



Review

Cassava in South America, Brazil's contribution and the lesson to be learned from India

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Genet. Mol. Res. 5 (4): 688-695 (2006)

Received July 24, 2006

Accepted August 14, 2006

Published November 17, 2006

ABSTRACT. South America is responsible for about half of the cassava world production. In the 1970's productivity of the crop on the continent was about 15 ton/ha, and dropped continuously until reaching 12 ton/ha in 2004. India's productivity of cassava increased from 10 ton/ha in the 1970's to 28 ton/ha in 2004. Brazil contributed significantly to improving cassava crops through the Instituto Agronômico de Campinas in the 1960's and 1970's. The Universidade de Brasília released high-protein content hybrids, apomictic clones and explored the potential of indigenous landraces.

Key words: Cassava, India, Plant breeding, Productivity

INTRODUCTION

Cassava is an important subsistence crop in South America (FAO, 2004). Because of its high calorie productivity (Coursey and Haynes, 1970), biological efficiency as an energy producer (Vries et al., 1967), year round availability, tolerance to extreme stress conditions, adaptations to a wide range of ecological conditions (Jones, 1970), and its ability to grow in suboptimal soil (Papadakis, 1966), cassava can play a major role in alleviating the continent's food supply problem.

In the early 1970's the U.S. president, upon being alerted to developing countries' food crisis, appointed a Science Advisory Committee Panel on the world's food supply to report on food research priorities. It recommended that the agricultural potential of vast areas of uncultivated land, particularly in South America and Africa, be thoroughly evaluated for sustained food production and placed emphasis on cassava as a selected crop which has the potential for satisfying the huge demand for food (Hendershott, 1972). Since that time, much attention has been paid to cassava as a priority crop in the newly created International Centers for Agricultural Research. The International Center for Tropical Agriculture, at Cali, Colombia, was given a mandate for improving cassava throughout the world and in South America in particular.

PRODUCTIVITY DURING THE LAST 20 YEARS

Productivity per hectare is the criterion for assessing crop improvement. In this context, on the basis of FAO data, and the statistical yearbooks of the same organization over the last 30 years, the following can be noted:

- During the 1960's, the total area cultivated in South America (about 2,480,000 hectares) produced 34,400,000 tons. The productivity per hectare was approximately 14.3 tons.
- Brazil's contribution was 88% of the total production of South America and one third of the worldwide production.
- Since the beginning of 1972, productivity per hectare began to decline continuously in South America, dropping from 14.3 to 11.8 ton/ha during the 1980's (Table 1).
- In Brazil, the major producer all over the world, the decline was also continuous during the 1970's and 1980's. It deteriorated from 14.6 ton/ha in the 1960's to 12.1 ton/ha in the 1980's.

CAUSES OF DETERIORATION IN CASSAVA PRODUCTIVITY

The deterioration in cassava productivity on the continent during the 1970's and the 1980's is due to the following facts. The principal producer of the continent, São Paulo State, contributed about 1/3 of the total production of the country with an average productivity of 21 ton/ha. This level of productivity was possible because of the dedicated, brilliant and conscientious work of the Instituto Agronômico de Campinas (IAC) and its cassava breeders (Table 2). Since the beginning of the 1970's, the farmers of São Paulo replaced cassava cultivation with other cash crops. The cassava area decreased in the country and the whole continent. In the meantime, cassava cultivars planted in other Brazilian states did not show the good perfor-

Table 1. Productivity of cassava in South America and Brazil during the last 20 years.

Year	Productivity in Brazil (ton/ha)	Productivity in South America (ton/ha)
1969-71	14.6	13.8
1979-78	11.7	11.5
1979-81	11.7	11.6
1983-85	11.5	11.4
1986-88	12.2	12.1
1989	12.5	12.5

Source: FAO Yearbook, 1989.

Table 2. Productivity of principal clones released by IAC in different counties of São Paulo State, without fertilizers.

Clone	Productivity (ton/h)	No. counties	Confidence range
1. Branca Santa Catarina	34.0	71	30.6-37.4
2. Cafelha	33.3	23	26.4-40.2
3. Itu	26.5	24	22.3-30.7
4. Tatu	32.8	12	24.6-41.0
5. IAC 5-123	37.2	20	30.6-43.8
6. IAC 5-165	33.0	28	27.9-38.1
7. IAC 5-156	34.5	16	26.4-42.6
8. IAC Iracem	37.9	18	43.7-51.7
9. IAC Mantiqueira	47.7	9	43.7-51.7

Source: Report of tuber and root section, IAC, 1976.

mance of IAC's cultivars in São Paulo State. Consequently, this contributed to reducing cassava productivity in Brazil and the whole continent.

THE SUCCESS OF INSTITUTO AGRONÔMICO DE CAMPINAS CULTIVARS

The highly productive, well-adapted IAC cultivars are simple products of the cassava breeding program in this institution. The IAC cassava program began by determining good progenitors from whose progeny new cultivars could be selected on the basis of productivity and resistance to diseases and insects. This was carried out through comprehensive tests of combining ability, which included clones collected from São Paulo and Minas Gerais States. In these states, wild species of *Manihot* normally grow very close to cultivated cassava clones and natural interspecific hybridization frequently occurs between them (IITA, 1983; Nassar, 1984). Progeny seedlings of these natural crosses grow simultaneously, and some of them are selected by farmers, reproduced vegetatively, giving rise to new clones. These clones grow in commercial plantations and are subject to auto-pollination due to the monoclonal system of

plantations (Nassar and O'Hair, 1985). Emerging homozygous plants have genes of wild species introgressed into their genomes. This cycle of hybridization is repeated in nature and inbred clones enriched by high adaptive genes of the wild species come to cultivations by farmers. These clones are the type of clones collected by IAC breeders and used in their combining ability trials. Among them were the most successful clones ever known in the history of cassava: Branca Santa Catarina, Mantiqueira, Engana Ladrão, and others.

In its evaluation, to release new cultivars, the IAC carried out performance trials of root yield under suboptimal conditions of soil and mineral nutrients to ensure the largest amplitude of cultivar adaptations. Through a number of counties, ranging from 9 to 70, these cultivars showed the highest productivity compared to those released by other institutions (Tables 2 and 3).

Table 3. Productivity of cassava clones released by the International Center for Tropical Agriculture (CIAT) in different counties of Colombia.

Clone	CIAT HG (ton/ha)	Meida Luna (ton/ha)	Carimagua (ton/ha)
CM 309-41	30.4	10.7	3.8
CM 342-55	37.6	25.9	5.7
CM 430-37	48.0	9.5	18.2
CM 308-197	36.9	16.0	1.5
CM 426-6	36.0	21.9	7.6
CM 440-5	29.2	9.1	4.1
CM 471.4	30.7	12.3	0.8
CM 451.1	31.2	14.0	3.5
CM 321-188	43.8	16.9	1.8

Source: CIAT Annual Report (Informe, 1980).

The combining ability approach followed by the IAC to produce superior progeny and perpetuate selected individuals by cloning showed more potential and effectiveness than the method of recurrent selection followed by other institutions. It seems that nonadditive genes and heterosis are predominant in cassava as modes of gene action.

PROSPECTS OF IMPROVEMENT IN THE NEAR FUTURE

The University of Brasília adopted three lines of research which has been carried out by this researcher since 1975.

Exploration of wild-genetic resources

Cassava originated in the Northern Amazon, South America (Nassar, 1978a). In various parts of the continent, wild relatives grow naturally and exhibit a vast array of genetic variations yet to be explored and utilized as a source of many genes (Nassar, 1978b; Nassar, 1986). In the meantime, many leading scientists emphasized the valuable sources of wild species in breeding crops (Monaco and Carvalho, 1971; Frey, 1976; Rick, 1978). However, very little work has been done to systematically improve cassava by introgressed genes from wild species up to the mid 1970s. Beginning at that time, wild species from the whole continent were

collected, evaluated and maintained in a living collection. Interspecific hybridizations were carried out systematically by Pereira et al. (1981). Interspecific hybrids were produced and used in the program at Brasília, while some of them were donated to IITA in 1979, 1980, 1981. These hybrids and their progenies were developed by Hahn et al. (1990), an IITA breeder, and gave rise to the most resistant cultivars to mosaic ever known in West Africa. The cultivars of the family MS raised from these hybrids cover now 4 million hectares in Nigeria and brought the country to be the first ranking producer all over the world (Nassar and Grattapaglia, 1986).

The following is a summary of breeding trials with these species:

- 1- *M. pseudoglaziovii* Pax & Hoffmann. Natural hybrids with cassava have deep fibrous roots, tolerant to drought. When the hybrid backcrossed to cassava it gave a progeny among which clones adapted to arid conditions were selected (Nassar, 1980).
- 2- *M. glaziovii* Muell. Arg. Its hybrids with cassava were produced by both this author and Hahn et al. (1990), IITA, and gave rise to the MS family of cultivars mentioned above. The introgression of resistance to mosaic genes from this species by Nichols in the 1940's gave the most impressive example of the utilization of wild species and saved the crop in East Africa from mosaic devastation (Nichols, 1947).
- 3- *M. anomala* Pohl. First backcrossed generation has been obtained by this author (Nassar, 2004) and selection is under way. Hybrids of this species with cassava show adaptation to shadow, and may be of potential use in consorciated plantations of cassava with other crops. They also show resistance to the mealybug, a very dangerous pest in West Africa.
- 4- *M. oligantha* Pax & Haffmann. Its hybrid with cassava showed high protein content; twice that of the common cultivars (Nassar, 1989). However, it was extremely susceptible to bacterial blight. The backcrossed generation of this hybrid with resistance to bacterial blight clone is being evaluated now and selection is under way.
- 5- *M. neusana* Nassar. Its hybrid with cassava is very vigorous and has tremendous leaf and vegetative growth that makes it a candidate for a forrage plant. The hybrid shows high frequency of meiotic restitution which may lead to production of triploid and trisomic hybrids in the second generation.

Production of polyploid hybrids by the manipulation of meiotic restitution

Tetraploid and triploid cultivars of vegetatively reproduced crops have been successfully used by plant breeders. Trials of chromosome doubling in cassava were made early in the 1960's by using colchicines. However, this attempt has not led to the development of tetraploid or triploid cultivars, probably due to instability of the chimera produced. Recently, this author (Nassar, 2004) has discovered that interspecific hybrids of cassava exhibit a meiotic irregularity accompanied by high frequency of meiotic restitution which leads to the production of $2n$ hybrid diploid gametes. The author manipulated this phenomenon to produce a productive triploid that was tolerant to drought conditions (Nassar, 1991). In addition to this triploid, the author proceeded to the production of a trisomic hybrid adapted to savanna conditions.

Interspecific hybrids of cassava with *M. glaziovii*, *M. pseudoglaziovii*, *M. anomala*, and *M. aesculifolia* were polyploidized artificially by colchicine treatment. Polyploid types of these interspecific hybrids had their fertility restored which enabled further backcrosses and manipulation towards the production of triploids.

Development of apomictic true breeding lines

Since cassava is vegetatively propagated by means of stem cuttings, it is considered to be a labor intensive crop. Vegetative cuttings are also often responsible for the spread of diseases and pests throughout the tropics. This author (Nassar, 1985) and O'Hair (1985) proposed the idea that the use of true seed in place of stem cuttings for cassava production would eliminate these problems and potentially reduce production costs. One limiting factor, though, is the lack of quick and uniform seed germination. Another difficulty is the genetic segregation and lack of true breeding lines. If apomictic easily germinated lines could be developed, this idea would be successful. Since 1993, this author (Nassar et al., 2000) has been involved in the use of mass selection to gradually modify the cassava population with respect to seed dormancy and has obtained an easily germinated seed population. During the last years, genes of apomixis were successfully introduced from the wild-species *M. glaziovii* and *M. neusana*. Various apomictic clones were developed by this author. Molecular markers were used to confirm the apomictic nature (Nassar et al., 2000; Nassar, 2001, 2002).

EXPLORING THE POTENTIALITY OF INDIGENOUS CASSAVA CLONES

Brazil is the origin of the crop where it has been domesticated by indigenous groups.

Genetic diversity of its landraces is immense and yet to be explored. In the latest years, this researcher collected these indigenous clones systematically and could select from them high B-carotene content that reached 8 mg/kg combined with excellent palatability (Nassar et al., 2005). It was also possible to select some clones that are rich in lycopene having 6-8 mg/kg (see photo).



A LESSON TO BE LEARNED FROM INDIA

The tripled productivity of cassava from 10 ton/ha in the 1970's to 28 ton/ha in India has attracted scientists from all over the world. Enquiries about this magic had been always raised. Some explanations were given by Nair (2006) which are summarized here. These are:

- 1- Breeding high yielding short duration (6 to 7 months duration) hybrids/varieties by the Central Tuber Crops Research Institute.
- 2- Establishment of a strong government extension program to help farmers adopt scientific management practices.
- 3- Formation of a cooperative marketing venture by the state government to assure prices for farmers.

The principal cause of this excellence is undoubtedly the leading work of CTCRI and its devoted breeders.

ACKNOWLEDGMENTS

Research partially supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). The above mentioned living collection of wild cassava has been established with the help of the International Development Research Center, IDRC, Ottawa.

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