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CASSAVA PRODUCTIVITY WORLDWIDE: AN OVERVIEW

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Abstract

Cassava (Mandioca) is the most subsistence crop in the world tropics particularly Northern East Brazil. Analizing FAO data of cassava productivity in the last thirty years in South America, Nigeria and India, it is noted a constant level of productivity existed in South America around 12.5 ton/hectar while it was 14 .6 during the whole l960s. In Nigeria , it was around 9 ton/hectare during the l980 increased to 11.5 in the 1990s. In India the yeald increased constantly from 14 t/há in the begining of the l970 to 24.5 t/h in the l990s. It is deduced that root production in cassava is highly affected by heteroses. Apomixis is an efficient mean to preserve heterotic vigour. Moreover, it functions as a filter against accumulation of bacteria and virus on stem cuttgings. Interspecific hybridization may provide new genes for which cassava is defficient.

Key words: Root productivity, polyploidy, heterosis, apomixis, interspecific hybridization

Cassava (Mandioca), *Manihot esculenta* Crantz ranks the fourth of the world staple crops, consumed by more than 800 million people (4). In some countries around the world such as Northern East Brasil, Ghana, Nigeria in Africa, some islands in Indonesia and the Pacific ocean more than 70% of calories consumed daily by the population comes from cassava. Among other crops, it is credited by high calories productitivity (31); biological efficiency as an energy producer (3),year round availability and adaptation to suboptimal soil (2). In the early 1970's 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 tat the agricultural potential for vast areas of uncultivated land , particularly in South America and Africa, be thouroughly 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. Since that time much 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 given a mandate for improving cassava throughout th world and in South America in particular.

Cassava Productivity during the last 30 years.

Cassava Productivity per hectar (rendment) is the criterion for assessing crop genetic improvement. Therefore we selected three areas around the world which contribute significantly to the whole world production and studied its productivity during the last 30 years. These are South America , Nigeria and India. The FAO production yearbook in l998 was the source of our informations. On the basis of FAO data of l998, and years before , the following can be noted:

1.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. Brasil's contribution was 88% of the total production of South America and one third of the worldwide production.

2. Brazil's contribution was 88% of the total production of south America and one third of the world wide production.

3. Since the beginning of 1972, productivity per hectare began to decline constantly in South America, dropping form 14.3 t/ha to 11.8 t/ha during the 80's (table 1).

4. In Brazil, the major producer all over the world, the decline was also constant during the 70's and the 80's. It dropped from 14.6 t/ha in the 60's to 12.1 t/ha in the 80's.

In Nigeria, productivity per hectar in the beginning of 70s was l0.5, increased to ll.5 in the 80s, dropped to l0.5 by the end of 80s and recuperated in the beginning of 90s, reaching ll.5 ton/hectar once again by the end of 90s

In India, productivity per hectar in the beginning of 70s was 9.0 increased in the 1980s to 17.7 t per hectar, and continued increasing by fantastic rhythm in the 90s to about 24.5 ton.per hectar (Table 1., Figs.1, 2, 3, 4, 5).

Table 1. Evolution of cassava rendment in the last 30 years in South America, Nigeria and India (ton/hectar).

	South America	Nigeria	India
1960s	14.6	9.3	9.0
1970s	11.7	10.1	16.4
1980s	12.4	10.8	19.2
1990s	12.3	11.3	24.5

Source: FAO Production Yearbook, 1998.

Figure 1

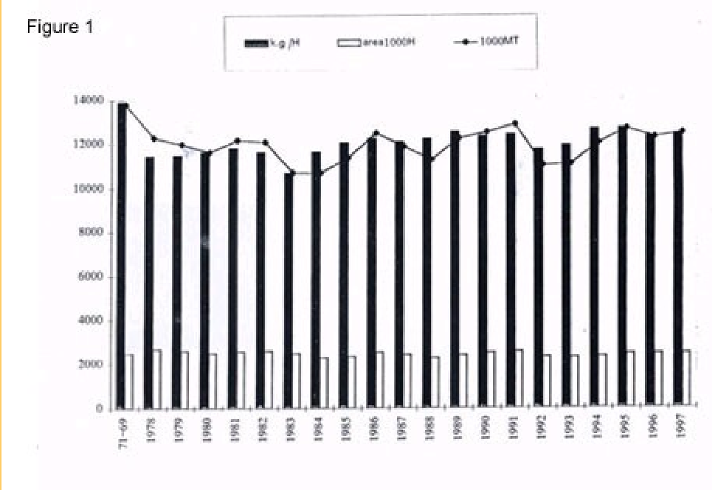


Figure 2

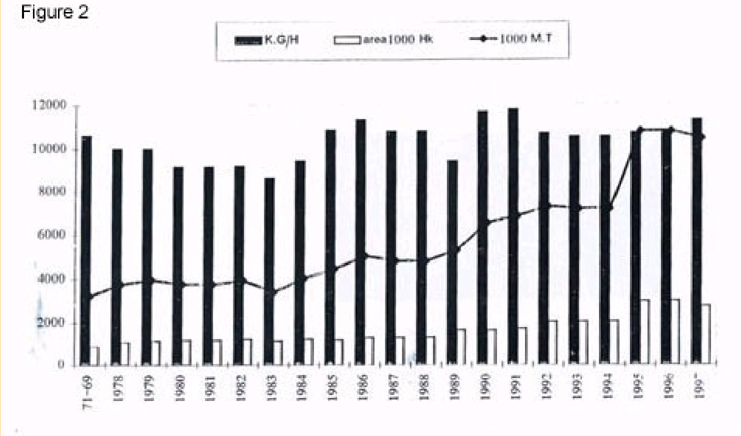
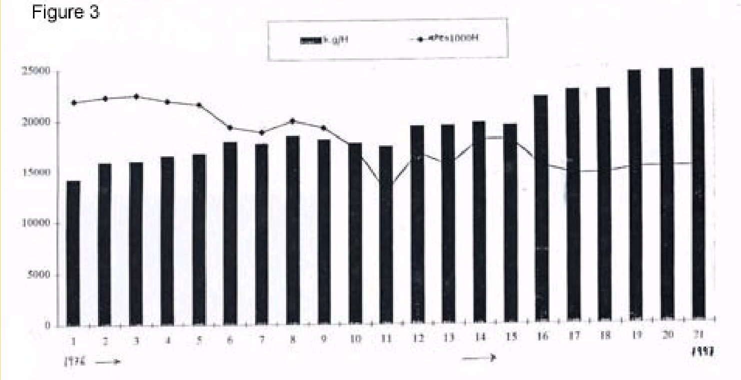


Figure 3



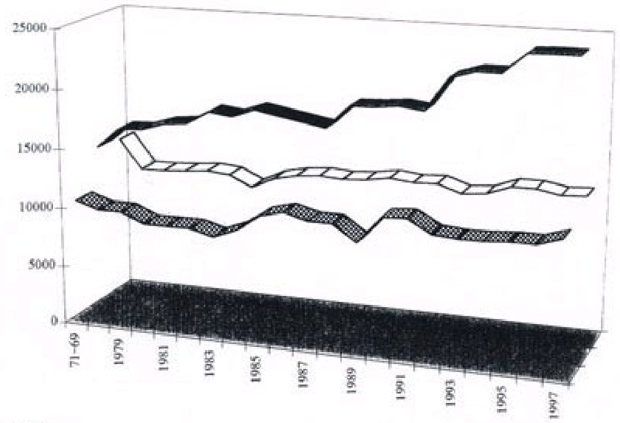


Figure 4

The Causes of Cassava productivity changes in different Areas

The drop of cassava productivity in South America continent during the 1970's and the 1980's is due to the following facts. The principal producer of the continent, the Sao Paulo state in Brazil contributed with about 1/3 to the total production of the country with a productivity average of 21 t/ha. This level of productivity was possible due to approach followed by the Instituto Agronômico de Campinas (IAC) (Table 2). Since the beginning of the 1970's the farmers of Sao Paulo replaced cassava cultivation by other crops due to the government policy of subsidies, consequently cassava has not been able to compete (1,20)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 performance of IAC's cultivars in Sao Paulo state. Consequently, this contributed to reducing cassava productivity in Brazil and the whole continent.

The higtly 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 including clones collected from the Sao 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 (8,13,15,20). 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 subjected to autopolliinization due to the monoclonal system of plantations (17). Emerging homozygous plants will 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 Ladrao 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 countries, ranging from 9 to 70, these cultivars showed the highest productivity compared to those released by other institutions(Table 2, 3). 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. It seems that nonaddictive genes and heterosis are predominant in cassava as modes of gene action.

Table 2. Productivity of principal clones released by IAC in different Counties of São Paulo state, without fertilizars.

Clone	Productivity	N.º Counties	Confidence range
1. Branca S. Caterina	34.4	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. Iracema	37.9	18	43.7 - 51.7
9. Mantiqueira	47.7	9	43.7 - 51.7

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

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

Clone	CIAT HQ t/h	Media Luna t/h	Garimagua t/h
CM 309-41	30.4	10.7	3.8
CM 342-55	37.6	25.9	5.7
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 drop of cassava productivity in Nigeria in the 80s is due to the invasion of mealy bug introduced in the country accidently in the 70s, It was controlled by an effective biological program by the end of 80s. The recuperation in the 90s is an evident of clones superiority released by IITA (International Institute of Tropical Agriculture). What is extremely impressive is the vertical rythm of productivity increase in India in the 80s and 90s thanks to the leading work of the Central Root and Tuber Center (CTCRI) at Kerala. Both of IAC (Instituto Agronomic de Campinas, Brazil) and CTCRI (Central Tuber Crops Research Institute,India) followed methods based on heterotic effect to increase cassava root production. The best Indian Cultivars H-96, H-165, H-226, Sree Visakham and Sree Sohya came from hybrid origin where a top cross test was applied (2,29). Thus it seems that the use of hybrid vigour and exploiting heteroses is the best method for breeding this crop.

Transferring seed abroad for the use by other countries may lead to breackdown of this heteroses in future generations. If apomixis gene was introduced to cassava cultivars, it may save superior genotypes from segregation. Apomixis exists in wild species and may be transferred to the cultivate by means of interspecific hybridization (21,13,21). Other useful genes can be trasferred also such as high protein content(24), tolerance to drought and so many others(22,23). Production of polyploid types may be a promising option for increasing cassava productivity in suboptimal conditions. One of the best productive Indian Cultivars, Sree hansha is a triploid type. In Brazil, the most tolerant to drought cassava clones is a natural triploid called Manebeba Branca. Considering these facts, a cassava improvement plan may be be defined as follows:

I. **Exploration of wild genetic resources**: cassava originated in the Northern Amazon, south America (8). 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 (8,10,11,12). In the meantime, many leading scientists emphasized the valuable sources of wild species in breeding crops (5,6,7). Through the program of the First author at the Universidade de Brasilia. This author systematically collected, evaluated and manipulated these wild species, incorporating their useful genes for improving the crop (12,13,15,16) such as tolerant to drought clones(28, 29), high protein content combined by low HCN hybrids(18). Recent studies shows that cassava cultivars are not the typical allogamous material breeders believed in the past. They also show genetic poverty through so many characters , consequently they have to be enriched continuously by introgressed genes of wild relatives. The classical case of exploring *M. glaziovii* by Nichols (27) in the 1940's resulted in salvation of the crop in East Africa from extinction due to devastation of the African mosaic. Interspecific hybrids of cassava with wild species showed high productivity under semiarid conditions in Brazil (19). In Brazil, responsible for about 88% of the cassava production in the continent, vast areas of uncultivated savanna (cerrado) has the greatest potentiality for production of cassava if well utilized, planted by highly productive cultivars like the model IAC has done in the Sao Paulo State. If introgressed genes of vigorous wild Manihot species, native of the cerrado, were introduced to cassava cultivars, this would contribute significantly to increase the production in the whole continent. Wild species, native of the cerrado (Central Brazil savanna) and those native of the caatinga (Northeastern Brazil savanna) were well evaluated by the first author and have their useful genes incorporated to the cultivate(15). The following is a summary of breeding trials made by him:

M. pseudoglaziovii Pax & Hoffmann. Natural hybrids whith cassava has 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 .

M glaziovii Muell. Arg. Its hybrids and backcrossed generations with cassava were produced by the first author(22) The introgression of resistance to mosaic genes from this species by Nichols in the 1940's(27) gave the most impressive example of the utilization of wild species and saved the crop in East Africa from mosaic devastation.

M. anomala Pohl. Hybrids and backcrossed generations have been obtained by the first author. Hybrids of this species with cassava show adaptation to shadow, and may be a potential for use in consorsiated plantations of cassava with other crops. They also show resistance to the mealybug, a very dangerous pest in West Africa.

M. oligantha Pax & Hoffmann. Its hybrid with cassava showed high protein content; twice that of the common cultivars (24). The evaluation of the hybrid for protein content during about l5 years showed constant high protein content combined by low HCN. This hybrid is being propagated now to be distributed to farmers by the Brazilian corporation for Agricultural Research.

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 le d to production of triploid and trisomic hybrids in Ithe second generation(16,23). It is also a sources of apomixis genes (21,23,26).

2. **Production of polyploid hybrids** 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 colchicine. However , this attempt has not led to the development of tetraploid or triploid cultivars, probably due to instability of the chimera produced. Interspecific hybrids of cassava with the wild exhibit a meiotic irregularity accompanied by high frequency of meiotic restitution which leads to the production of 2n hybrid diploid gametes(25). The First author manipulated this phenomenon to produce a productive triploid that was tolerant to drought conditions (19). In addition to this triploid, the first author proceeded to the production of a trisomic hybrid which show high productivity combined to adaptation to savanna conditions (23). Polyploidy serves also for restauration of fertility in the interspecific hybrids. If interspecific hybrids were polyploidzed ,they would restore fertility and be able to cross with dipoid cultivate producing triploids that are vigorous due to both heteroses and ploidy level. Polyploidy have been achieved in several and different interspecific hybrids by this author, trials of their crosses with cassava are under way.

3. **Development of apomictic true 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. Nassar and O'Hair (17) proposed the idea that 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 have been successful. Since 1983, the first author is involved in the use of mass selection to gradually modify the cassava population with respect to seed dormancy and has obtained easily germinated seed population. During the last years, by the use of molecular, cytogenetic and embryonic techniques, facultative apomicticic clones have been selected and developed by him among this easily germinated seed population. Molecular, and embrionic study has confirmed the transference of apomictic gene from both *M. neusana M.dichotoma* to cassava (21,26). Seeds of these facultative clones have been provided to both of CIAT, IITA, and CTCRI. Another advantage of apomictic clones ,rather than preservation of genetic superiority, is that it function as a filter for virus and bacterial germs which accumulate year after year on cassava vegetative growth through the use of contaminated cuttings. By the use of apomictic clones we avoid extinction of superior clones like what happened with the most excellent Brazilian Títu ever known in the history of the crop; Vassourinialo Guaxupe and many others.

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