CASSAVA GERMPLASM CONSERVATION AND CROP IMPROVEMENT IN INDONESIA

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ABSTRACT

Improved cassava cultivars are one of the most readily adoptable components for inducing better farm management, which in turn will lead to increased farm productivity and income. There are three phases needed for successful varietal improvement. The first phase corresponds to the collection as well as evaluation of cassava germplasm, the second phase corresponds to the generation of advanced breeding materials, while the third phase corresponds to the selection of new cultivars, their release and dissemination.

Up to the moment, there are 259 cassava genotypes conserved in one of RILET's substations as a field germplasm bank, which has to be rejuvenated each year. It consists of 145 local materials and 114 breeding materials from several sources, either introductions, mainly from the Thai-CIAT program, or from domestic institutes as well as advanced breeding materials obtained by RILET. The number of accessions will increase, since in 2002 another 50 local clones were collected under collaboration of RILET-CIAT-ACIAR. Some clones have been characterized as the gene sources for high dry matter or starch content, low HCN content, tolerance to red mite and adaptation to low soil fertility.

Advanced breeding materials are produced every year through the crossing of selected parents, either through controlled or open pollination. Due to limited resources, only about 2000 seeds can be produced each year. Every specific objective of character improvement will need up to five crossing cycles in an attempt to increase the chance of getting the required genotype. RILET has adopted the conventional breeding methodology developed by CIAT. At present we have materials at all breeding stages, beginning from hybridization up to multilocational tests. Since 2002 RILET has been using biotechnology tools such as marker-assisted selection using Randomly Amplified Polymorphic DNA (RAPD) for selection of tolerance to red mite.

Two cassava varieties have been officially released in 2000, both originally from Thailand, i.e. Rayong 60 renamed as UJ-3, and Kasetsart 50 renamed as UJ-5. Two other new varieties were officially released in 2001, which are Malang 4 and Malang 6. Malang 4 was selected among open pollinated lines from Adira 4 as female parent, whereas Malang 6 is the selected line from a cross made between MLG 10071 and MLG 10032 as female and male parents, respectively. There are several promising lines in the preliminary and advanced stages of selection, which are able to produce more than 10 tonnes of starch per hectare.

INTRODUCTION

Cassava in Indonesia is known as the "poor people's crop", since this crop is generally grown in marginal low-fertility soils with no or very limited external inputs; in agroclimatic zones where both intensity and distribution of rainfall are too risky for growing other annual crops; in locations where the topography is hilly or undulating with usually less developed infrastructure, especially for transportation. The debate about whether cassava is the cause or the result of poverty is never ending, since this phenomenon is analogous to answering which came first, the chicken or the egg. Whatever the truth, poverty and cassava are indeed closely linked.

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That cassava is one of the most efficient crops in converting radiation energy has already been stated many times before, particularly that cassava is highly adapted to adverse conditions and produces very cheap calories. This can be misleading, however. These statements are true when cassava is grown under unlimiting environments as well as in the context of crop comparison. Kawano (2001) stated that cassava can be a very problematic crop if the cultural practices used, or the environment, are not appropriate. So, it is not surprising that for those who are not familiar with the crop, cassava is often considered as an indefensible villain.

We, the authors, consider that the improvement and development of cassava as one of the potential tools in fighting poverty, is not only in the hands of cassava experts but also in the hands of decision-makers who may know little about cassava. The public usually considers cassava to be a cheap crop. Henry and Gottret (1996), as quoted in Hershey and Howeler (2001), showed that production costs, farmgate price of roots and the cassava starch price all increased markedly from Thailand to Brazil to Colombia. They suggested that the price differences among countries is mainly due to differences in production and processing costs, but we suggest that, to some extent, those price differences are also due to differences in social appreciation.

People who have to make decisions on budget allocations, but who know little about cassava may not see the need to approve money for breeding research when several varieties yielding more than 40 t/ha fresh roots are already available. However, high yields obtained in breeding plots are nothing more than the phenotypic expression of yield potential. We all know that "no matter how perfect the environment, high yield expressions can not be achieved if the genes required are not present", but those that do not know often do not realize that no matter how perfect the genetic constitution, this will not lead to high yields as long as the required environmental conditions are not present.

In the future, everyone concerned with cassava need to make more appropriate statements. Cassava is not very different from any other upland crop. When well-managed, and with proper inputs, the crop can offer great benefits. The crop's biological potential yield, sometimes up to 100 t/ha, is irrelevant under the conditions in which cassava is actually grown. Indeed, even up to the present the world's average cassava yield is only about 10 t/ha. Increasing the yield from 10 t/ha is analogous to climbing a mountain; it is impossible to do that in a straight line.

In Indonesia cassava remains a crop mainly grown by and for the poor, directly or indirectly affecting the lives of millions of people. In the future, it will most likely be grown with relatively low inputs, and certainly under unpredictable agroclimatic conditions. This leads to an array of production constraints. In that situation, breeding activities can be expected to offer one of the key components for achieving higher yield and production.

Hershey (1988) stated that the objectives of every breeding program at whatever level – international or national – should coincide with the needs of the targeted producers, processors and consumers. Furthermore, research must operate within an evolving context where the principle constraints on the development of the crop often shift from production to utilization to processing and marketing. The breeding objectives should be based on a clear understanding of the role of increased or stabilized crop productivity on agricultural policy. However, the rate of progress in genetic improvement is inversely proportional to the number of breeding objectives.

Iglesias *et al*. (1995) stressed that under yield limiting conditions, most of which are outside the farmers' control, one of the main objectives should be to develop improved cultivars that can produce reliable yields under field conditions. Given the wide range of environmental conditions and production systems, it is impossible to obtain a single genotype that is well adapted to the majority of growing conditions; in other words, developing specifically adapted genotypes is more appropriate than generally adapted ones. Ideally, the number of specifically adapted genotypes should be proportional to the number of specific growing locations. However, as the needed resources are limited we have to prioritize.

Two major environmental components are soil and rainfall, of which the former can be controlled to some extent while the latter can not. Howeler (1992) estimated that cassava in Indonesia is grown on the following soil orders: 24% on Alfisols, 22% on Ultisols, 20% on Entisols, 18% on Inceptisols, 8% on Vertisols, 6% on Mollisols, 2% on Histosols and 1% on Oxisols. Up to the present the two first soil orders have been used as selected soil environments for cassava breeding. Confounded within soil orders are rainfall pattern, which can be bimodal or unimodal. Lampung province, which has mainly Ultisol soils and a bimodal rainfall pattern was chosen as one representative location, while East Jave province, having a unimodal pattern and mainly Alfisols, was chosen as another location.

Cassava breeding was broken down into its three elements; these include the accumulating of a source of genetic variation, creating further genetic variations or recombinations by crossing, and subsequently selecting superior genotypes within this range of variation, finalizing with multilocation testing leading to varietal release.

CASSAVA GERMPLASM CONSERVATION

Germplasm Collection

The Research Institute for Legumes and Tuber Crops (RILET), located in Malang, East Java, Indonesia, was founded in April 1995. It was assigned the national mandate to generate technologies for legumes and tuber crops, focusing on the generation of new varieties and improved cultural practices. Thus, in 1995 cassava breeding was initiated. However, previously, when the institute was still called MARIF (Malang Research Institute for Food Crops) the embryo activity for breeding, which is cassava germplasm collection, had already been initiated.

In 1985, under the Agricultural Technical Aids 272 (ATA-272) Project, funded by the Dutch government, upland crop germplasm collections, including that of cassava, were started. The cassava germplasm was conserved as a field collection, which was replanted every year, while the accessions were documented in a catalogue containing the passport data. Unfortunately, all information has not yet been updated. The first collection consisted of 204 cassava clones. Passport date, giving information about the origin, name and code of an accession, the institute from where it was obtained, and, in case of locally collected varieties, the place of collection. Germplasm was coded MLG (abbreviation of Malang) followed by a number. The numbers 10001–12500 have been reserved for cassava. So, the first cassava germplasm collection consists of MLG 10001 to MLG

10207 (MLG 10005, MLG 10026 and MLG 10167 were lost). This first collection was acquired either from other institutes or from farmers.

Up to the moment there are 259 cassava genotypes conserved in one of RILET's substations as a field germplasm bank, which has to be rejuvenated each year. It consists of 145 local varieties and 114 breeding lines from several sources, either introductions, mainly from the Thai-CIAT program, or from domestic institutes, as well as advanced breeding lines of RILET. Since 2002, another 50 local clones have been collected under a collaborative agreement between RILET, CIAT and ACIAR.

Germplasm Evaluation

The germplasm was evaluated for general characteristics such as morphological or botanical traits and yield related characters, as well as specific traits, mainly resistance to brown leaf spot caused by *Cercospora henningsii*, resistance to red mites (*Tetranychus* sp.), and the dry matter content of peeled roots. Due to technical limitations, only 114 out of 204 clones have been evaluated. Some charactertics are shown in **Table 1**.

The correlation coefficients between several traits were determined, as well as a preliminary indication of broad-sense heritability, calculated according to Singh and Chaudary (1979). The results are shown in **Table 2**.

Besides for morphological traits, 51 local accessions have also been evaluated for physico-chemical traits. Characterizations include flesh color, taste, texture, water content, protein content, starch content, HCN content and the recovery percentage of chips at 6% water content. These general results are presented in **Table 3**.

In anticipation of breeding for specific adaptation to low soil fertility, 198 clones were evaluated in terms of their response to fertilizer application during 1998/99. Calculating their low-soil-fertility adaptation index, as described by Iglesias *et al*. (1995), 10 out of the 198 tested clones were identified as highly adapted, i.e. having an adaptation index above 2.

The frequency distribution of the index value was highly skewed to the left; this indicates that the number of accessions which adapted well to low soil fertility was lower as compared to those that were not adapted. Two clones which had an adaptation index of more than 3, MLG 10032 and MLG 10033, yielded 60.52 and 48.56 t/ha with application of fertilizer while without fertilizer they still yielded 33.90 and 38.25 t/ha, respectively. However, since these two local clones have the same local name and originated from neighboring districts, it is very likely that they are duplicates.

Characterization to determine the materials' suitability for cassava-based food products is ongoing. From preliminary results it can be concluded that only a few clones are suitable for making specific products, while a larger number of clones were found to be suitable for several other products.

Table 1. Characterization data of RILET cassava germplasm.

Parameter	Value	
1. Number of accessions in 1985	204	
- local varieties	151 (74.0%)	
- breeding lines	25 (24.5%)	
- released varieties	2 (1.0%)	
- *M. glaziovii*	1 (0.5%)	
2. Root parenchyma color of 114 accessions		
- white	91 (79.8%)	
- yellow	23 (20.2%)	
3. Outer root skin color		
- brown	104 (91.2%)	
- white	10 (8.8%)	
4. Branching habit		
- branching	52 (45.6%)	
- non-branching	62 (54.4%)	
5. Root number/plant harvested at 6 MAP	F_0	F_1
average	6.52	6.74
maximum	11.00	12.00
minimum	2.00	3.60
standard deviation	1.74	1.74
phenotypic C.V.	26.70	25.80
6. Root weight/plant harvested at 6 MAP		
average	0.83	0.63
maximum	2.38	1.23
minimum	0.28	0.27
standard deviation	9.33	0.20
phenotypic C.V.	39.30	31.20
7. Root number/plant harvested at 10 MAP		
average	7.89	6.52
maximum	11.80	9.80
minimum	4.70	2.80
standard deviation	1.56	1.47
phenotypic C.V.	19.70	22.60
6. Root weight/plant harvested at 10 MAP		
average	2.28	1.45
maximum	5.00	3.29
minimum	0.63	0.70
standard deviation	0.87	0.44
phenotypic C.V.	37.90	30.70

Note: Evaluation of 114 clones planted at 20,000 plants/ha (1.0 m x 0.5 m);
F_0 = without fertilizer; F_1 = 200 kg urea + 70 TSP + 150 KCl/ha.

Table 2. Correlation coefficients between traits and broad-sense heritability values of several traits.

Item	Value
1. Root number vs. root weight at 6 MAP without fertilizer, n = 112	0.53
2. Root number vs. root weight at 6 MAP with fertilizer, n = 116	0.66
3. Root number vs. root weight at 10 MAP without fertilizer, n = 114	0.50
4. Root number vs. root weight at 10 MAP with fertilizer, n = 116	0.65
5. Root number at 6 MAP vs. root number at 10 MAP with fertilizer, n = 116	0.52
6. Root weight at 6 MAP vs. root weigh at 10 MAP without fertilizer, n = 114	0.63
7. Specific gravity at 6 MAP vs. specific gravity at 10 MAP with fertilizer, n = 116	0.81
8. Broad sense heritability of root number at 6 MAP, transformed Vx	0.35
9. Broad sense heritability of root number at 10 MAP, transformed Vx	0.41
10. Broad sense heritability of root weight at 6 MAP, transformed logx	0.23
11. Broad sense heritability of root weight at 10 MAP, transformed logx	0.27
12. Broad sense heritability of root specific gravity at 6 MAP	0.80
13. Broad sense heritability of root specific gravity at 10 MAP	0.80

Note : MAP = months after planting

Table 3. Average, standard deviation, and coefficient of variation of several physico-chemical traits of 51 local accessions.

Item	Water content[1] (%)	Protein content[2] (%)	Starch content[2] (%)	HCN content[3] (ppm)	Chips conversion[4] (%)
1. Average	63.38	1.68	53.83	29.79	38.20
2. Standard deviation	4.31	0.98	5.05	18.30	6.55
3. Coefficient of variation	6.81	58.58	9.38	61.41	17.14
4. Flesh color: 8 yellow; 43 white					
5. Taste: 5 bitter; 46 not bitter					
6. Texture: 6 glazy; 45 crumbly after cooking					

[1] Water content: on wet basis
[2] Protein and starch contents: on dry weight basis
[3] HCN content on wet basis
[4] Chips at 6% water content

CASSAVA IMPROVEMENT

The cassava breeding methodology used at RILET remains essentially the same as that described by Koes Hartojo *et al.* (2001). Non-bitter as well as bitter types are evaluated equally for all other traits. Both types were evaluated for high yield and starch content, while only selected genotypes that already had three of the most required characters were evaluated for adaptation to low soil fertility as well as tolerance to red mites. These evaluations were carried out by teams from the relevant disciplines, particularly soils and plant nutrition, plant protection and post-harvest technology.

During the period of 1998/99 to 2001/02 we produced about 2000 hybrid seeds, per year, either from controlled crosses or through open pollination. The substation at which we conducted these hybridizations is essentially rainfed, so the number of seeds produced is very dependent on the rainfall conditions. Sometimes it is much less than expected, sometimes more. During 1998/99, 1999/00, 2000/01 and 2001/02 we produced 952, 3604, 2,112 and 1,700 seeds, respectively. Thus, we produced a total of 8,368 seeds.

In 1999/00 we took 200 clones to Lampung and tested them there as well as in south Malang. As already described above, Lampung is representative of areas with Ultisols and with a bimodal rainfall pattern, while south Malang has calcareous Alfisols with a unimodal rainfall pattern. Only 171 clones out of 200 tested grew well, so statistical analysis were conducted only for those 171 clones which were present in both locations.

The interaction between location and genotype was highly significant. There was only one clone which could be selected for both locations at the 30% selection intensity. **Table 4** shows 14 clones which had yields of 35 t/ha fresh roots or more, averaged for the two locations, while the yield levels at 30% selection index were 24.25 and 48.30 t/ha for south Malang and Lampung, respectively.

Table 4. Fresh root yields and origin of selected clones in the Preliminary Yield Trials in south Malang and Lampung in 1999/2000.

		Yield (t/ha)		
	Clone No	South Malang	Lampung	Origin
1	MLG 10219	25.50	48.94	West Java
2	MLG 10172	34.75	(43.38)	East Java
3	MLG 10197	(5.13)	73.56	Central Java
4	MLG 10015	37.88	(39.13)	East Java
5	MLG 10186	34.63	(41.75)	Central Java
6	MLG 10027	(20.63)	52.19	East Java
7	MLG 10234	(21.50)	58.44	East Java
8	MLG 10127	(17.88)	57.50	East Java
9	MLG 10248	(15.38)	61.00	East Java
10	MLG 10032	(7.84)	71.25	East Java
11	MLG 10130	27.13	(43.75)	East Java
12	MLG 10124	(23.75)	49.81	East Java
13	MLG 10039	36.13	(45.13)	East Java
14	MLG 10134	(14.63)	57.25	East Java

Note: Figures in brackets means that the clones were not selected in the specified location.

The highly significant interaction between location and genotypes was also supported by other experiments which used the same germplasm but at a more advanced stage of selection. **Table 5** shows the ten genotypes which were selected in each location under 30% selection index. Again, the average yield in Lampung was significantly higher than in south Malang. Only two out of 25 tested clones could be selected for both locations. The two clones selected for both locations were out of seven and four clones selected for each location, i.e. south Malang and Lampung, respectively.

Table 5. Fresh root yields of selected clones in the Advanced Yield Trial in south Malang and Lampung in 1999/2000.

		Yield (t/ha)		
	Clone No	South Malang	Lampung	Origin
1	MLG 10200	(13.88)	45.00	Local Central Java
2	MLG 10034	31.13	(37.50)	Local East Java
3	MLG 10050	40.88	(35.50)	Local East Java
4	MLG 10020	(2.38)	48.13	Local East Java
5	MLG 10113	43.50	66.25	Breeding lines
6	MLG 10102	26.25	(27.50)	Local East Java
7	MLG 10018	20.75	(17.50)	Local East Java
8	MLG 10227	(10.38)	43.75	Local West Java
9	MLG 10025	34.25	(15.63)	Local East Java
10	MLG 10128	28.75	(33.75)	Local East Java

Note: Figures in brackets means that the clones were not selected under 30% selection indices, which were 19.44 and 41.61 t/ha for south Malang and Lampung, respectively.

From the above results it can be concluded that breeding cassava for a specific location is much more feasible as compared to breeding for general adaptation. The number of selected clones selected for each of these two locations was much higher. Since the multiplication rate of cassava is one of the most limiting factors for their rapid dissemination, the greater the number of varieties, the longer it will take.

As expected, during the period 2000–2001, the number of officially released varieties also increased (**Table 6**). Two varieties were released each year. The two varieties released in 2000 were introduced from Thailand. Rayong 60 and Kasetsart 50, which were released in Thailand in 1987 and 1992, respectively, were both released in Indonesia in 2000. Particularly Kasetsart 50, which according to Kim *et al*. (2001) has become the most popular new variety in Vietnam, is also doing well in Indonesia and already occupies at least half of Lampung's cassava area.

Table 6. High yielding cassava varieties officially released in Indonesia during 1978–2001.

	Variety name	Type of crosses	Year of release	Taste	Origin
1	Adira 1	Open	1978	Non-bitter	BORIF
2	Adira 2	Open	1978	Bitter	BORIF
3	Adira 4	Open	1986	Bitter	BORIF
4	Malang 1	Controlled	1992	Slightly bitter	CIAT, Colombia
5	Malang 2	Controlled	1992	Non-bitter	CIAT, Colombia
6	Darul Hidayah	Selfed	1998	Non-bitter	Indonesia
7	UJ-3 (Rayong 60)	Controlled	2000	Bitter	Thai-CIAT
8	UJ-5 (KU 50)	Controlled	2000	Bitter	Thai-CIAT
9	Malang 4	Open	2001	Bitter	RILET
10	Malang 6	Controlled	2001	Bitter	RILET

A vital part of any plant breeding program is the availability of adequate genetic diversity for all the traits for which improvement is sought. We think that we can not progress quickly using only a limited diversity. However, since our financial resources remain limited, we always welcome other national cassava programs to provide us with clones with superior traits. Within the RILET-CIAT-ACIAR agreement, initiated in 2002, we continue to collect our local cassava germplasm. Around 50 local accessions have already been collected and are ready to be evaluated in 2002/03.

Hopefully, from our 2001/02 multi-locational trials, other clones can be promoted based on the results from the Lampung locations only. In one location, which can be considered very marginal (Gunung Katun plantation) there were two prospective clones which significantly outyielded all UJ-clones developed by the Great Giant Pineapple Comp. in Umas Jaya.

If more high-yielding varieties would be available, there would be new ways to reduce poverty, either by stabilizing the production level by liberating areas previously used for cassava for other crops, or by stabilizing the cassava area as long as the demand for cassava increases.

We totally agree with Hershey and Howeler (2001) that it is not so easy to make the rural poor the beneficiaries of the highest possible proportion of cassava added value. But, although not easy, it is not impossible, and very likely it could be possible. If we, who are specialists in cassava production, are not firmly grounded in that conviction, what else can be expected from others?

CONCLUSIONS

- Even with very limited financial resources, Indonesia's cassava breeding program continues to progress. We admit that due to our limited program the chance for success is rather low. But with the help of "the invisible hands", we are never desperate or ashamed doing the best we can, whatever small our contribution might be.
- For rapid progress in breeding we can not rely on limited genetic variation, but for the sake of efficiency and effectivity we are inviting other strong national cassava programs as well as international centers to enrich our genetic stock, which is relatively limited but reliable. Let's together, hand in hand, contribute to the building of a healthy agriculture, scientifically, morally and legally.
- Considering that conventional breeding methods must deal with very large numbers of materials in the hope to find the most suitable genotype(s), we are now starting to use biotech to enhance our breeding efficiency. Significantly, the Donald Danforth Plant Science Center, through its International Laboratory for Tropical Biotechnology, has selected cassava as one of its mandated crops.

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