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CASSAVA IN SOUTH AMERICA: A PLANT BREEDER'S VIEWPOINT

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ABSTRACT

South America is responsible for about half of total world production of cassava. Productivity per hectare of the crop has deteriorated constantly in the continent in the last 20 years. The causes of this deterioration and a proposal for a plant breeding approach are discussed.

Key words: Cassava, South America, productivity.

Cassava is the most important staple subsistence crop in South America [1]. Because of its high calorie productivity [2], biological efficiency as an energy producer [3], year round availability, tolerance to extreme stress conditions and adaptions to a wide range of ecological conditions [4], its ability to grow in suboptimal soil [5], cassava can play a major role in alleviating the continent's food supply problem.

In the early 1970s, the U. S. President, being alerted to the developing countries food crisis, appointed a Science Advisory Committee panel on world food supply to report on food research priorities. It recommended that the agricultural potential of vast areas of uncultivated lands, 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 [6]. Since that time, great attention has been paid to cassava as a priority crop in the newly created International Centers for Agricultural Research (IARs). The International Center for Tropical Agriculture (CIAT) at Cali, Colombia, was designated 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 its statistical Yearbooks over the last 30 years, the following can be noted:

1. During the 1960s, the total area cultivated in South America (about 2,480,000 ha) produced 34,400,000 tonnes. Productivity per hectare was approx. 14.3 tonnes.

2. Brazil contributed 88% of the total production of South America and one-third of the entire world production.

3. From the beginning of 1972, productivity per hectare began to decline constantly in South America, dropping from 14.3 t/h to 11.8 t/h during the 1980s (Table 1).

4. In Brazil, the major cassava producer in the world and principal producer in South America, the decline was also constant during the 70s and the 80s. It dropped from 14.6 t/ha in the 60s to 12.1 t/h in the 80s.

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

Year	Productivity in Brazil t/ha	Productivity in S. America, t/ha
1969–71	14.6	13.8
1976–78	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.

CAUSES OF CASSAVA PRODUCTIVITY DETERIORATION

The decline in cassava productivity in the continent during the 1970s and 1980s is due to fact that in Brazil, the principal producer of the continent, the state of Sao Paulo contributed about 1/3 of the total production with average yield of 21 t/h. This level of productivity was possible thanks to the dedicated, brilliant and conscious work of the Instituto Agronomico de Campinas (IAC) and its cassava breeders (Table 2). From the beginning of the 1970s, the farmers of São Paulo replaced cassava cultivation by other cash crops. The cassava area diminished in the state year after year to about half of the previously cultivated area. This reflected on the reduction of productivity in the country and in the whole continent.

THE SUCCESS OF IAC CULTIVARS

1. The highly productive, well adapted IAC cultivars are a product of the cassava breeding program in this institution. The starting point is the scheme drawn up for cassava improvement, which continued in subsequent years.

The IAC cassava program began with the identification of good progenitors from whose progeny new cultivars could be selected on the basis of productivity and diseases and insect resistance. This was carried out through comprehensive tests of combining ability including clones collected from the states of São Paulo and Minas Gerais. In these states, wild species of *Manihot* normally grow very close to cultivated cassava clones and natural interspecific hybridization between them occurs frequently [7, 8]. Progeny seedlings of these natural crosses grow simultaneously and some of them, selected by farmers, are reproduced vegetatively, giving rise to new clones. These clones are grown in commercial plantations and are subject to self-pollination due to the monoclonal system of cultivation [9]. The emerging homozygous plants will have genes of wild species introgressed into their genomes. This cycle of hybridization and selfing is repeated in nature and inbred clones enriched by high adaptive genes of the wild species come under cultivations. These clones are the type collected by IAC breeders and used in their combining ability trials. Among them came the most successful clones ever known in the history of cassava: Branca Santa Catariña, Mantiqueira, Engana Ladrão, and others.

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

3. The combining ability approach followed by IAC to produce superior progeny selections proved more rewarding and effective 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 FOR IMPROVEMENT IN THE NEAR FUTURE

1. *Exploration of wild genetic resources.* Cassava originated in the Northern Amazon, South America [10]. In various parts of the continent, wild relatives grow naturally and exhibit a vast array of genetic variation yet to be explored and utilized as a source of many genes [11–15]. In the meantime, many leading scientists emphasized the importance of wild species in plant breeding [16–20]. However, very little work has been done on systematic improvement of cassava through

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

Clone	No. of counties	Yield, t/ha mean	Yield, t/ha range
Branca Santa Catarina	71	34.0	30.6–37.4
Cafelha	23	33.3	26.4–40.2
Itù	24	26.5	22.3–30.7
Tatu	12	32.8	24.6–41.0
IAC 5-12-3	20	37.2	30.6–43.8
IAC 5-165	28	33.0	27.9–38.1
IAC 5-156	16	34.5	26.4–42.6
IAC Iracema	18	37.9	43.7–51.7
IAC Mantiqueira	9	47.7	43.7–51.7

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

introgression of genes from wild species, with the exception of the patient and persistent work of Hahn at IITA and the present author at Brasilia. In the other International centers concerned with cassava research, this vital aspect is neglected to an extremely prejudicial point. In spite of possessing all kind of wild cassava germplasm that are provided by the IBPGR (International Board of Plant Genetic Resources) and the IDRC (International Development Research Center) through this author, no attempt was ever made to reproduce dormant seed, create a living collection and, far less, to carry out any interspecific hybridization. Probably this is due to patient work needed to break interspecific barriers and to introgress foreign genes that are frequently associated with unfavourable characters.

Table 3. Productivity of cassava clones released by CIAT in different counties of Colombia

Clone	Tuber yield, t/ha		
	CIAT Hq	Meida Luna	Carimagua
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).

Recent studies show that the present cassava cultivars are not the typical allogamous material breeders believed in the past [9, 21]. They also show genetic poverty for many characters [22]. Consequently, they have to be enriched continuously by introgressed genes of wild relatives. The classical case of exploring *M. glaziovii* by Nichols [23] in the 1940s resulted in salvation of the crop in East Africa from extinction due to devastation by the African mosaic. Interspecific hybrids of *M. pseudoglaziovii* with cassava produced by this author has shown high productivity under semiarid conditions of Brazil [24]. In Brazil, which produces about 88% of cassava in the continent, vast areas of uncultivated savanna (cerrado) land have a great potential for cassava cultivation, if well utilized and planted with high yielding cultivars the way IAC has done in the state of S. Paulo. If introgressed genes of the vigorous wild *Manihot* species native to the cerrado are introduced to cassava cultivars, this would contribute significantly to cassava production in the whole continent. Wild species native to the cerrado (Central Brazil savanna) and those native to the catinga (Northeastern Brazil savanna) were evaluated in detail by us [25, 26]. Moreover, they were subjected to genetic manipulation at the International Institute of Tropical Agriculture (IITA) [8, 27–29]. The following is a summary of breeding trials with these species.

M. pseudoglaziovii Pax & Hoffmar. Natural hybrids with cassava have deep fibrous root tolerant to drought. The hybrid backcrossed to cassava gave a progeny, among which clones were selected adapted to arid conditions [24].

M. glaziovii Muell. Arg. Its hybrids with cassava were produced at IITA. Backcrosses are under way. Introgression of mosaic resistance genes from this species by Nichols in the 1940s was the most impressive example of the utilization of wild species which saved the crop in East Africa from mosaic devastation.

M. anomala Pohl. First backcrossed generation has been obtained [8]. Selection is underway. Hybrids of this species with cassava show adaptation to shade and may be useful in consorciated plantations of cassava with other crops.

M. oligantha Pax & Hoffmann. Its hybrid with cassava has high protein content, almost double the common cultivars [28]. However, it was extremely susceptible to bacteriose. Backcrossed generation of this hybrid with bacteriose resistant clone is being evaluated now and selection is underway.

M. neusana Nassar. Its hybrid with cassava is very vigorous and has profuse leaf and vegetative growth, thus a suitable candidates for a forage plant. The hybrid shows high frequency of meiotic restitution which may lead to production of triploid and trisomic in the second generation.

2. *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. Attempts on chromosome doubling in cassava were made early in the 1960s using colchicine. However, it did not produce tetraploid or triploid cultivars, probably due to instability of the chimeras produced. Recently it was discovered that interspecific hybrids of cassava exhibit meiotic irregularities accompanied by high frequency of meiotic restitution, leading to the production of diploid (2n) hybrid gametes. This phenomenon was used to produce a high yielding triploid which was also tolerant to drought [24]. Besides, a highly productive trisomic adapted to savanna conditions was also produced.

3. *Development of true breeding apomictic lines.* Since cassava is vegetatively propagated by stem cuttings, it is considered to be a labour intensive crop. Vegetative cuttings are also often responsible for the spread of diseases and pests throughout the tropics. We [9] proposed that the use of true seed in place of stem cuttings for cassava production would eliminate these problems and reduce production costs. One limiting factor, though, is lack of quick and uniform seed germination. Another difficulty lies in the genetic segregation and lack of true breeding lines. If easily germinated apomictic lines were developed, this idea would be realized successfully. Since 1983, we have employed mass selection to gradually modify the cassava population with respect to seed dormancy and obtained an easily germinated seed population. During the last 2 years, by controlled crosses and the use of marker genes, two facultative apomictic clones have been selected from this easily germinated seed population. There is strong evidence that genes for obligate apomixis exist in cassava populations. A detailed survey may isolate such clones.

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REFERENCES

1. FAO. 1989. Production Yearbook. Rome.

2. C. A. de Vries, J. D. Ferwerds and M. Flach. 1967. Choise of food crops in relation to actual and potential production in tropics. Neth. J. Agr. Sci., **15**: 241–246.

3. D. G. Coursey and P. H. Haynes. 1970. Root crops and their potential as food in the tropics. World Crops, **22**: 261–265.

4. W. O. Jones. 1959. Manioc in Africa. Stanford Univ. Press, Stanford: 315.

5. J. Papadakis. 1966. Crop ecology survey in West Africa (Liberia, Ivory coast, Ghana, Togo, Kahomy, Nigeria). FAQ, Rome.

6. C. H. Hendershott. 1972. Preface. *In*: A Literature Review and Research Recommendations on Cassava. Georgia Univ. Press, Athens.

7. Nagib M. A. Nassar. 1984. Natural hybrids between *Manihot reptans* Pax and *M. alutacea* Rogers & Appan. Can. J. Plant Sci., **64**: 423–425.

8. Nagib M. A. Nassar. 1989. Broadening the genetic base of cassava, *Manihot esculenta* Crantz, by interspecific hybridization. Can. J. Plant Sci., **69**: 1071–1073.

9. Nagib M. A. Nassar and S. O'Hair. 1985. Variation among cassava clones in relation to seed germination. Ind. J. Genet., **45**: 394–398.

10. Nagib M. A. Nassar. 1978. Conservation of the genetic resources of cassava, *Manihot esculenta* Crantz: Determination of wild species localities with emphasis on probable origin. Econ. Bot., **32**: 311–320.

11. Nagib M. A. Nassar. 1978. Hydrocyanic acid content in some wild *Manihot* (cassava) species. Can. J. Plant Sci., **58**: 577–578.

12. Nagib M. A. Nassar. 1978. Wild *Manihot* species of Central Brazil for cassava breeding. Can. J. Plant Sci., **58**: 257–261.

13. Nagib M. A. Nassar. 1979. Three Brazilian *Manihot* species with tolerance to stress conditions. Can. J. Plant Sci., **59**: 553–555.

14. Nagib M. A. Nassar. 1985. *Manihot neusana* Nassar: A new species native to Parana, Brazil. Can. J. Plant Sci., **65**: 1097–1100.

15. Nagib M. A. Nassar. 1986. Genetic variation of wild *Manihot* species native to Brazil and its potential for cassava improvement. Field Crops Res., **13**: 177–184.

16. L. C. Monaco and A. Carvalho. 1971. Transfer of rust resistance from *Coffea canifora* to *C. arabica*. Cien. Cult., **23**: 101–102.

17. K. J. Frey. 1976. Plant breeding in the seventies: useful genes from wild plant species. Egypt. J. Genet. Cytol., **5**: 460–482.

18. J. R. Harlan. 1976. Genetic resources in wild relatives of crops. Crop Sci., **16**: 329–332.

19. J. G. Hawkes. 1977. The importance of wild germplasm in plant breeding. **26**: 615–621.

20. C. M. Rick. 1978. Potential improvement of tomatoes by controlled introgression of genes from wild species. *In*: Broadening the Genetic Base of Crops (eds. A. C. Zeven and A. M. Harten). Pubs. Pudoc, Wegeningen.

21. A. S. Pereira, J. O. Lorenzi, D. A. Monteiro and A. A. Veiga. 1981. Estudo de uma progenia de autofecundacão de mandioca guaxupe. Bragantia, **40**: 217–219.

22. Nagib M. A. Nassar and D. Grattapaglia. 1986. Variabilidade de clones de mandioca em relacão á fertilidade e aspectos morfológicos. Turrialba, **36**: 555–559.

23. R. F. W. Nichols. 1947. Breeding cassava for virus resistance. East Afr. Agric. J., **12**: 184–194.

24. Nagib M. A. Nassar. 1992. Production of triploid cassava, *Manihot esculenta* Crantz. Field Crop Res., **30** : 173–182.

25. Nagib M. A. Nassar and C. P. Costa. 1977. Tuber formation and protein content in some wild cassava (mandioca) species native to Central Brasil. Experientia (Basel), **33**: 1034–1063.

26. Nagib M. A. Nassar. 1978. Microcenters of wild cassava (*Manihot* spp.) diversity in Central Brazil. Turrialba, **28**: 345–247.

27. Nagib M. A. Nassar. 1980. Attempts to hybridize wild *Manihot* species with cassava. Econ. Bot., **34**: 13–15.

28. Nagib M. A. Nassar and G. Dorea. 1982. Protein content of cassava cultivars and its hybrid with wild *Manihot* species. Turrialba, **32**: 429–432.

29. S. K. Hahn, K. V. Bai and R. Assiedu. 1990. Tetraploids, triploids, and 2n pollen from diploid interspecific crosses with cassava. Theor. Appl. Genet., **79**: 433–439.