alternative uses as food, feed and for many industrial purposes – while it can also grow well in many unfavorable environments – it is an ideal crop to initiate rural development through the commercialization and processing of cassava roots and dry chips, thus allowing farmers to earn money to buy inputs to further intensify their agricultural activities, whether in food crops, horticultural crops, fruit trees, aquaculture or livestock production. This also creates on- and off-farm jobs for an ever increasing and restless young generation. Thus, besides improving the productivity of cassava as a food crop, it is an opportunity to enhance its use in animal feeding, in small-scale processing into a variety of dishes and products for sale, and eventually for production of starch and fuel-ethanol, both for domestic use and export. The current, seemingly insatiable need for cassava dry chips, starch and ethanol in China, has resulted in marked increases in the price of these cassava products, thus providing an opportunity for cassava farmers in Asia to expand their area and intensify their production, to benefit from new markets and improve their income and livelihood. This has been the key issue that the ACIAR-funded cassava project intended to address.

2. OBJECTIVES

The general objective of the ACIAR-funded cassava project was to increase the productivity of cassava-based cropping systems through the widespread adoption of higher yielding cassava varieties of superior nutritional quality, and improved cultural practices that increase yields while protecting the soil from erosion and nutrient depletion.

The specific objectives of the project were:

1. To support national institutions in conducting strategic and applied research in cassava production and on-farm utilization that will overcome important constraints identified at the farm level.
2. To strengthen inter-institutional as well as inter-disciplinary collaboration and the capacity for farmer participatory research in national institutes and in selected farm communities.
3. To develop, with farmers, new high-yielding cassava varieties of superior nutritional quality, improved crop management practices that increase yields and maintain the soil resource, and better utilization through small-scale processing and on-farm animal feeding of roots and leaves.
4. To disseminate new technologies at the local, provincial and national level using farmer participatory extension methodologies.

3. METHODOLOGY

3.1. Institutions and Persons Involved in the Project

In accordance to the objectives of the research project, the persons involved in this project came from many different fields and institutions, i.e. Prof. Wani Hadi Utomo, cassava agronomist at Brawijaya University; Dr. Koeshartojo, cassava breeder of ILETRI in Malang; Mr. Wargiono, cassava agronomist in CRIFC in Bogor; Dr. Djoko Santoso and Mrs. Enggis Tuherkish from the Soil Research Institute in Bogor; Dr. Marjuki, animal nutritionist at Brawijaya University; Dr. Suhardjo and Mrs. Endah Retnaningtyas, cassava processing specialist from BPTP for East Java in Malang, and Mr. Aldon Sinaga, agribusiness specialists from the University Tribhuwana in Malang. The project was later joined by Mr. Adi Widjaja, leader of an NGO, Budi Mixed Farming (BMF), which was helping cassava farmers in Pati district of Central Java.

3.2. Location

Initially, the work was done in Malang (East Java), Gunung Kidul (Yogyakarta), and Tamanbogo (Lampung). In the second year, additional work was also carried out in Sukabumi (West Java), and with the involvement of Mr. Adi Wijaya from BMF, it was extended to Pati (Central Java).

3.3. Methodology

In order to improve the collaboration among institutions and among scientists, a small workshop was held prior to initiating the research activities. The workshop discussed the existing problems, alternative solutions and the design of project activities. The outputs of the workshop were:

1. Identification of the main problems encountered for cassava development, i.e. (a) low interest of farmers to plant cassava because planting cassava is not profitable due to the limited utilization and unpredictable price, (b) low yield due to lack of high-yielding varieties and soil degradation, and (c) low adoption of improved technologies.

The activities to solve these problems were:

2. To conduct experiments on: (a) varietal evaluation, (b) soil fertility management to obtain sustainable production, (c) technologies for leaf production, and (d) the use of cassava, especially leaves, for animal feeding.

   The experiments were conducted on research stations or research sites, and to some extent these include on-farm experiments. The research was basically designed and managed by researchers; farmers are sometimes paid to maintain the experiment weed-free and may be paid for their labor during planting and harvest. The experimental sites and the types of experiments, which include trials on cassava agronomy, soil fertility managements and animal feeding with cassava leaves, are presented in **Table 1.**
3. To develop, together with farmers, new high-yielding varieties of superior nutritional quality, improved crop management practices to increase yields and to maintain the soil resource and better utilization through on-farm processing or its use in animal feeding.

The research was conducted in the form of FPR trials, which in turn were followed by the dissemination of the farmer-selected technologies using farmer participatory extension (FPE) methodologies.

Table 1. Type of on-station and on-farm cassava experiments conducted by partner institutions in Indonesia.

Location	Year(s)	Type of experiment
Jatikerto, Malang	2004-07	1. Use of chem. fertilizers and manures; C+Maize
Jatikerto	2004/05	2. Variety x spacing x pruning for leaf production
	2005/06	3. Spacing x N application rates for leaf production
	2006/07	4. Variety x cropping system x spacing for leaf production
Karangploso, Malang	2004/05	1. Methods of cassava leaf silage production
Karangploso	2005/06	2. Levels of cassava leaf silage for feeding sheep
Tamanbogo, E.Lampung	2004/05	1. Long-term NPK experiment conducted since 1991
	2005/06	to determine the long-term nutritional requirement of cassava
	2006/07	intercropped with maize and upland rice
Tamanbogo	2004/05	2. Variety evaluation experiment; C + Rice
Playen, Yogyakarta	2004/05	3. Variety evaluation experiment
Ngadirejo, Malang	2004-07	1. On-farm evaluation of new breeding lines
Sempol, Malang	2004-07	2. On-farm evaluation of new breeding lines
Karang Gayam, Blitar	2006/07	3. On-farm evaluation of new breeding lines
Selorejo, Blitar	2006/07	4. On-farm evaluation of new breeding lines
Tamansari, Pati	2005-07	1. On-farm evaluation of promising varieties

The conceptual model for this methodology is shown in **Figure 1 (**Howeler, 2001**)**. The unique feature of this approach is that farmers are involved in all steps of the process, from diagnosing their main problems, to selecting and testing various solutions, to selecting and then adopting those varieties or practices most suitable for their particular conditions; farmers can also help to disseminate those selected technologies to other farmers and communities through farmer-to-farmer extension. The sites of FPR activities were usually close to areas where on-station or on-farm experiments were also being conducted, so that these experiments could serve as "demonstration plots".

As indicated in **Figure 1**, the first step in conducting FPR trials is to select an appropriate site, in an area where cassava is presently an important crop or where it may become so in the future. Often times, local extension workers request to be involved in the project as farmers have shown interest in improving their cassava production. After an initial meeting to explain the objectives of the project and to gauge the interest of farmers and local leaders and extensionists to participate, the project staff visits the community and conducts a Rapid Rural Appraisal (RRA), to learn more about cassava production and utilization practices, and to diagnose, together with farmers, the problems that need attention. After prioritizing the problems and possible solutions, farmers can decide what type of trials they want to conduct on their own fields. Farmers who volunteer to conduct these FPR trials may be taken to a demonstration plot or other villages where experiments are already being conducted. Farmers evaluate and discuss the various treatments being demonstrated and then select those they consider most suitable for their own conditions.

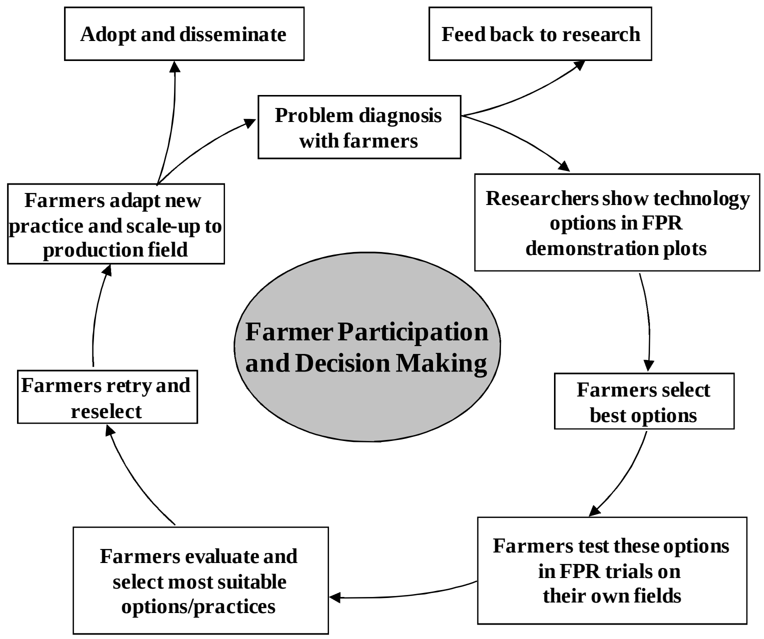

Figure 1. Farmer participatory model used for the development of sustainable cassava-based cropping systems in Asia.

Thus, farmers discuss and decide, while researchers and extension workers help farmers in selecting reasonable treatments, but without imposing their own opinions. At time of planting, the project staff helps the farmers set out the experiments and provides the planting material, seed or fertilizers, if required. Farmers themselves are the owners and managers of the trials, but project staff should visit regularly to discuss and solve the problems that might occur.

At some occasions, especially at harvest time, both collaborating and non-collaborating farmers from the village or district are invited to harvest the trials and to judge and select the best or preferred treatments. Some of these farmers may then be interested to join the project and in the following year may do the experiments in their own fields.

Most of these trials have 4-5 treatments with one treatment being the traditional farmer's practice for comparison. To facilitate accurate yield measurements it is suggested that the trials are conducted in small plots, often 5x5 or 6x6 m, and that stakes are planted at a regular plant spacing, often 1x1 m or 0.9x0.9 m. At time of harvest, the collaborating farmers in the village, together with project staff, help each other harvest all the trials and determine the yields in all treatments. Later in the day, or the following day, a farmer field day is organized in which other farmers in the village or from neighboring communities can visit the trials, see the piles of harvested roots and evaluate the usefulness of each treatment. Finally, the yield data are tabulated, averaged and presented to the group for discussion and selection of best treatments by raising hands. The farmer-selected varieties or practices may then be tested again the following planting season, or be directly adopted in their larger production fields.

Oftentimes FPR trials are conducted in a particular village for 2-3 years until farmers have tested and selected the best options for adoption, at which point other new villages are selected and the process is repeated. Once farmers see in their own trials that a certain variety or practice produces higher yields or at a lower cost, they will want to adopt those varieties or practices. The project staff can help farmers to obtain the necessary planting material, seed of intercrops, or other inputs that are sometimes hard to find. Farmers from other new villages may want to visit those villages that have already adopted some new technologies in order to see and discuss their benefits. These farmers may either want to conduct their own FPR trials or start adopting those practices that others have already tested and selected. These cross-visits between villages is one way to stimulate farmer-to-farmer extension, which is often more effective than the traditional extension practices.

4. ACHIEVEMENTS AGAINST SPECIFIC PROJECT OBJECTIVES

4.1. To Support National Institutions in Conducting Strategic and Applied Research

Of the eight activities listed, the main focus has been on soil fertility maintenance, plant spacing and nitrogen fertilization for leaf production, varietal evaluation and improvement, and on-farm animal feeding. The first two activities were done in experimental stations, and were conducted by the project team. These experiments also function as demonstrations. The last two activities were done on farmers' fields and were conducted by farmers, while project staff acted as facilitators and provided guidance to conduct the experiments (these activities are also to achieve Objective 2)

4.1.1. Soil fertility management for sustainable production

Two experiments were conducted to determine the most economic way to achieve long-term sustainable cassava production; one was done on an acid soil in Lampung, and one on a low soil organic matter soil in Malang. The results, presented in **Figure 2,** shows that in a sandy loam acid soil in Tamanbogo, Lampung, the application of N, P and K are absolutely required by both cassava and the intercropped rice. The application of N-fertilizer had a negative effect on the growth and yield of rice, but not on cassava. In 2004/05 the rice in these plots fertilized with high rates of N grew very poorly and hardly produced any grain. It was thought that the negative effect of high rates of N application was due to the acidification effect of the applied urea fertilizer. Therefore, in 2005/06 and 2006/07 dolomitic lime was applied to all plots, and as a result the rice grew better and produced grain. The same phenomenon actually had occurred for the intercropped maize, which had already disappeared in the eighth year (**Figure 3**). These results indicate that cassava is much more tolerant than maize or upland rice to acid soil conditions, characterized by a low pH and high levels of exchangeable aluminum (Al).

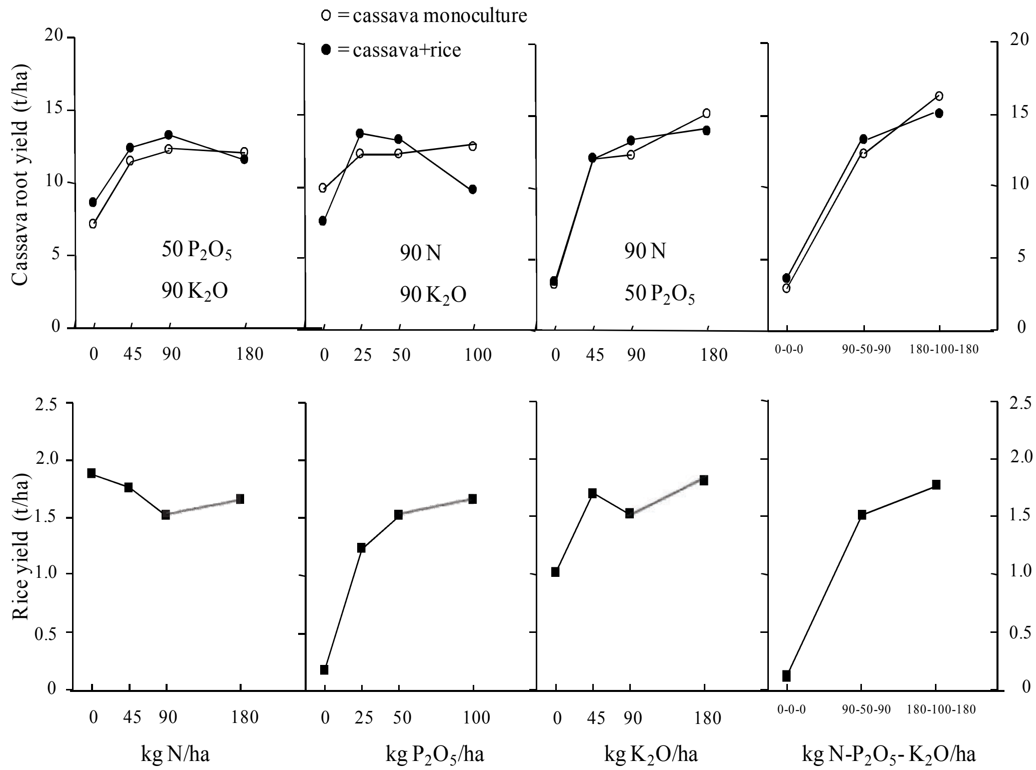

Figure 2. Effect of applications of various levels of N, P and K on the yields of cassava and intercropped rice, during the 16th consecutive cropping cycle in Tamanbogo, Lampung, Indonesia in 2006/07.

Figure 3 shows that the yield of intercropped maize decreased with an increase in the exchangeable Al saturation (as a result of acidification by N fertilizer), and the crop stopped to grow completely as soon as the exchangeable Al saturation was around 60%, while rice yields decreased when the Al-saturation reached about 80%. **Figures 2** and **3** also show that with correct fertilizers, after 16 years of continuous cropping, the acid low-fertility Ultisols could still produce reasonable yields of cassava. It is suggested that the application of organic matter, either in the form of organic compost or animal manure may further increase the yields.

As a result of the Participatory Rapid Appraisal, (PRA) (see section 3.2.1below), an experiment to use organic manures was conducted to determine the most sustainable cassava production practices. The experiment was carried out at Jatikerto Experiment Station, about 20 km south-west of Malang city. The results, presented in **Table 2,** show that without N fertilizer cassava yields rapidly decreased. The yield in the first year was 26 t/ha, but decreased to less than 10 t/ha in the third year. Application of N-fertilizer and/or FYM could minimize the yield decrease. The result in **Table 2** shows that in the third year the yield of cassava fertilized with 135 kg N/ha (as urea) was 29.90 t/ha; this is still 90% of the yield in the first year (32.50 t/ha). The cassava yield decrease when 10 t/ha of FYM had been applied was 32% (the yield decrease from 35.50 t/ha to 24.10 t/ha). The yield decrease could be further minimized by the application of nitrogen fertilizer combined with 5 t/ha of FYM or compost. Application of K fertilizer on this K-rich soil did not have any positive effect on cassava yield, at least until the third year of cropping.

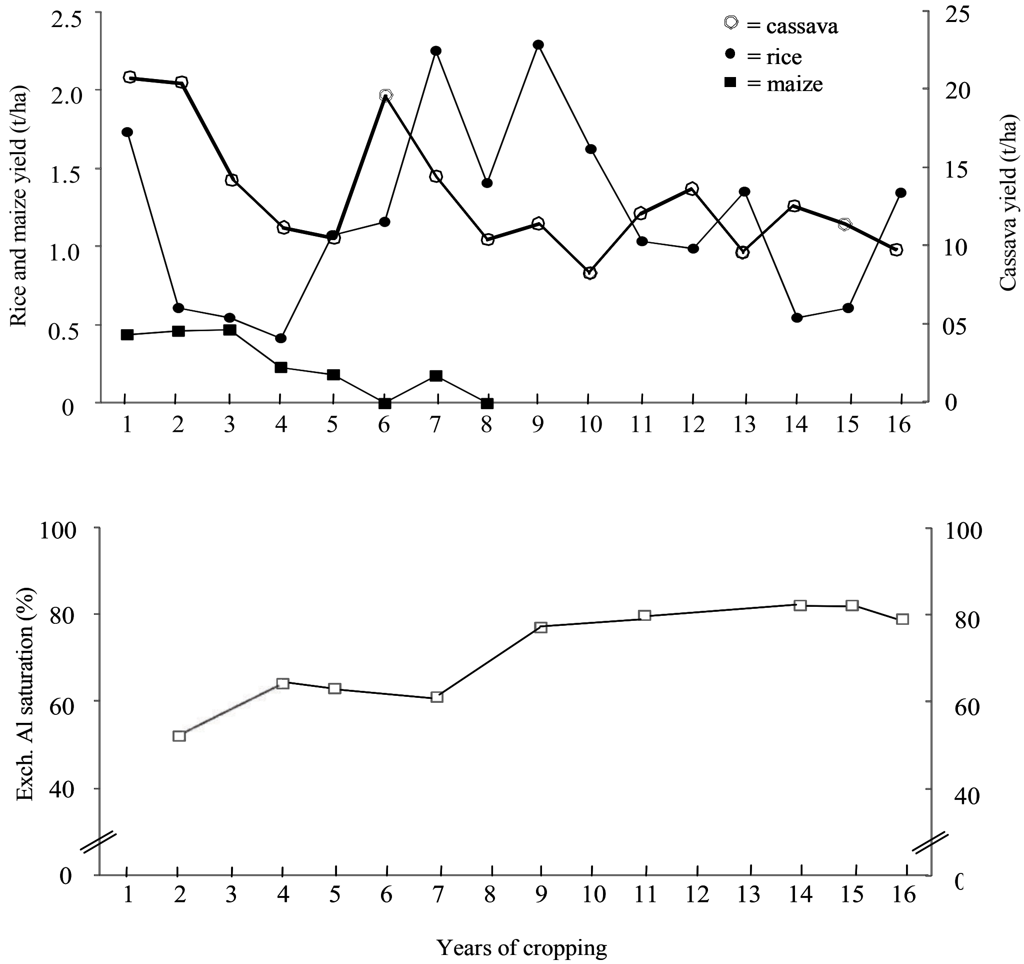

Figure 3. Change in the yields of intercropped maize and rice during 16 consecutive years of growing cassava, Adira 4, with intercropped rice and maize. Data are average values of 12 NPK treatments in a long-term NPK trial conducted in Tamanbogo, East Lampung, Lampung, Indonesia from 1991 to 2007.
Below: The change in the average percent Al-saturation of the soil
Note: 2 t/ha of lime were applied in Rep III before the 15th crop cycle and another 2 t/ha in Reps I and III before the 16th crop cycle.

Table 2. Effect of various fertilization alternatives on the intercropped maize yields and cassava root yields when grown for three consecutive years in Jatikerto, Malang, East Java from 2004/05 to 2006/07.

Treatments		Maize grain yield (t/ha)			Cassava root yield (t/ha)		
$N-P_2O-K_2O$ (kg/ha)	Organic (t/ha)	1st year	2nd year	3rd year	1st year	2nd year	3rd year
0-0-0	0	2.40	1.10	1.06	26.00	10.96	9.83
135-0-0	0	3.80	1.93	3.37	32.50	35.60	29.90
135-50-0	0	3.74	2.07	3.33	43.88	36.80	28.40
135-50-100	0	3.76	2.10	3.43	42.05	37.47	28.17
0-0-0	10 FYM	2.83	1.66	3.00	35.50	26.53	24.10
0-0-0	10 Compost	2.69	1.63	2.55	33.00	22.67	20.63
135-0-0	5 FYM	3.86	2.26	3.71	48.61	35.63	30.50
135-0-0	5 Compost	3.36	1.97	3.51	46.66	39.33	33.60
135-50-0	5 Compost	3.72	1.87	3.79	46.11	39.07	36.27
135-0-0	5 Sugar mud	3.78	1.67	3.21	36.67	33.73	29.57

The yield stability of maize could not be concluded, because of the high fluctuation from year to year. In the second year, the yields of maize decreased in all treatments. However, in the third year, except for the unfertilized (0-0-0) treatment, maize yields increased to about the same levels as those of the first year. This fluctuation was not considered as the effect of the treatments, but as the response of maize to climatic conditions. Maize is very sensitive to climatic conditions, especially rain at the time of planting. We can only conclude that: without fertilizer application (0-0-0 treatment), the yields of maize, like those of cassava decreased with time. The yield of unfertilized maize in the first year was 2.40 t/ha, but decreased to 1.06 t/ha in the third year.

4.1.2. Planting cassava for both root and leaf production

Two experiments were conducted to explore the production technology for growing cassava to optimize total biomass production, i.e. (1) The effect of pruning on leaf and root yields of three cassava varieties planted at two plant spacing in a cassava + maize intercropping system; and (2) The effect of nitrogen fertilizer application to cassava planted for leaf production in a cassava + maize intercropping system. The experiments were conducted at Jatikerto station in Malang, East Java.

In the first experiment there were three pruning treatments, i.e. (a) No pruning, but at time of root harvest the young shoots were also harvested, (b) top pruning, by cutting the young shoot at a height of 30 cm above the ground, and (c) leaf pruning, by harvesting the whole leaves. The first pruning was done at three months after planting followed by pruning at 2-month intervals. The results of this experiment indicate that pruning and cassava plant spacing did not significantly influence maize yields, as the average maize yield was 4.75 t/ha. This is reasonable, because at those two cassava spacing maize was planted at the same density, and since maize grows faster than cassava, the growth of maize was not seriously affected by the cassava. Cassava leaf and root yields, on the other hand, were significantly influenced by both the pruning treatments and the cassava plant spacing **(Table 3).**

Table 3. Effect of pruning and cassava plant spacing on dry leaf and fresh root yields of three cassava varieties in a cassava + maize intercropping system at Jatikerto Experiment Station in Malang, E. Java in 2004/05.

Cassava Varieties	Plant spacing (m x m)	Pruning methods	Dry pruned leaf yield[1)]	Fresh root yield
			(t/ha)	
UB 477-2	1.0 x 1.8	None	2.39 a	52.32 j
		Top	5.10 de	10.77 ab
		Leaf	3.17 bc	23.07 ef
	1.0 x 0.4	None	3.28 bc	64.72 k
		Top	7.14 f	13.58 b
		Leaf	4.11 cde	32.22 g
UB ½	1.0 x 0.8	None	2.30 a	42.79 i
		Tope	5.01 de	7.71 a
		Leaf	3.54 bcd	21.49 de
	1.0 x 0.4	None	3.19 bc	53.88 j
		Top	6.92 ef	11.09 ab
		Leaf	4.21 cde	27.44 fg
Faroka	1.0 x 0.8	None	1.90 a	37.39 h
		Top	3.18 bc	6.77 a
		Leaf	2.80 a	15.10 bc
	1.0 x 0.4	None	2.70 a	52.44 j
		Top	4.15 cde	9.94 ab
		Leaf	3.84 cde	23.80 e

Means followed by the same letters in each column are not significantly different (P = 0.05)

The data in **Table 3** also show that there was an interaction between pruning methods, cassava plant spacing and cassava varieties. Pruning, both top and leaf pruning, significantly decreased the root yields. In general, UB 477-2 produced the highest leaf and root yields.

In the second experiment, cassava, UB 477-2, was planted and pruning was done by cutting off the whole tops at about 30 cm above the ground; the first pruning was done at about 75 days, after which pruning was done at 2 month intervals. The results, given in **Table 4,** show that cutting off the cassava tops four times during the growth cycle significantly decreased the root yields, at both cassava plant spacing. Application of N fertilizer to the pruned cassava, up to 600 kg urea/ha, increased both the leaf and root yields. However, the maize yields were not significantly influenced by the cassava pruning, or spacing treatments, nor by the rate of nitrogen application. This is not surprising, because in this cropping system the maize grows much faster, and tends to be taller than cassava, so that in terms of light competition, there was no effect of the cassava on maize. It seems that application of 300 kg urea/ha was sufficient to meet the maize' requirement in the pruned cassava system. The lower yield of maize when cassava was planted at high density (1.0 x 0.4 m) can be attributed to nutrient competition rather than light competition. The data in **Table 4** also show that the cassava yield in this latter treatment was very high, and much higher than those in other treatments.

Furthermore, data in **Table 4** shows that under the current prices and experimental conditions, the net income from growing cassava for both leaf and root production, using a cassava + maize intercropping system, was less profitable than growing cassava without leaf pruning, and that high rates of N application are required to increase the net income when tops are cut off regularly for leaf production.

Table 4. Effect of pruning, plant spacing and rate of N application on the leaf and root yields of cassava and the yield of intercropped maize, as well as on the gross and net income in 2005/06.

Pruning/spacing/urea rate	Maize yield (t/ha)	Dry leaf yield (t/ha)	Fresh root yield (t/ha)	Gross income maize grain[2)]	Gross income cassava leaves[2)]	Gross income cassava roots[2)]	Production costs[3)]	Net income
				('000 Rp/ha)				
No pruning/1.0x0.8/300	3.27	1.34[1)]	46.76	5,232	2,010	18,704	4,702	21,244
No pruning/1.0x0.4/300	2.64	1.68[1)]	48.68	4,224	2,520	19,472	4,981	21,235
Leaf pruning/1.0x0.8/300	3.68	3.14	10.11	5,888	4,710	4,044	5,247	9,395
Leaf pruning/1.0x0.8/400	3.97	4.32	13.62	6,352	6,480	5,448	6,275	12,005
Leaf pruning/1.0x0.8/500	4.04	6.27	15.82	6,464	9,405	6,328	7,823	14,374
Leaf pruning/1.0x0.8/600	3.97	7.73	18.09	6,352	11,595	7,236	9,025	16,158
Leaf pruning/1.0x0.4/300	2.97	4.18	12.27	4,752	6,270	4,908	6,028	9,902
Leaf pruning/1.0x0.4/400	3.17	5.19	15.81	5,072	7,785	6,324	6,936	12,245
Leaf pruning/1.0x0.4/500	3.05	6.32	19.02	4,880	9,480	7,608	7,923	14,045
Leaf pruning/1.0x0.4/600	3.43	9.07	20.57	5,488	13,605	8,228	10,026	17,295

[1)] Cassava leaves at time of root harvest only

4.2. To Develop, with Farmers, New High-yielding Cassava Varieties and Improved Cultural Practices, and Better Utilization Through On-farm Processing and Animal Feeding

4.2.1. FPR trials

The first activity of FPR was to conduct a Participatory Rapid Appraisal (PRA). Due to the limitation of personnel, time and budget, the PRA was only conducted in Malang. The PRA was done to explore, together with the farmers, the problems that farmers face, their needs, and willingness to participate in finding solutions. The results have been reported by Yunawati *et al.*, (2009). From this PRA, farmers identified some problems in cassava production and considered several possible solutions which they used as experimental treatments in FPR trials conducted on their own land. In other locations, no PRAs were conducted, but at the beginning farmers were still involved in the discussion and selection of the experimental treatments. The number of participating farmers and the type of experiments conducted by the farmers are presented in **Table 5.**

In Malang, several experiments were conducted at the Brawijaya University experiment station in Jatikerto (see section 3.1). These experiments were used as demonstration plots during farmer field days. Field days were held by inviting the farmers, both the participating and non-participating ones, to visit, to take measurements, to evaluate and to select the experimental treatments. It was expected that some of these farmers would test the selected treatments in their FPR trials on their own fields. The field days for maize were held at the time of harvest of the intercropped maize in order to evaluate the maize stand and yield. The evaluation of cassava was done during the cassava harvest.

Table 5. Number and type of FPR trials conducted in Indonesia from 2004/05 to 2006/07.

	Variety			Fertilizers			Animal feeding	
District, Province	04/05	05/06	06/07	04/05	05/06	06/07	05/06	06/07
E. Lampung Lampung	-	3	3	2	9	3	-	-
Sukabumi, W. Java	-	3	6		3	-	-	-
Gunung Kidul, Yogyakarta	3	5	2	2	3	1	-	-
Malang, East Java	8	7	3	3	10	-	1	1
Total	**11**	**18**	**14**	**7**	**25**	**4**	**1**	**1**

The results of the farmers' evaluation and selection are shown in **Table 6** for maize and in **Table 7** for cassava. None of the farmers were interested in growing cassava for leaf production. The farmers argued that growing cassava for leaf production is less profitable than producing only the roots (see 3.1.2).

It is interesting to note that, based on the farmers' preferences, none of the farmers put the nitrogen fertilizer + manure as their first selection. However, after conducting the trial and seeing this treatment on their own fields, farmers selected this treatment. Although they put the NPK treatment as their second choice, they did not want to try this treatment because of the high cost and the difficulty of obtaining P and K fertilizers. Later (after they came to evaluate the demonstration plots in the third year), they were happy with their selection because they saw that this treatment (N fertilizer + manure), which they had tried in their own fields, resulted in a more stable cassava root yield.

Table 6. Farmers' preference for experimental treatments of organic and inorganic fertilizer application based on maize performance.

(1) Preference based on maize stand (total farmers involved were 30).

Preference ranking	Treatment[1)]	Number of farmers	Treatment	Number of farmers	Treatment	Number of farmers
First	N	12	NPK	9	NM	5
Second	NM	15	NPK	7	N	6
Third	NPK	11	NM	8	N	5
Fourth	N	9	NP	7	NM	7

(2) Preference based on maize grain performance and grain yield.

Preference ranking	Treatment[1)]	Number of farmers	Treatment	Number of farmers	Treatment	Number of farmers
First	N	15	NP	8	N	5
Second	NPK	11	N	9	NM	6
Third	NM	12	NB	9	NPK	6
Fourth	NM	11	N	10	NP	5

[1)]M= cattle manure; B= Blotong (sugar cane industry by product)

Table 7. Farmers' preference for experimental treatments of organic and inorganic fertilizer application based on cassava performance.

(1) Cassava preference based on cassava stand (total farmers involved were 30)

Preference ranking	Treatment[1)]	Number of farmers	Treatment	Number of farmers	Treatment	Number of Farmers
First	N	16	NP	7	N	3
Second	NPK	12	N	9	NM	6
Third	N	13	NM	9	NP	6
Fourth	N	12	NM	8	NP	5

(2) Cassava preference based on root performance and root yield.

Preference ranking	Treatment[1)]	Number of farmers	Treatment	Number of farmers	Treatment	Number of Farmers
First	N	21	NP	9	NM	5
Second	NPK	14	NP	9	NPK	5
Third	NM	11	N	9	NPK	5
Fourth	NPK	11	NP	10	N	7

[1)]M = cattle manure

The results of various FPR trials conducted in many parts of Indonesia can be summarized as follow:

1. Variety trials:

Malang	: the selected varieties are: UB 477-2, Faroka and UB ½
Pati	: the selected varieties are: UB 477-2, Markonah and KU 50.
Gunung Kidul	: the selected varieties are CMM 96-36-255, KU 50, UB ½ and UB 477-2
Sukabumi	: CMM 96-36-255, Bandung, Mangu, KU 50, UB ½ and UB 477-2
Lampung	: CMM 96-36-255, KU 50, Malang 6 and CM 99-23-12

2. Production technology trials:

Malang	: application of 135 kg N/ha + 5 t manure/ha
Gunung Kidul	: application of 200 kg urea/ha + 2 t manure/ha
Lampung	: application of 100-100-100 kg N-P_2O_5-K_2O/ha + 2 t manure/ha

4.2.2. Animal feeding trials.

After obtaining good results with the use of cassava leaf silage for feeding sheep (see Howeler, 2006) at the experiment station, a similar trial was conducted with farmers in Batu district. In this case, farmers preferred to use the leaf silage for feeding dairy cattle as they had observed that sheep or goats require time to adjust to eating the silage, while cows prefer the silage over their main diet of elephant grass. The result, presented in **Table 8,** show the effect of feeding cassava leaf silage on milk production in six farms as well as on the protein and fat content of the milk. On average, milk yields increased 6.2% with the feeding of cassava leaf silage in addition to the normal diet of elephant grass supplemented with some feed concentrate; the protein and fat contents of the milk increased by 13.6 and 2.5%, respectively.

Table 8. Effect of feeding dairy cattle with cassava leaf silage on milk yield and quality in six FPR feeding trials conducted by farmers in Tlekung village of Junrego subdistrict in Batu district of E. Java, in 2006/07.

	Daily milk yield (liters/cow)		
	Before[1)]	During[1)]	Significance
Farm 1	11.25	11.71	0.042
Farm 2	15.33	16.28	0.116
Farm 3	11.41	11.03	0.038
Farm 4	10.86	11.65	0.003
Farm 5	12.86	15.21	0.000
Farm 6	9.23	10.28	0.000
Average	**12.40**	**13.17**	**0.000**
Protein content (%)	3.15	3.58	-
Fat content (%)	3.62	3.71	-

[1)] Before and during the feeding of cassava leaf silage at about 6 kg/head/day in addition to the normal ration of 30-40 kg elephant grass plus 5-8 kg concentrate feed

After conducting the trial, farmers were very enthusiastic about the use of cassava leaf silage as they can probably reduce the amount of expensive feed concentrate. Their main problem, however, is to find enough cassava leaves as cassava growth is slow at the high elevation of nearly 1000 m above sea level where dairy farming is commonly practiced, while cassava leaves are generally available only at time of root harvest, i.e. in Aug-Sept of each year.

4.2.3. Cassava small-scale processing

In order to broaden cassava utilization and marketing, the project succeeded to establish three farmers' agro-enterprise groups, two groups in Jatisari village called "Mekar Sari" and one in Sempol village called "Puji Makur"; the latter with 37 members. The groups, with both male and female members, learned how to make *kripik* and *krupuk* using cassava fresh roots and cassava starch, as well as some other ingredients like maize. They have already produced a recipe book in the Indonesian language for 32 cassava products.

4.3. To Disseminate New Technologies Using Farmer Participatory Extension (FPE) Methodologies.

Although the transfer of selected technologies was not practiced long enough to be clearly evaluated, it can be suggested that the FPR methodology used is appropriate for generating and transferring the production technologies for cassava-based cropping systems. In Malang during the first year there were only three collaborating farmers, but this increased to ten farmers in the second year, and to 16 farmers in the third year. In the third year, 13 of those 16 farmers had already adopted the selected technologies on all of their farm land.

The project ended in 2007, so we could not further evaluate the full results of our work. However, a small survey conducted in February 2009 in Jatikerto, Malang, showed that out of 86 respondents, 56 farmers (65%) planted the variety UB 477-2 and 65 farmers (76%) used cattle manure for their cassava crops. At the beginning of the project, none of the farmers planted UB 477-2, and only seven farmers used cattle manure (Yuniwati *et al*., 2010).

4.4. To Strengthen Inter-institutional Collaboration and Capacity for FPR in National Institutions.

The ACIAR Cassava Project has provided an opportunity to cassava researchers to meet at least once a year, to learn what others were doing, and to collaborate with each other in the provision of planting material of new varieties, and to share knowledge about improved production techniques, processing or animal feeding

To improve the research capacities of cassava researchers and to broaden the vision of cassava farmers, extension workers, and processors, a training course was held in Batu in East Java. The course was taught by resource persons from Indonesia, Vietnam, and East Timor and from CIAT, and consisted of 5½ days of lectures, demonstrations and field trips; it covered a wide range of topics, such as cassava production techniques, small-scale processing into a variety of products, use of cassava for animal feeding and farmer participatory methodologies for research and extension.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Technology transfer is a long process; therefore, it was difficult to draw a clear conclusion from the three years of activities. However, from our experiences there were some results that can be further explored to produce more reliable conclusions:

1. Several new cassava varieties, such as UJ-3, UJ-5, Malang 6, UB 477-2 and UB ½ were tested in various locations in Indonesia and they seem to be rather widely adapted, while the local varieties Faroka, Markonah, Manggu and Bandung, and the breeding lines CMM 96-36-255 and CMM 99-23-12 seem to be more suitable in particular areas such as in Malang (E. Java), Pati (C. Java), Sukabumi (W. Java), Gunung Kidul (Yogyakarta) and Sukadana (Lampung), respectively.
2. Due to the great variability in soils, climates and end-uses, especially in Java, it is difficult to identify one cassava variety that is well adapted throughout the country. Thus, it may be necessary to develop specific varieties for specific areas and end-uses.
3. In Lampung province where cassava is mainly grown for starch extraction, farmers select varieties mainly based on yield and starch content; in Malang and Pati districts of East and Central Java, respectively, farmers also select mainly on yield, while in Gunung Kidul district of Yogyakarta and Sukabumi district of W. Java farmers consider both yield and eating quality as important selection criteria.
4. In the acid infertile soils of East Lampung the main limiting nutrient for cassava is K followed by P, while in the volcanic ash-derived soils of Malang district the main limiting factor is N, especially if cassava leaves are harvested for animal feeding several times during the growth cycle.
5. With very simple equipment farmers can make several types of cassava-based products at home for sale in order to have some additional income.
6. Cassava leaves are a good source of protein that will increase the live weight gain of sheep and increase the milk yield of dairy cattle if fed in the form of leaf silage.
7. In Indonesia, especially in Java, farm size is very small and farmers tend to be very interested in trying out new varieties or technologies in FPR trials to increase their yields and income.

5.2 Recommendations

1. In Indonesia cassava is starting to play an increasingly more important role as an industrial crop for production of animal feed, starch, starch-based products, such as sorbitol and bio-degradable plastics, as well as bio-ethanol. In addition, cassava can become an important source of foreign exchange by the export of dry chips, starch or ethanol, especially to China, Korea and Japan. Considering the increasing demand for cassava roots for these diverse and rapidly growing markets, the current number of researchers working on cassava, and the funds available for research, are clearly inadequate. For Indonesia to remain competitive on world markets, cassava yields will need to increase further, mainly by breeding new and higher yielding varieties through modern breeding techniques combined with biotechnology. Besides higher yields, the various industries will demand different products, such as high-protein roots for animal feeding, low- or zero-cyanide for processing into food, either low- or high-amylose cassava for different end-uses such as biodegradable plastics, and sugary cassava for

production of ethanol. These specific-quality cassava varieties are being created or discovered at CIAT in Colombia, but they need to be improved for local adaptation by well-trained cassava breeders in Indonesia. Moreover, due to the huge variability in soils and climates there is a lot more to be done in the area of soil fertility management and soil erosion control. While there are currently few important diseases and pests in cassava in SE Asia, these can accidentally be introduced from India, Africa or Latin America. Thus, it is important to have local expertise in the area of cassava disease and pest management and to start incorporating cassava mosaic disease (CMD) resistance into existing high-yielding varieties. Thus, a whole new generation of cassava scientists need to be employed and trained, in order to face the challenge of increasing the productivity of the crop to meet the rapidly increasing demand.

2. While considerable progress has been made in the area of cassava production, little attention has been paid to improving processing efficiency, either by production of more suitable varieties for a particular industry, or by the development of new processes, enzymes etc that will reduce the cost of conversion to value-added products. The area of bio-engineering of cassava-based products needs urgent attention in Indonesia.
3. The long and fruitful collaboration between CIAT and Indonesian cassava researchers has produced some excellent varieties, but neither the personnel nor the funds have been available for more widespread testing, multiplication and distribution of planting material of these varieties. The bottle-neck for the successful establishment of large cassava plantations for production of bio-ethanol – by necessity mainly in the outer islands of Kalimantan, Sulawesi, East Nusa Tenggara and in some underutilized areas of Sumatra – will be the availability of planting material of high-yielding and high-starch varieties. These still need to be tested for local adaptation, and the most suitable varieties, once identified, will need to be multiplied in order to rapidly expand the planted area.

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