Article

Cassava: Some Ecological and Physiological Aspects Related to plant Breeding.

Nagib M. A. Nassar

Departamento de Genética, Universidade de Brasília, Brasília, Brazil

Abstract

Cassava is the principal food for poor people in the tropics. India leads the world by productivity of 26 t/h. It reproduces by cuttings which accumulates pathogens. Apomixis represents an alternation to avoid this contamination. Apomixis genes were discovered in the wild and transferred successfully to the cultivate. Wild cassava relatives have proved sources for many useful characters, such as tolerance to bacteria blight and mosaic. More than 2million hectars in Nigeria are now planted by cultivars stem from cassava hybrids with Manihot glaziovii. This species is potential too for breeding cultivars tolerant to mealy bug, and offers the safest way to control this pest Cassava diversity in unmanaged ecosystems is affected highly by both environment and human pressures.

Key words

wild relatives, climatic requirements, apomixis, reproduction, unmanaged ecosystems, mealy bug

Introduction

Cassava, *Manihot esculenta* Crantz is cultivated throughout the lowland tropics. Typically the crop is grown between 30 North and 30 South of the equator, in areas where the annual mean tempertafture is greater than 18 C. It possesses many attributes such as efficient carbohydraste producion(77, 6)), tolerance of low soil fertility, recovery from damage caused by pests and diseases, insurance against famine via underground conservation for long periods, and its adaptation to mixed cropping systems. It is the sixth major staple crop in the world after rice, wheat, maize, potato , and sweet potato with annual production of 185 million tones (9). Nigeria and Brazil accounts for about one third of the whole world production (table 1). The continent of Africa is responsible for more than half of the world production.

Table 1. Cassava production, area harvested and yield and in Africa, and selected major producer countries (Source, FAO Yearbook,2002)

Country	Area Harvested (ha)	Production (millions)	Yield (kg/ha)
Africa	11,204,924	100,689,149	8,986
Angola	575,000	5,400,000	9,391
Brazil	1,687,275	23,108,076	13,695
Colombia	208,377	2,214,990	10,629
Congo, Dem.Rep.	1,839,962	14,929,410	8,114
Ghana	794,440	9,731,040	12,248
Índia	270,000	6,900,000	25,555
Indonésia	1,290,000	16,723,257	13,963
Nigéria	3,455,000	34,476,000	9,978
Tanzania	660,000	6,888,000	10,422
Thailand	1,030,000	16,870,000	16,378

Consumption and Uses The root is principally used as a human food, either fresh (boiled, backed, fried or in numereous processed forms (17). It is estimated that in 2002, more than 700 million people consumed cassava in one form or another (9). It is used for animal feed too, and as a raw material for producing starch, starch-based products and starch derivatives. Cassava starch is an important raw material in food processing, paper, textile and adhesive manufacturing and in oil drilling industry. It is also a raw material for producing many derived sugar products, such as glucose, maltodextrines and mannitol (1).

In Africa, cassava is used principally for humam consumption, . While the main value comes from its starchy roots, its leaves are eaten frequently in Africa. It contains 25- 36% on a dry matter weight.

In west and east Africa, Gari is the most popular form for consumption. To produce Gari, tubers are peeled, grated, pressed, sieved, toasted and separated into various particle sizes. In this kind of food as well as in other types, techniques and methods applied are designed to eliminate the poisonous cyanogenic glycoside from tubers

An Outlook for Cassava breeding: During so many decades in the last century clonal selection was the predominant method for cassava improvement at national centers of Africa and Brazil. The only exception was the pioneering work of Storey and Nichols (1938) in Amani, Tanzania (Formerly Tanganyika) where they hybridized M. glaziovii with cassava to produce clones resistant to Cassava Mosaic Disease (CMD). Their work saved the whole East Africa from this disease that arrived there in the 1920's. Their hybrid clones were not only resistant to mosaic but also productive and tolerant to drought (75,76). They are still maintained at Amani and have been used by breeders of the Intrnational Instiute of Tropical Agriculture IITA as a source for resistance to CMD first in West Afrca and later on throught the continent.

In Brazil, In the Decade 1950s, Normanha Santana and Araken Soares at the Instituto Agronomico de Campinas (IAC) began their program by identifying parental sources of new cultivars which were selected due to their productivity and resistance to diseases and insects. They carried out comprehensive tests of combining ability among clones collected from Sao Paulo and Minas Gerais states. In these states, wild species of Manihot normally grow in close proximity to cultivated cassava clones and natural interspecific hybridization frequently occurs between them (33, 36) Progeny seedlings of these natural crosses grow simultaneously and some of them are selected by farmers and reproduced vegetatively giving rise to new clones. These clones grow in commercial plantations and are subjected to selfing and ensurng offspring to inbreeding due to the monoclonal system of plantations (34, 35). Emerging homozygous plants will have genes of wild species introgressed to these plants genomes. This cycle of hybridization is repeated in nature and inbred clones enriched by high adaptive genes of wild species brought to cultivation 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 Cateria, Engana Ladrao and others.

In the process of releasing new cultivars, Normanha and Araken carried out performance trials of root yield under subopitimal conditions of soil and mineral nutritions to broaden the scope of cultivar adaptation. This combining ability approach to produce superior progeny was highly effective and brought the state of Sao Paulo to the highest level of productivity in the world in the decade 1960, reaching 23 ton/h. In the decade 1970s and the years after breeder of the Centro Internacional de Agricultura Tropical (CIAT) followed method of recurrent selection but this method showed a very little success; i.e. productivity of cassava in Colombia continued to be at level of 1975, with yield of 10 ton/h. This author began a program supported by the Canada International Development Research Center (IDRC) aiming to utilize wild cassava for improvement of cultivated cassava improvement. Wild species for he geetic enhancement of cassava cltigens. Wild Manihot species were collected from south America and Mexico, evaluated throroughly and hybridized with cultigens to incorporate their useful genes . Cultivars with high protein content , apomixis, tolerance to drought, resistance to bacterial blight high yield were bred (Nassar,28, 29,37, 39, 41, 44, 49).

In the decade 1990s, IITA scientists successfully bred cassava *cultivars* with a durable resistance to diseases of Bacteria blight and cassava mosaic (CMD)(14). For this achievement they used hybrids of cassava wh wild relatives, some of which were supplied by this author. IITA deployment of this material in Uganda was a great success. IITA produced millions of cassava plantlets and cuttings and delivered them into the hands of Nigerian farmers. The improved plants not only resisted diseases but slowed its spread in non resistant cultivars. It is stimated that more than 2 millions hectars are planted now in Nigeria by these cultivars resistant to Bacteria Blight and CMD (8).

The Indian Scientists of the Central Institute of Root Crops Research (CTCRI) , brought cassava in India to the highest productivity all over the world i.e. 26 t/h. In their work they followed trials of combining ability(Anonymous, 1989, Rajendran et al. 2000). It is impressive that productivity of cassava in India increased from 10 t/h in the 1960s to 26 t/h in 2000 while South America dropped constantly from 14.5 th to 12 .5 t/h in the same period (9 38, 61).

General Description

Morphology: Cassava is a shrub, 1-3 m heigh with tuberous adventitious roots arising from stem cutting. Roots have various forms and shapes from long to slender to globose. The plant stem is woody and glabrous, but in some cases slightly pubescent, branched and predominantly brown, sometimes yellow or silver. Leaves are alternates, simples, stipuled and palmately lobed.The inflorescence is a panicle having bracts and bracteoles that are normally inconspicuous and caducous. Flowers are monoecious with pistillate ones few in number, positioned at the base. They open first (protogyneous). The staminate flowers are apical and numerous. Perianth is composed of 5 tepals. The ovary has a nonelobed disc, 3 carpellate. Staminate flowers have 10 stamens in two whorls. Pollen is large, and in many cultivars, sticky. Fruit is shizocarp, 3 lobes and usually winged. Seed is caranculate, elongate and frequently mottled brown. Cassava roots are composed of peel which is about 10-20% of the tuberous root. The cork layer represents 0.5 to 2.0% of the total tube weight. The edible fleshy portion makes up 80 or 90% of the tuber. It is composed of 60 to 65% water ,30 to 35% carbohydrate, 1 to 2% protein, 0.2 to 0.% fat, 1 to 2% fibre, and 1 to1.5% mineral matter of the tuber flesh (35, 48).The protein of cassava tuber is rich in argenin but is low in methionine and lysine. It seems that there is a relatively large amount of non- protein nitrogen in the tuber so that protein content estimated from nitrogen analysis tend to be higher than those estimated from amino acids, some of this non protein nitrogen originated from glycosides. Hence, caution must be taken when selecting high protein content cultivars. It is possible that high protein cultivars are no more than high glycoside content cultivars(49).

Growth Cassava is a perennial plant. It is reproduced via by stem cuttings in production , but in plant breeding it is propgated in the first cycle from sexual seed.. Stems when planted produce sprouts and adventitious roots within a week. Seed when used for propagation is slow germinating, and normally suffers from dormancy. Scarifying the seed and filing the micropylar end does not break dormancy. The best treatment is thermical. i.e. temperature of 18 C for 16 hrs and 26 for 8 hours to achieve seed germination (Nassar and Pio 1983). Seedlings ensuing from sexual seed is normally weaker than those arise of cuttings. This is logical due to genetic heteroszygosity structure of cuttings, while the sexual seed are homozygous for recessive and prejudicial genes.

For about a month and a half approximately after sprouting, the plant shoot expands and its depth increases. Vegetative growth and leaf area approaches a maximum within five months (78). Flowering of the plant depends on the variety and on the environmental conditions, but once initiated , it continues periodically for the rest of the plant life. Root enlarges , with deposits of starch by he eighth week after planting. Thickening commences at the proximal part of the root and progresses towards the distal part. The thickening of roots stops after 7 to 9 months in most of cultivrs (3).

Cassava is usually harvested after one year, butt it also be harvested after two years. However ,because of its perennial nature it continues to grow for several years if left in the ground. Drought impedes its growrh In such environment, cassava ceases to grow, and shed its leaves, root growth also also stop. When the next rainy season comes, the plant resume growth.

Reproduction

The plant is typically allogamous due to its monoecious flowering structure and protogynous pattern. Female and male flowers are born in the same panicle. In each inflorescence , the female flowers open first, while the male flowers open two weeks later, making the plant protogynous in addition to its moneceious structure. This disposition leads to allogamy of the plant; i.e. obligate outcrossing , consequently high heterozygous . Sporadically certain environment that male and female flowers of different plants open in the same time, and since the plantation is constituted by only one clone, self pollination occurs. Seed obtained from such pollination is considered partially inbred would produce plant with reduced heterozygosity. Some such seed drop and germinate in the next season. If a plant was selected by farmers and grown vegetatatively , it will lead to establishing a clone with modified structure , having some degree of homozygosity . If this process is repeated for several generations it would have changed the genetic nature of the crop, shifting it from a highly heterozygous to homozygous plant (52). This belief is supported by Pereira et al (69) worked with non-segregating progeny from Brazilian clones Guaxupe and Mantequeira.

Pollination is by insects (entomophilus). A survey (58) found Various Hymenoptera and Coleoptera were detected, but the principal pollinator in about 70% of floweres was honey bees (Apes mellifera). Other species of coleoptera such as Trigone sinipes were collected. Outcrossing , therefore is predominant and reaches 100% as seen from using morphological gene markers in the progeny. A percentage of inbreeding, however does exist (69). Pollen varies in fertility from almost sterile to 95% fertile (22). Female flowers open by 11-12 *am* (22) Receptivity of the stigma was found to be 6 hours before flower opening. Pollen viability is reduced to about 50% day after opening, and lose its viability after 2 days.

Apomixis (Seed formation without fertilization)has been reported in cassava by Nassar (39, 59, 43, 44). Moreover, Nassar and coworkers transferred the gene from the wild to the cultivated species (43). In cassava, it is an alternative to reproduction by cuttings which normally practiced by farmers. The latter type of propagation leads to accumulation of viral and bacterial diseases that reduce productivity and may cause extinction of superior genotypes. Thus, by the use of apomictic plants in propagation, systematic pathogens could be avoided, and the genetic segregation for good characters in the progeny is excluded. An additional and important advantage of the induction of apomixes in the cultivated cassava is that it will assure preservation of superior clones rather than their extinction. Plant-produced stems through apomixis from a contaminated clone will be free from viral and bacterial pathogens and can begin a new cycle of clone life. Had apomixis been found or introduced into the excellent Brazilian clones like Guaxupe and Vassourinha, they would not have become extinct, and could have been preserved for a long time. The use of apomixis in preserving superior genotypes and filtering the bacterial contamination benefits also international cassava programs that export their germplasm routinly. It is sufficient, for the destination country to produce only one plant and further reproducion can be done vegetatively to maintain the original superior genotype.

Classification

Cassava is a single species , Manihot esculenta Crantz synonymous with *Manihot utilissima* Pohl. It belongs to the family Euphorbiaceae. It has a sporophytic chromosome number 2n= 36. Some aneuploids were reported for certain cultivars (22, 57) but this is not common. Polyploids are rare though for some auhors (19) cassava could be an allotetraploid.

Cassava cultivars have been classified according to morphology (e.g. leaf shape and size, plant height, stem color, petiole length and color, inflorescence and flower color, tuber shape and color, earliness, and content of cyanogenic glycoside in the roots.

Cyanogenic glycoside has been used to place cassava cultivars into two major groups: the bitter cultivars ,in which the cyanogenic glycoside is distributed throughout the tuber and is at a high level, more than 100 mgm/kg; and the sweet varieties, in which the glycoside is confined mainly to the peel and is at a lower level. The flesh of sweet varieties is therefore relatively free of glycoside, although it always contains some (5). In general, sweet cassavas tend to have a short growing season; their tubers mature in 6-9 months, and deteriorate rapidly if not harvested soon after maturity. The bitter cassava cultivars, on the other hand require 12-18 months to mature, and will not deteriorate greatly if left unharvested for several months after maturity (4).

Relatives

Relatives of cassava are perennial and vary in growth pattern from nearly acaulescent subshrubs to small trees. Decumbent subshrubs, semiherbaceous subshrubs, shrubs, and small trees are found in the genus(71). The branching pattern is typically dichotomous or trichotomous, having at the point of branching a terminal inflorescence. Bark of the woody species is generally smooth. Many of the species are lacticiferous, and some species particularly M. glaziovii (Ceara rubber) are still cultivated in some countries(Brazil and Nigeria) for rubber producion(72,73) This species was used by Storey and Nichols in the 1930s in Tanzania (Formerly Tanganyka) to transfer resistance to mosaic disease. Populations of this species now grow near IITA HQ at Lagos, Nigeria**.** Many species such as group tripartita have their stems adapted to marked dry periods; die back to a root crown regularly and shed their leaves during the dry season. species are found on limestone derived and well drained soils. All of the species are damaged by frost with exception of very few such as M. grahamii and M.neusana whose native distribution in regions with occasional frost. All species are monoecious, some few are dioecious which make them obligate cross pollinated. In many species, they are protogeneous , i.e. having pistillate flowers open before staminate flowers of the same inflorescence. Pollination is by insects to whose bodies the sticky pollen adheres . This cross pollination phenomen leads to formation of extremely heterozygous gene pools. Being polyploid species, partially apomictic, and having week barriers in addition to the allogamous nature, this led to the rapid speciation of this group and formation of the large number of species (42, 43, 44, 45).

All species of the genus Manihot are native to Souh America(particularly Brazil). The only species found in other tropical regions of the world are those that have been introduced since Columbus voyages to days American continent. The species of *Manihot* are all rather sporadic in their distribution and rarely become dominant of the local vegetation. Majority of these species are found in relatively dry regions, and only a few are found in rain forest regions. Their typical habit are openings in the forest as the case of *M. anomala*. So they are typically heliophiles grow only in the absence of shading.. Many of them such as *M. pohlii*, *M.zehntneri* and *M.grahamii* are weedy types capable of invading new agitated areas.. Many Manihot species are found on limestone derived and well drained soils. All of the species are damaged by frost with exception of very few such as *M. grahamii* and *M.neusana* whose native distribution in regions with occasional frost.

Wild *Manihot* species have been used by this author as a source of useful characters, the most notable achievement was the production of high protein content which reached 4% of peeed roots, i.e., double of protein content in common cassava, combined by low HCN content of 90 mgm per kg. (49). The wild parent was *M. oligantha(*Nassar, 1978b, 1978c*).* Recently, the same author has transferred successfully genes of apomixis from the wild species *M.neusana* Nassar (Nassar et al.200, and Nassar 2000). Probably the most important of the utilzation of wild cassavas is the discovery of a durabe resistance to mealy bug in *M. glaziovii* and the transference of its genes to common cassava through traditional interspecific hybridization(41,47). This interspecific hybrid could be polyploidized and having its fertility restored (47). This material may play an important role in alleviating all Africa from the danger of mealy bug sould the system of biological control for combating this pest may broke down due to its artificial structure. Signs of mealy bug virulescent attack in the last years in certain areas in Zaire was reported. Apparently introducing a durable genetic resitance may be the most effective and economic solution.

Climatic requirements: Cassava is a lowland tropics plant . It needs a warm, moist climate where mean temperature ranges from 25 to 29ºC. It poorly grows under cold climates . At temperature below 10ºC its growth stops.

The plant grows best when rainfall is 100 to 150 cm, but it can stand rainfall as low as 50cm per year. When moisture availability is low, the cassava plant ceases growth and shed some of its older leaves to reduce transpiration. When moisture becomes available , the plant resumes growth and produces new leaves. The ideal soil for cassava is a light , sandy loam soil of medium fertility. Drainage is important. On clay or poorly drained soil, growth is generally poor. Cassava can grow and yield well on soils of low fertility where production of most other crops would be uneconomical. On highly fertile soil, cassava produces excessive vegetation at the expense of root formation.

Cassava tuber root formation is controlled by photoperiod. Under short day conditions tubering occurs readily , but when the day length 12h, growth is delayed ,and yield reduces (4). Above 1000 m height, cassava grows slowly and yields poorly.

Ecology of cassava in unmanaged and managed ecosystems

In unmanaged ecosystems **c**assava genetic diversity and how it been originated should be important subject in any ecological esearch. It depends on farming practices as well as cultural aspects of farmers themselves. For example ,how long it takes a farmer to plant a new cassava form, and how many stems the household has in stock. Some farmers plant cassava every day for a week, and then stop for two or three months. As a result, several months can separate the youngest and the oldest plants in a single system.

Although human and natural selection works independently within a certain ecological system they may act as similar agents on cassava genetic diversity ; For example human selection for productivity may reinforce natural selection (74). In certain environmental conditions, cassava diversity may be affected. For example flood may cause disease or lost a certain variety. A variety may accidentally lost, simply for lack to suitable space.

Since cassava is propagated by stem cuttings and this material is widely exchanged by farmers of different villages, a variety accidentally lost in a farm can be recovered easily and the risk of loosing varieties diminishes (74). In general cassava genetic diversity in unmanaged systems is shaped by both environmental and human pressures.

Cassava genetic diversity does exist due to two reasons : first occurrence of occasional sexual propagation, and second infusion between types of cassava that have similar phenotypes, but are of different genetic constitution. On the other hand genetic diversity at intervarietal level may diminish because of genetic drift, for example, cassava plant produces limited number of cuttings. Certain plants (genotype) may be eliminated as their cuttings not being replanted for one reason or another.

In managed farming ecosystem, the modes of production of cassava receives more attention than its genetic diversity . As a perennial crop it may be managed in the tropics to fix the highest level of solar energy Thus the management of cassava is a way of responding to the need to use solar energy more efficiently. Ffloukes and Preston (10) proposed that high yields of foliage may be obtained if cassava was managed as a semi-perennial crop with repeated harvesting of the foliage at 2 to 3 month intervals. This idea was adopted in Dominican Republic by these authors who showed that the fresh foliage could be used as a source of protein and for supplementing a liquid diet of molasses-urea for attending cattle.

Interaction of cassava with Insects : The most important insects attack cassava :

1. Cassava mealybug (*Phenacoccus manihoti*) which was accidentally introduced into Africa in the early 1970s in the present Zaire has spread all over Africa (15). Some ecological approaches and cultivation practices are used to minimize damage caused by the cassava mealybug. For example, early planting in areas with heavy and long first rains sustains minimal damage because the number of mealybugs is markedly reduced during the rainy season . This enables the plants to establish and withstand the attack from the mealybug in the succeeding months of the dry and wet seasons. Several workers have recommended this early planting approach for the control of cassava mealybug (18). However, this recommendation may not be widely adopted in Tanzania because of interference with the different cropping patterns.

There are now some high yielding varieties such as Migyera , Nase I and TMS 4(2) 1425 which are tolerant to P.manihoti and recovers quickly with the first rains after attack by the pest during the dry season . Chemical treatments of late planted cassava with systemic insecticides(Fudaran 5G) or foliar systemic insecticides (Ultracide 40EC, Rogor) did not lead to significantly higher yields than those form the control plots. The subsequent discovery of Epidinocarsis lopezi in South America and its introduction and release in Africa, signaled an integrated approach to the control of this pest throughout the region. Life-table analysis confirmed that E. lopezi is the key mortality factor in reducing mealybug population (62).However in the last three years , some cases of mealybug devastation were recorded, but the biological control still effective . production of genetically resistant cultivars may add significantly to its control. A combination of crop resistance, optimal insecticide use mostly to disinfest planting material, early planting , weed control and biological control by use of E. lopezi can be an effective control of the mealybug infestation at the farm level and raise yields and production.

2.**Green spider mite**(*Manonychellus tonajoa*) It is reported to occur in Tanzania , Kenya, Uganda, Congo, Nigeria, and Burundi. This mite is found principally on buds and leaves. It causes deformation of recent emerged leaves, and yellowish spot. Chemical treatment by chlorobenzilate can be effective but it is expensive. In Brazil many clones proved to be resistant to this pest. In Africa, farmers are successfully using IBM by combining IITA technology that includes biological control and bred germplasm with partal resistance (8).

3.**The variegated grasshopper(***Zonocerus variegatus)* : Infected plants are completely defoliated. It does considerable damage to cassava in both west and east Africa countries. Most of the damage is done during the dry season and early in the rainy season. Grasshopper does not attack cassava until its nymph has reached the fourth instar. No effective control measure has yet been found. Grasshopper prefers certain cultivars to others. Therefore it may be possible select cultivars that are unattractive to the grasshopper.

4.**White flies:** (*Bemisia tabaci*) do little direct damage to cassava. However they are important pests of cassava because they transmit cassava mosaic disease. It can be controlled by occasional sprays of insecticide (e.g., sevin) during the first six months after planting. This will keep the white fly population low. The insect is unlikely to become very serious by harvest time

Tendency of weediness. Because of weak barriers between cassava and wild relatives it tends to hybridize with them when it comes in close contact with these species. A large number of its wild relatives are weedy types; i.e., they invade agitated habitats that are disturbed by man. The progeny of this hybridization is a complex of cassava and wild species (could be *M.tipartita, M. anomala,M. zenerneri* and *M. grahamii*) This species complex behaves as a weedy, and can be detected in the margens of cassava plantations if it grown near wild relatives. In the long run, these hybrids, following natural selection develop new weedy species.

Nassar (21)hypothesized that a number of wild Manihot species may have been developed as a result of chance hybridization between cassava cultivars and local relatives. The stability of these wild species is minimal. However, across years many phenotypic variations are found and could easily expand the species boundaries.

Interaction of cassava with microorganisms and wild life: Several microorganisms and pathogens are reported to be found that interact with cassava. The most important one of them is gemini virus,cassava mosac disease (or CMD) which almost caused a disaster in the last decades.

1. **Cassava Geminivirus**: Since 1988, severe epidemics have traversed Tanzania and Uganda and causing devastating losses and food shortages .Comprehensive surveys carried out in 1990 to1992 and again in 1994 in all cassava-growing districts revealed that CMD occurred throughout the two countries. There was almost total infection in certain parts of the two countries where symptoms were very severe. Healthy plantations became heavily infected within a few months of planting.

Observations on the progress of the epidemic across East Africa showed that the front is characterized by large population of whiteflies and by a high incidence of CMD mainly due to recent infection by the whitefly vector. The lower leaves of plants infected in this way seem healthy while the youngest leaves show severe symptoms. Remaining leaves are reduced in size and show marked distortion and malformation which give infected plants a paint-brush-like appearance.

Plants show severe CMD symptoms due to the use of cuttings from plant infected by whiteflies the previous year. If this material is used in the absence of adequate stocks of healthy cuttings, the ensuing plants are severely stunted and produce no or very poor yields. Strain of the virus has been identified as the most likely cause. The possibility of a new biotype of whiteflies B. tabaci is being investigated. (65). The current epidemic has led to a drastic decrease in cassava production and to the virtual elimination of the crop in some areas. Moreover, over 500 local cassava genotypes are threatened with extinction and special measures have been necessary to protect the crop (8). The epidemic has had serious consequences for communities heavily dependent on cassava as a staple food and cash crop. There have been massive food shortages and almost starvation in some districts.

2.**Xanthomonas campestris pv. cassavae manihotis** causes the cassava bacterial blight (CBB) , which leads to severe losses in the savanna areas of East Africa particularly on susceptible varieties grown on poor soils (66).CBB causes up to 70% reduction in yields of cassava tubers and planting materials . The disease is spread through infected planting material , Wind driven rainplash, insects and the movement and use of infected implements (66,67) . The use of resistant varieties, cultural practices and sanitation are the recommended control methods. Hybrids of cassava with *M. galziovii* showed high level of resistance to this pathogen.

Conclusion

Cassava is a monocious plant but selfing does occur due to monoclonal cultivation system. It seems that heterotic effect is predominant in root prodution. For this reason, breeding method of combining ability showed high success when used, enabling India to triplicate its productivity during thirty years jumping from 9 t/h in the 1960s to 26 t/ h in 2000 while other centers for cassaa research stationed in the same level of productivity during the same period. Productivity in South Ameria was 14.5 in the 1960 and dropped to 12.5 during the thirty following years.

Mealy bug is the most important danger threatening cassava in Nigeria and Zaire. Biological control proved effective in the last twenty years, but some cases of its virulescent attack were recorded in the last three years

The breackdown of this introduced artificial ecosystem may happen. The most durable mean is to breed cassava cultivars resistant to this pest. *M. glaziovii* proved an excellent resource. It is also very resistant to bacteria blight and Mosaic.This author has bred plyploidized interspecific hybrids bewteen this species and cassava, restoring its fertility and facilitating its utilization. The ideal method to control mealy bug is to breed cultivars from this material. The author is making it disponible for IITA researchers.

Wild *Manihot* are sources for valuable characters for improving the crop. They were neglected for a long time. However, A successful case was its manipulation by IITA Scentists in the decade 1980 who successfully utilized a material provided by this researcher to produce cultivars resistant to bacteria blight and mosaic. These cultivars are cultivated now in more than 2millions hectars in Nigeria.

Apomixis offers a very valuabe mean to protect the crop against contaminationan and permit maintining heterosis effect. It was transferred from the wild species successfully by this author to the cultigen. Moreover having its level increased to about 90% apomictic progeny.

References

1. Anonymous 1989. Central tuber crops research institute annual report. Thruvandrum,1989, 86 pp.2

Balagolapan,C., Paejalma G., Panda S.K. and, Moorfkithy S.N.1988. Cassava in food , feed and Industry. Boca Raton, Fl. MSA,CRC Press Incorporated.

3.Beck, B. D. 1960. Cassava trials on Moor plantation. Rep. Dept. Agric. Rfes. Nigeria, 1958-1959.

4.Bolhuis, G.G. 1966.Influence of length of the illumination period on root formation in cassava , Neth. J.Agric Sci. 14,151-262.

5.Bruijn,G.H. 1971. A study on cianogenetic character of cassava (*Manihot esculenta Crantz*) , Mededelingen Landbouwhogesschool Wangeningen,140pp.

6.Coursey,D.G.,and Haynes P.H., 1970. Root crops and their potential as food in the tropics World Crops 22(5): 261-265.

7.Costa, L. R., Nassar N.M.A. and PERIM S. 1984. Padrão de crescimento de raízes e partes aéreas da mandioca, Manihot esculenta Crantz. Turrialba. 34:530-531.

8.Dixon,A. G.O.A. , Brandyop, R. and Ortiz, R. 2003. Cassava From poor farmers crop to Pacesctters of African Rural Development. Chronica Horticulturae 43 3-69 FAO Yearbook 2002.

10.Ffoulkes D. and Preston T.R. 1978 . Cassava or sweet potato forage as combined sources of protein and rhoughage in molasses based diets: effect of supplementation with soybean meal.Tropical Animal production (3): 186-192.

11. Fabres, G. 1980. Entomophagus insects associated with cassava mealybug on the People’s Republic of Congo. IN: Tropical root crops: research strategies for 1980’s . Ottawa: International Development Research Center FAO (Food and Agriculture Organization) Yearbook, 2002

12.Grattapaglia, D.E., Nassar N.M.A. and Dianese J. 1986. Biossistemática de espécies brasileiras do Gênero *Manihot* baseada em padrões de proteína da semente.Ciência e Cultura (J. Brazilian Assoc. of Sci.) 19(3) 294-300.

13.Grattapaglia, D.E., Costa, S. and Nassar N.M. A.1996. Strict maternal inheritance of RAPD fingerprints confirms apomix in cassava (*Manihot esculenta* Crantz). Can J. Plant Scj. 76:379-382.

14.Hahn , S.K., Howland A.K., Terry E.R. 1980. Correlated resistance of cassava to mosaic and bacterial blight diseases. Euphytica 29:305-311.

15.Hahn,S.K.,Williams, L. 1973. Investigations on cassavain the republic of Zaire. In Report on comissaire d etat a l agriculture. International Institute of Tropical Agriculture, Ibadan, pp 12.

16.Hannsford C.G. 1936. Report of the pathologist . In Annual Reports of the Department of Agriculture, Uganda, Government printer, Entebbe.48pp

17.Lancaster,P.A., Ingram J.S. and lim M.Y., and Coursey D.G.1982. tradicional cassava based foods: Survey of processing techniques. Econ. Bot. 36(1): 12-45

18.Leuschener. 1980. Pest control for cassava and sweet potato. In: Root crops in Eastern Africa held 23-27 November 1980 in Kigali, Rwanda. Ottawa: International Development Research Center 1982.

19.Magoon,M.L., Joss, J. S. and Appan, S. G. 1966. Cytomorphology of interspecfic hybrid between cassava and ceara rubber. Cromosome Information Sevice (japan) pp8-10.

20.Pereira, A. S. ;Lorenzo, J. O , Monteiro, D. A , Veiga, A A 1981. A Study on progeny of Self fertized Cassava clone Guaxupe (In Portuguese). Bragantia 40:217-219

21.Nassar N.M.A., 1978ª: Conservation of the genetic resouces of cassava (*Manihot esculenta*): Determination of wild Species localites with emphasis on probable origin. Econ. Bot., 32: 311-320.

22.Nassar N.M.A.1978b. Genetic resouces of cassava: Chromosome Behaviour in some *Manihot* species. Ind. J. Genet., 38(1): 135-137.

23.Nassar N.M.A.1978c. Hydrocyanic acid content in some wild *Manihot*(cassava) species. Can. J. Pl. Sci., 58: 577-578.

24.Nassar N.M.A.1978d. Microcenters of wild cassava *Manihot* spp. diversity in central Brazil. Turrialba, 28(4): 345-347.

25.Nassar N.M.A., 1978e. Some further species of *Manihot* with potential value to cassava breeding. Can. J. Pl. Sci., 58: 915-916.

26.Nassar N.M.A. 1978f. Wild *Manihot* species of Central Brazil for cassava breeding. Can. J. Pl. Sci., 58: 257-261.

27 Nassar N.M.A.1979a . A study of the collection and maitainance of the germoplasm of wild cassavas. *Manihot* spp. Turrialba, 29(3): 221-221.

28 Nassar N.M.A. 1979b .Three brazilian *Manihot* species with tolerance to stress condictions. Can. J. Plant Sci, 59: 533-555.

29 Nassar N.M.A. 1980a.Attempts to hybridize wild *Manihot* species with cassava. Econ. Bot., 34 (1): 13-15.

30 Nassar N.M.A. 1980b : The need for germoplasm conservation in wild cassava. Ind. J. Genet., 39 (3): 465-470.

31.Nassar N.M.A. 1982 . Colleting wild cassavas in Brazil. Ind. J. Genet., 42: 405-411.

32.Nassar N.M.A.1983. A quebra da dormência da semente das espécies selvagens da mandica, *Manihot* spp. Ciência e Cultura, 35(5): 630-632.

33.Nassar N.M.A.1984. Natural Hybrids between *Manihot reptans* Pax and *M. alutaced* Rogers & Appan. Can. J. Pl. Sci., 64: 423-425.

34.Nassar N.M.A.1985. *Manihot neusana* Nassar: A new species native to Parana, Brazil. Can. J. Pl. Sci., 65: 1097-1100.

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

36.Nassar N.M.A.1989. Broadening the genetic base of cassava, *Manihot esculenta* Crantz by interespecific hybridization. Can. J. Pl. Sci., 69: 1071-1073.

37.Nassar N.M.A.1991. Production of triploid cassava, *Manihot esculenta* Crantz by hybrid diploid gametes. Field Crops Res., 13: 173-182.

38.Nassar N.M.A. 1992.Cassava in South America: A plant breeder view. Ciência e Cultura. 44:25-27.

39.Nassar N.M.A.1994. Selection and development of apomitic cassava clones. Ciência e Cultura. 1.6.:168-171.

40.Nassar N.M.A. 1994. Relationship between *Manihot* species: A review. Proceedings of the 2nd Inter. Sci. Meet. The cassava biotecnology network(Bogor). 90-100.

41.Nassar N.M.A.1997.Development of cassava interespecific hybrids for savana (cerrado) conditions. J. Root Crops. 22:9-17.

42.Nassar N.M.A.1999. Cassava,*Manihot esculenta* Crantz genetic resources: Their collection , evaluation and manipulation. Advances in Agronomy 69;179-230.

43.Nassar N.M.A. 2000. Wild Cassava, Manihot spp.: Biology and potentialities for genetic improvement. Genet.&Molecular Biol. 23:201-212.

44.Nassar N.M.A. 2000. The transference of Apomixis genes from *Manihot neusana* Nassar to cassava, M. esculents Crantz. Hereditas: 132:167-170.

45.Nassar N.M.A. 2000 .Cytogenetics and Evolution of Cassava (Manihot esculenta Crantz). Genetics and Molecular Biology 23: 4, 1003-1014.

46.Nassar N.M.A.2001 . The nature of apomixis in cassava(*Manihot esculenta* Crantz). Hereditas 134:185-187.

47.Nassar, N. M. A. 2004. Polyploidy, Chimera and fertility of interspecific cassava , *Manihot esculenta* Crantz The Indan J. Genet. & Plant Breed vol. 62 (In press).

48.Nassar N.M.A.,and Costa C.P.,1976:Tuber formation and protein content in some wild cassava (mandioca)species native to Central Brazil. *Experientia,* 33: 1304-1306.

49.Nassar N.M.A., Dorea G.1982. Protein contents of cassava cultivars and its hybrid with *Manihot* species. Turrialba, 32(4): 429-432.

50.Nassar N.M.A.,and Teixeira R.PIO.1983. Seed germination of wild cassava species (*Manihot spp.*). A quebra de barreira da semente das espécies selvagens da mandioca.*Manihot spp.*(In portuguese) – *Ciência e Cultura*, 35(5)630-632

51.Nassar N.M.A., and Cardenas R. 1985. Collecting wild cassava in Northern Mexico. FAO/IBPGR Newsletter 65:29-31.

52.Nassar N.M.A., O'Hair.1985. Variation among clones in relation to seed germination. *Indian J. Genet.* 45(2):429-432.

53.Nassar N.M.A., Grattapaglia D.1986e. Variabilidade de clones de mandioca em relação à fertilidade e aspectos morfológicos. Turrialba, 36(4): 555-559.

54.Nassar N.M.A., Silva J.R., Vieira C.1986.Hibridação insterespecífica entre mandioca e espécies silvestres do *Manihot*. Ciência e Cultura. 33(6):1050-1055.

55.Nassar N.M.A., Freitas M.1997. Porspects of polyploidizing cassava. *Manihot esculenta* Crantz, by unreduced microspores. Pl. Breed. 116:195-197.

56.Nassar N.M.A., Nassar Hala N.M., Vieira C., Saraiva S.L.1995. Cytogenetic behavoir of interespecific hybrids of cassava and *M. neusana* Nassar. Can. J. Pl. Sci., 75:675-678.

57.Nassar N.M.A., Nassar Hala N.M., Vieira C, Carvalho A.1996. Inducion of a productive aneuploid in cassava, *Manihot esculenta* Crantz. Braz. J. Genet. 19:123-125.

58.Nassar N.M.A., Carvalho A., Vieira C. 1996. Overcoming barries between cassava *Manihot esculenta* Crantz and wild relative. *M. pohili* Warwa. Braz. J. Genet. 19:617-620.

59.Nassar N.M.A., Vieira C., Grattapaglia D.1998a. Molecular and embrionic evidence of apomix in cassava interespecific hybrids (*Manihot* spp.). Can J. Pl. Sci. 78:348-352.

60.Nassar N.M.A., Vieira C., Grattapaglia D.,,1998b: Evidence of apomixis in cassava (*Manihot esculenta*)Crantz . Genet.&Mol.Biol.21:527-530.

61.Nassar, N. M. A ,Elkholy H. and Eltantaway, A. 2002. Cassava productivity worldwide? An overview. Revista Ceres 49?369-381.

62.Neuenschwander , P.1990. Understanding higher level interactions as a key to successful biological control. In: Integrated pest management in root and tuber crops: Proceedings of a Workshop held at the Biological Control Center of Africa , 10-14 December 1990, in Cotonou, Republic of Benin. p.37.

63.Nichols R.F.W.1950. The brown steak disease of cassava. Distribution, climatic effects and diagnostic symptoms. East African Agriculture Journal,15:154-160

64.Normanha,E.S.,and Pereira A.S. 1950.Aspectos agroconomicos da cultura da mandioca. Braganthia 10(7): 179-202.

65.Otim-Nape G.W.1990.Root crops in Uganda .in:Agricutural Research in Uganda:Five year Research Plan.Vol 1. Hartmans(ed) USAID.Kampala.

66.Otim-Nape G.W. and Sengooba T. 198. Cassava Bacterial Blight in Uganda. In Terry E.R., A.K. Oduro and F. Caveness, (eds). Tropical Root Crops. Proceeding, 1st Symposium of the international society for the Tropical Root Crops, Africa Branch (ISTRC-AB) Ibadan , Nigeria.pp.61-65

67.Otim-Nape G.W. 1993. Epidemiology of the African cassava mosaic Gemini virus disease in Uganda. Ph.D Thesis, University of Reading , UK 152pp.

68.Papadakis, J. 1966. Crop ecology survey in west África (Libéria, Ivory coast, Ghana, Togo, Dahomy, Nigéria), FAO, Rome.

69.Pereira,A.S., Lorenzi J.O., Monteiro D.A., Veiga A.A. 1981. Estudo de uma progênie de autofencundação de mandioca Guaxupé. Bragantia 40:217-219.

70.Rajendran, P.G./ Ravindran, C. S./ Nair & Nayar, T. V. R. True cassava seed (TCS) for rapid spread of the crop in non traditional areas. Thiruvananthapuram. Central Tuber Crops Research

2000. 22p (Tech.Bull. no.28)

71.Rogers, D.J.1963 . Studies of *Manihot sculenta* Crantz (Cassava) and related species, Bull. Torrey Bot.,90,43-54.

72.Rogers, D.J. 1965 .Some botanical and ethnological considerations of *Manihot sculenta*. Economic Botany 19: 369-377.

73.Rogers, D.J., Appan S.G. 1973. *Manihot, Manihotoides* (Euphorbiaceae) Hafner Press,New York,272

74.Salick J., Cellinese N. and Knnap S.1997. Indigenous diversity of cassava: generation , maintenance, use and loss among the Amuesha, Peruvian upper Amazon. Economic Botany 51(1): 6-19.

75.Storey H.H.1936. Virus disease of east African Plants :VI, A progress report of studies of the diseases of cassava. East African Agricultural Journal 2, 34-39.

76.Storey H.H., and Nichols R.F.W.1938.Studies on the mosaic disease of cassava . Annals of Applied Biology,25,790-806

77.Vries C.A., Ferweda J.D., and Flach M.1967 . Choice of food crops in relation to actual and potential production in the tropics. Neth.J. Agr. Sci. 15:241-248.

78.Williams C.N. and Gazhali S.M. 1969. Growth and productivity of tapioca(*Manihot utilissima*) 1, Leaf characteristics and yield, Exp. Agric.,5,183-194.

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