

CASSAVA BREEDING AND VARIETAL DISSEMINATION IN INDIA- MAJOR ACHIEVEMENTS DURING THE PAST 25-30 YEARS

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ABSTRACT

Cassava (*Manihot esculenta* Crantz) has been grown in India for more than a century. Although cassava breeding was initiated during the 1940s in Kerala, intensive research on breeding of superior varieties began only after the establishment of the Central Tuber Crops Research Institute (CTCRI) in 1963 in Trivandrum, Kerala. The Institute has an immense wealth of cassava germplasm, both indigenous and exotic. Nine superior varieties were released by CTCRI, three of them developed by selection, five by intervarietal hybridization and one by triploidy breeding. The high yielding hybrids not only increased cassava cultivation but also spread the crop outside Kerala. At present cassava is cultivated in 12 states and two union territories of the country, but the major producer is Kerala followed by the neighboring states of Tamil Nadu and Andhra Pradesh. The hybrids H-226 and H-165 are the most popular varieties in the industrial areas of Tamil Nadu and Andhra Pradesh, but the recently released triploid hybrid 'Sree Harsha', with its high yield, high starch and good culinary quality, holds great potential for both industrial use and human consumption. The three short-duration varieties are highly preferred by farmers as a rotation crop in the paddy-based cropping system. Very recently, two superior top-cross hybrids, having high yield and good culinary quality, were developed from inbreds and are ready for formal release.

In recent years the spread of cassava outside Kerala has been quite substantial. In Tamil Nadu and Andhra Pradesh, where cassava is mainly used as an industrial crop for starch and sago manufacture, cassava area and production are expanding. In the northeastern states, where it is used mainly as a food crop, cultivation is also gradually increasing. In non-traditional areas of central India, the crop is being introduced through the true seed program. Nevertheless, the total area and production of cassava in India is declining, especially in Kerala, due to the prominence gained by plantation crops like rubber, black pepper, coffee etc. which provide more cash income. Therefore, the future increase in cassava production seems possible only by increasing the productivity in the existing areas of cultivation, expanding its adoption in different cropping systems and introducing the crop to new, non-traditional areas. To fulfil this goal, a new challenge in cassava breeding would be the development of gene pools with adaptation to the main biological and physical environmental stresses, development of varieties having resistance to CMD and red mite as well as drought tolerance, the nutritional improvement of cassava roots by protein enrichment, as well as the development of high-yielding, high-starch and high eating-quality hybrids, which will be acceptable to farmers, processors and consumers. Among the conventional breeding techniques, triploidy and top crossing are probably better tools for this. However, biotechnological approaches through gene transfer might tackle the challenges in a shorter time, but this will require coordinated research efforts among international and national agricultural institutions.

INTRODUCTION

In India, cassava occupies about 0.26 million ha of land producing 5.868 million tonnes of fresh roots. It is cultivated in 12 states and two union territories, but the major producers are the three states of the southern peninsular region, i.e. Kerala, Tamil Nadu and Andhra Pradesh. These three states make up 88% of the cultivated area and 99.3% of the production volume. Kerala holds the key position in cassava cultivation in India, probably

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because it was to this state that the crop was first introduced into the country in the 17th century. In the latter part of the 19th century, cassava became an important food crop of Kerala, often forming life-saving sustenance during periods of famine. It gradually spread to the neighboring states of Tamil Nadu and Andhra Pradesh. Contributions to the breeding research on cassava in India have been made almost entirely by the Central Tuber Crops Research Institute (CTCRI) in Trivandrum, Kerala, and its Regional Center at Bhubaneswar in the north-eastern state of Orissa. Contributions to varietal development were also made by the Agricultural Universities of the states of Kerala and Tamil Nadu. Beside this, the All India Co-ordinated Research Project on Tuber Crops with its 11 centers, also contributes to varietal improvement by regional testing of varieties at an advanced stage of development.

Early Research

Cassava research in India started in the 1940s. The first phase consisted of a period of about 20 years from the 1940s to the 1960s, before the inception of CTCRI. The Tapioca Research Station of the State Government was established in Trivandrum in 1944, which initiated organized research on cassava breeding and produced the earliest improved varieties of the crop. The most significant and lasting contribution of the initial phase of cassava research was the selection of the Malayan clone, M4, revolutionizing cassava cultivation in Kerala (Abraham, 1956). Even after 44 years, M4 remains the best table variety with unmatched culinary quality. Its cooked roots are mealy, soft and highly palatable with negligible cyanogen content. Although several varieties and breeding lines have culinary qualities comparable to that of M4, none is as stable in yield performance as the latter, especially under different soil and climatic conditions. A major hindrance in transferring the culinary quality of M4 through conventional breeding is the limited flowering capacity of the variety, apart from the complexity of the character itself.

RESEARCH AT THE CENTRAL TUBER CROPS RESEARCH INSTITUTE

In 1963, the Central Tuber Crops Research Institute (CTCRI) of the Indian Council of Agricultural Research (ICAR) was established for research on tropical tuber crops, with main emphasis on cassava. Achievements in cassava breeding and varietal dissemination in India have since been largely due to the contributions from CTCRI.

Genetic Resources

An exhaustive collection of the genetic resources of cassava was assembled at the Institute. Local varieties and types from within the country and accessions from abroad were collected. The major sources of exotic genetic stocks are from Colombia, Madagascar, Nigeria, Thailand, Ghana, Uganda, Malaysia, Indonesia, Sri Lanka, Senegal and Gabon. The genetic resources have been the precious starting material of CTCRI, which became instrumental in subsequent breeding achievements. At present the germplasm collection consists of 781 exotic and 806 indigenous accessions, making a total of 1587. In addition, there are eight wild relatives of cassava: *M. anomala*, *M. caerulescence*, *M. euprinosa*, *M. flabellifolia*, *M. glaziovii*, *M. grahami*, *M. tristis* and *M. peruviana*.

Enrichment of germplasm by collecting varieties and types from within the country and abroad, and their evaluation, is a continuing process. During 1996, twenty-seven

combinations of F₁ seeds of cassava were received from CIAT, Colombia. Seeds germinated from 25 combinations. Germination ranged from 2-100%, with the majority of the combinations recording more than 50% germination. First clonal plants of 21 combinations were evaluated, recording root yields ranging from 0.41 to 3.01 kg per plant. The highest root yield was achieved by SM2371 (3.01 kg), followed by CM8809 (2.24 kg). The roots of these entries were sweet to the taste.

High-Yielding Varieties

Extensive intervarietal hybridization between superior varieties, and selection among recombinants resulted in the isolation and release of the first three high-yielding varieties of cassava from CTCRI in 1971. They are H-97, H-165 and H-226 (Magoon *et al.*, 1970). As the emphasis in breeding was on yield improvement, the culinary quality of those hybrids was not as good as that of the preferred local varieties; hence, they could not establish well as table varieties in Kerala. Nevertheless, they are the most preferred varieties in the neighboring states. In 1977, two higher yielding hybrids with improved culinary quality were released as Sree Sahya and Sree Visakham (Jos *et al.*, 1981).

H-97 is a hybrid between a local variety and a Brazilian selection. It has conical, short roots, yielding 25-35 t/ha, and has a crop duration of ten months.

H-165 is a hybrid between two local cultivars. The roots are relatively short and conical, yielding 33-38 t/ha. The variety is comparatively early maturing and can be harvested after 8-9 months.

H-226 is a hybrid between a local cultivar and the Malayan introduction, M4. The root yield is 30-35 t/ha, and crop duration is ten months. Both H-165 and H-226 are the predominant varieties cultivated in the states neighboring Kerala. H-226 has a high yield under irrigated cultivation in Tamil Nadu.

Sree Visakham is a hybrid between a local cultivar and a Madagascar variety. It has compact roots, which have yellow flesh due to a high carotene content (466 IU/100 g). Crop duration is ten months, and the root yield is 35-38 t/ha.

Sree Sahya is a multiple hybrid involving five parents, two of which are exotic and three indigenous. The roots are long-necked, yielding 35-40 t/ha. Crop duration is 10-11 months. Both Sree Visakham and Sree Sahya are improved table varieties, having better palatability than the former three hybrids.

Early Maturing Varieties

Over the last two decades the cultivation of cassava as a monocrop in the uplands started to decline in Kerala due to the cultivation of plantation crops which give higher income to the farmers. On the other hand, cassava is more and more being cultivated in low-lying areas after the main crop of rice, and for this short-duration varieties are needed. The early maturing (7 months) selection, Sree Prakash, released in 1987 (Nair *et al.*, 1988) was quickly adopted in paddy-based cropping systems in the low-lying areas. As cultivation of cassava in low-lying areas started to increase, better short-duration varieties

were needed. *Sree Jaya* and *Sree Vijaya* are two short-duration varieties which were released in 1988 for this purpose.

Sree Prakash is an indigenous selection. The plants are relatively short with high leaf retention. Its crop duration is 7-8 months and its root yield 35-40 t/ha.

Sree Jaya is a selection from indigenous germplasm. The plants are medium in height, yielding conical roots with white flesh. Its crop duration is six months and root yield 26-30 t/ha.

Sree Vijaya is a selection from indigenous germplasm. It has conical roots with yellow flesh and a root yield of 25-28 t/ha. Crop duration is six months.

The three short-duration varieties, having higher yield and excellent culinary quality, are much preferred by the farmers in Kerala, as they are ideally suited to cultivation in low-lying areas as a rotational crop after the paddy harvest. As the industrial belts of Tamil Nadu and Andhra Pradesh are continually in need of cassava roots, the short duration varieties are also becoming popular in those states.

Triploid Variety

As the role of cassava started changing from a human food item to an industrial raw material in the neighboring states, especially Tamil Nadu and Andhra Pradesh, higher yield became the most important factor. As a result, the high-yielding hybrids like H-165 and H-226 quickly dominated the industrial belts of Tamil Nadu and Andhra Pradesh. The demand was for higher dry matter and starch contents. Among the artificially produced polyploids, triploids were found to combine higher yield and higher starch content.

Sree Harsha is the first triploid variety of cassava, released in 1996 (Sreekumari *et al.*, 1999). It is a hybrid between a diploid selection and induced tetraploid of the released variety *Sree Sahya*. The plants are short, vigorous and non-branching or top-branching. The leaves are broad, thick and dark green in color. Its roots are very compact, yielding 35-40 t/ha. Crop duration is ten months, but because of its early bulking nature it can be harvested as early as the 7th month without any yield loss or starch reduction in the roots. *Sree Harsha* has recorded the highest starch content of 39.1% among the released cassava varieties.

Triploids are produced by crossing diploids with colchicine-induced tetraploids. Use of diploids as female parents was found to be more successful in the production of triploids while reciprocal crosses were unsuccessful. Certain parental combinations were found to be more fruitful in producing triploids.

Triploidy *per se* was found to be related to a number of desirable attributes in cassava, such as higher yield, higher harvest index, greater dry matter and starch contents in roots, rapid bulking, early harvestability, shade tolerance and tolerance to cassava mosaic disease (CMD). The triploid hybrid has made substantial advances in the breeding of cassava as it also combines high yield with excellent culinary quality, making it suitable as a dual purpose variety for both industrial and table purposes. Triploidy breeding in cassava

offers enhanced frequency of higher yielders in the progeny compared to other breeding methods, thus providing better opportunities for selection. Being vegetatively propagated but with a sexual reproduction system, cassava is a suitable plant for triploidy breeding. Although induction of tetraploidy, interploidy crosses, seed set, germination and recovery of triploids are beset with several hindrances, triploid breeding is worth the effort. All practical aspects of triploidy breeding in cassava have been standardized at CTCRI.

Heterotic Varieties

Cassava, which is highly heterozygous and cross-pollinated, is also found to be a suitable plant for exploitation of heterosis. Inbreds were produced up to the 5th generation. Although considerable inbreeding depression was manifested in varying degrees for almost all the characters, certain genetic stocks tolerated inbreeding depression to a great extent. Studies show that root yield and most of the yield components in cassava are governed by dominant gene action, suggesting the scope for exploitation of heterosis in cassava improvement. Heterosis for root yield, in different varieties, was found to range from 10-100% over the better parent. Two superior selections from top-cross hybrids of inbreds with the released variety Sree Visakham (TCH-1 and TCH-2) were found to have very palatable root quality, higher yield (42-44 t/ha), higher harvest index (69-71%) and lower cyanogen content (74-80 ppm). They have been tested in yield trials, on-farm trials and multi-location trials, and are now recommended for formal release (Easwari Amma *et al.*, 2000).

Other On-going Programs

1. Interspecific hybridization

Interspecific hybridization was carried out to transfer genes for CMD resistance, protein enrichment of roots, and stress tolerance to cassava from its wild relatives. The hybrids of cassava with *M. flabellifolia*, *M. tristis*, *M. caerulescence* and *M. peruviana* were backcrossed to elite cassava varieties. The BC₂ clones showed considerable improvement in starch content and root quality. Of the 1056 backcross hybrids, 147 showed storage root formation, and 35 were free from CMD. Cyanogen content of roots ranged from 24-64 ppm. Ten CMD-free BC₂ clones, having a lower cyanogen content and fairly good root quality, have been identified. The backcross breeding program is still in progress.

2. Tissue culture

Tissue culture programs are aimed at eliminating CMD through meristem culture, *in vitro* conservation of germplasm, micro-propagation, and anther/pollen culture for production of haploids. Lower levels of benzyl adenine, NAA and GA were found to be better for the development of meristem cultures in cassava (Unnikrishnan and Sheela, 1998). Sago made from cassava flour was found to be an excellent substitute for agar used in tissue culture medium (Nair and Makesh Kumar, 2000).

Of the 1587 germplasm accessions maintained in the field gene bank, 985 accessions (62.1%) are conserved as *in vitro* slow growth cultures. Work is in progress to conserve the rest of the accessions also in this manner. Slow growth up to ten months was induced with an osmotic retardant medium containing sorbitol or mannitol (0.5-3.0 g/l). The 24 accessions received as *in vitro* cultures from the CIAT-Thai program have been

micro-propagated and transferred to the field. One accession, MNGA-1, showed very low incidence of CMD under field conditions, and is being evaluated in multi-location trials.

3. Mutation breeding

Mutation studies are underway with the specific objectives of developing varieties with CMD resistance, and reducing the cyanogen content in the roots. Studies have indicated the possibility of reducing the level of cyanogen in cassava roots.

4. True seed program

The program for the propagation of cassava by true seeds has been taken up to popularize the crop in far-flung areas of the country with marginal soil conditions. This will help in reducing the bulk of initial planting material to be transported as well as in preventing the spread of CMD. In three non-traditional areas of the country, i.e. Coimbatore, Peddapuram and Jagadapur, seedlings from true seeds have been raised and their first clonal progenies are being evaluated.

5. Field production of healthy planting material

A simple nursery and field screening technique was found to be useful in producing healthy planting materials of cassava in bulk. Stakes of 7-10 cm length and with 3-4 nodes are planted closely together in nursery beds. On sprouting, only the symptom-free setts are retained for transplantation into the field while the rest are destroyed. Regular rouging of infected plants in the field is carried out. Spraying of insecticides at 40-day intervals is followed to control the vector population of CMD. By practicing this technique for three seasons, field incidence of CMD was reduced from 70% to 12% among ten varieties. Symptom-free plants can be obtained by this method even from infected plants (Mohankumar and Unnikrishnan, 1999).

BREEDING WORK ELSEWHERE

Apart from CTCRI, breeding research at the Agricultural Universities of Kerala (KAU) and Tamil Nadu (TNAU), and the Tamil Nadu Horticulture Department has resulted in the release of several other cassava varieties. KAU has released two short-duration varieties, i.e. Nidhi in 1993 and KMC-1 in 1998. TNAU released three varieties, i.e. CO-1, CO-2 and CO-3 in 1977, 1984 and 1993, respectively, and the Horticulture Department of Tamil Nadu released one variety, MVD-1, in 1993.

Nidhi is a clonal selection suited to areas of sandy loam soils of central Kerala. Crop duration is six months and its mean yield is 25 t/ha.

KMC-1 is a clonal selection suitable for intercropping in coconut gardens of central Kerala. Its crop duration is six months and its mean yield 30.5 t/ha.

CO-1 is a clonal selection from a local variety. Crop duration is 8-9 months and the mean yield is 30 t/ha.

CO-2 is a clonal selection from an open-pollinated seedling progeny of a local type. It has compact roots. Crop duration is 8-9 months and its mean yield is 35 t/ha.

CO-3 is a clonal selection from open-pollinated seedlings of Nigerian origin. Crop duration is eight months. Mean yield under irrigation is 42.6 t/ha and under rainfed conditions is 27.3 t/ha.

MVD-1 is a clonal selection exhibiting field tolerance to CMD. Crop duration is nine months and mean yield is 34.5 t/ha.

DISSEMINATION OF VARIETIES

Varietal dissemination of cassava in India is the epitome of a need-based spread of a backyard crop, from its obscure status as a subsistence or famine food to the more elevated status of an industrial raw material and cash crop. Cassava is the major tropical root crop cultivated in the country, occupying 63% of the total area under root and tuber crops.

Varietal Spread in Kerala

All the varieties released by CTCRI have been popularized in Kerala through extension activities. Sree Visakhm, Sree Jaya, Sree Vijaya, H-165 and H-226 are cultivated in different areas, depending on the farmer's choice of specific varieties. M4 is still very popular due to its excellent and stable culinary quality. Besides, there are more than 125 recorded local varieties that have evolved over the centuries through farmer selection of clones, chance hybrids or mutants. However, the extensive spread of CMD has led many excellent varieties like Kalikalan to the verge of extinction.

Kerala accounts for about 55% of the cassava cultivated area (142,000 ha) in India. But the majority of the area (69%) is planted to local varieties which are still preferred in the central and northern regions (80-90%); in the south, there are fewer local varieties (13-53%) with 40-50% of the area planted to M4. H-226 is cultivated up to 22% in the Pathanamthitta district in the south. In general, the high-yielding varieties are not very popular in the state because of their inferior culinary quality compared to M4 and other local varieties (Ramanathan *et al.*, 1989). The short duration varieties Sree Prakash, Sree Jaya and Sree Vijaya are becoming popular in the low lying areas of southern and central districts of Kerala but data on the extent of their adaption is not available.

Varietal Spread in Tamil Nadu

Tamil Nadu accounts for about 31% of the cassava area (65,700 ha) in India. Here, the crop is used as an industrial raw material, and nearly 85% of the cultivated area is planted to high-yielding varieties, mainly H-165 and H-226, followed by Sree Visakhm, Sree Prakash, Sree Jaya, Sree Harsha and CO-3. The largest number of cassava-based industrial units is concentrated in Salem district of Tamil Nadu, where cassava is largely (55%) cultivated under irrigation, resulting in the highest mean yield (46.3 t/ha in 1997) in the country.

Varietal Spread in Andhra Pradesh

Andhra Pradesh accounts for 7% of the cassava cultivated area (22,000 ha) in India. Cassava emerged as an industrial crop in the 1960s with the setting up of five sago factories; now, there are 63 factories. H-165 and H-226 are the major varieties. Also, local varieties and M4 are grown on a limited scale. The crop is mostly cultivated as a monocrop

and also as an intercrop in cashew, mango and coconut orchards during the juvenile stage of the latter crops. Schemes for modernization of cassava cultivation to ensure root availability for sago units have been launched jointly by CTCRI and a nationalized bank (State Bank of India). It is a unique venture covering both agriculture and manufacturing. With technical support from CTCRI, seven units have implemented the first stage of modernization by process improvements, resulting in a yield increase of 10%. In addition, new varieties are being tried out with a modified fertilizer package based on soil analyses. There is great demand for planting materials of the improved varieties.

Varietal Spread in Other States

In Karnataka, cassava cultivation is restricted to certain districts, and mostly local varieties are grown. Karnataka has congenial conditions for extensive cultivation of cassava, such as high annual rainfall, high temperature and humidity during the summer. Introduction of improved varieties, and adoption of required cultural practices can substantially increase production. However, processing industries have yet to be established in Karnataka.

In the other states, the area under cassava ranges from 200-4,000 hectares, and root production from 300-22,200 metric tonnes. The varietal coverage of those states is not exactly known, except in Assam where H-165 and Sree Prakash are prevailing. In the northeastern states, cassava is mostly used for human consumption, which means improved table varieties may have better acceptance.

Very recently, the states of Gujrat and Maharashtra have started producing cassava, and the crop is gaining importance there. The states also procure cassava starch from Salem (Tamil Nadu) for further processing and utilization.

NEW CHALLENGES

The Present Scenario

Both area and production of cassava in India have recorded steady increases up to the year 1975/76, after which they started to decline. Statistics show that 33.5% of the cassava area in the country has switched to other crops from 1975 up to the present. This is a reflection of the trend in the major cassava-producing state of Kerala, where 56.6% of the areas traditionally grown with cassava have been replaced by cash crops. Production has also declined by 52%. At the same time, Andhra Pradesh and Tamil Nadu have together recorded a tremendous increase in cultivated area by 45.7%, and production by 166.8% over the same period, with the highest yields recorded in Tamil Nadu, reaching an impressive figure of 46.3 t/ha in 1997. In short, the production slump in the country is due to a production decline in Kerala State. This decline is the result of a number of factors such as: 1) cassava in Kerala is not a cash crop; 2) higher income-generating plantation crops such as rubber, coconut, black pepper and coffee have been replacing cassava; 3) there is practically no industrial utilization of cassava to retain this crop as an income-earner in Kerala; 4) the crop is almost entirely used for table purpose, so palatability is very important; 5) the table varieties grown in Kerala are only average or moderate yielders; 6) considerable changes in dietary patterns and taste preferences have taken place due to the general improvement in the standard of living, and 7) the ready availability of cereals and other items has lessened the importance of cassava as a food.

Remedies for Boosting Cassava Production

The International Food Policy Research Institute (IFPRI) in 1999 has projected an increase in the global demand for cassava of 68% by the year 2020 (Scott *et al.*, 2000). Therefore, technologies to increase production have to be devised. Though the chances for expansion of the cassava area (as a sole crop) are very limited in Kerala, the possibility of incorporating cassava as a component in existing cropping systems is very high. The crop is traditionally cultivated under complex and diversified systems in homesteads and gardens, which are shaded by crops such as coconut, areca nut and fruit trees like jackfruit and mango. Replacement of traditional varieties by efficient, shade-tolerant, palatable varieties in coconut or areca nut-based cropping systems can enhance production without any area expansion in the uplands. The triploid hybrid Sree Harsha is palatable and shade-tolerant, and can be popularized for home-garden cultivation. The short-duration varieties need to be further tailored for still shorter crop duration to facilitate better utilization in low-lying areas after the paddy harvest. Since the existing short-duration varieties are cultivars which have resulted from only simple selection, it should be possible to genetically shorten crop duration further by secondary breeding using appropriate techniques.

The other states too have the potential of increasing cassava production further. In Tamil Nadu, since 80% of the produce is utilized by the starch and sago industries, high-yielding, high starch varieties like Sree Harsha and other short-duration varieties can further enhance production. In Andhra Pradesh, where yield are currently less than 10 t/ha, introduction of high-yielding, high starch varieties and scientific crop management practices can boost production substantially. Drought tolerant varieties in Tamil Nadu and Andhra Pradesh can boost up the production in non-irrigated areas. Karnataka, which has a favorable climate for cassava cultivation, should be encouraged to step up cultivation and to set up processing industries. In the northeastern states where cassava is used for human consumption, more palatable varieties should be introduced and popularized.

The Universal Problem

Yield in cassava has been steadily climbing as in the case of most crops, and it has as yet shown no signs of reaching a plateau. Hence, the major challenge and the imminent need of the day are for the development of varieties resistant to the CMD virus. Eradication of CMD alone can step up cassava production to a great extent. In CTCRI, comparison of CMD-infected and symptom-free plants of improved varieties has indicated a yield loss ranging from 10-20% due to the disease (Nair and Malathi, 1987). When meristem-derived, virus-free plants of the same varieties were compared to field-propagated, symptom-free plants (probably carrying latent infection), the former outyielded the latter by 12-24% (Nair, 1990). Obviously eradication of the virus from the plants can bring about an absolute increase in yield of 25-50%. In African countries, yield loss due to CMD has been reported to range from 44-88%. The magnitude of the devastating loss due to the disease is not often realized. Utmost priority should be given for the incorporation of genetic resistance in cassava against CMD.

Studies show that genetic erosion occurs in cassava for many characters and hence they have to be enriched continuously by introgressing genes from wild relatives (Nassar *et al.*, 2000). Many wild relatives of cassava exhibit a vast array of genetic variation which is yet to be exploited for crop improvement. Apart from *M. glaziovii* which was utilized in

the 1940s as a source of virus resistance, other useful species are *M. pseudoglaziovii*, *M. anomala*, *M. oligantha* and *M. nausana* from which valuable attributes like high productivity under semi-arid and arid conditions, shade tolerance, protein enrichment in roots, low cyanogen content, and high vigor could be incorporated into cassava by introgressive hybridization (Nassar, 1997; Nassar and Dorea, 1981).

Need for Biotechnology

Wherever vertical gene transfer or parent-offspring gene transfer by traditional methods is not possible, horizontal gene transfer or transfer of genes from one species to another, without passing through the sexual process, has to be made through biotechnological procedures. As one of the most frequent transgenic traits incorporated in crop plants is virus resistance, the know-how can be made use of in cassava as a top priority project. Biotechnology can augment conventional technologies to tackle serious limiting factors to productivity. Some other areas which require greater biotechnological attention are protein enrichment of roots, enhancement of root shelf life, and drought tolerance. The ability of cassava to thrive on marginal lands and poor soils has to be further improved by breeding varieties adapted to abiotic stresses. Only then can cassava cultivation be extended to vast, unused, tracts of land.

True Seeds

The use of true seed instead of stem cuttings will reduce production costs and also help eliminate pests and pathogens. True seed can also be employed to extend cultivation into non-traditional areas. The transfer of apomictic genes from wild species can produce uniform plants from seeds without any genetic segregation (Nassar *et al.*, 2000).

EPILOGUE

Genetic, technical, intellectual and financial resources are not evenly distributed around the globe. No single organization, nation or region has the complete supply of resources needed to breed the most productive varieties. There is a long history of international collaboration, germplasm exchange and interdependence in agriculture. What is needed today is a greater and more fruitful collaboration to make the most effective use of resources. Advances in agricultural technology could have its greatest impact as an effective instrument against poverty, hunger, malnutrition and environmental degradation. It is particularly pertinent to point out that some 700 million of the world's more than one billion poverty-stricken people are in Asia, and that about 500 million of them live in absolute poverty. Increasing cassava production in Asia and improvement of product quality can have a humble but beneficial effect on a hungry world.

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