Global Workshop on Root and Tuber Crops Propagation

Proceedings of a Regional Workshop held in Cali, Colombia 13 16 September, 1983

Centro Internacional de la Papa (CIP)
International Institute of Tropical Agriculture (IITA)
United Nations Development Programme (UNDP)
Centro Internacional de Agricultura Tropical (CIAT)

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Technical editor: James H. Cock

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Preface

All of the commonly grown tropical root and tuber crops are normally reproduced vegetatively. Although each crop is propagated in its own peculiar ways, there are many common problems and the same principles can be used to resolve them. Whilst there are still many gaps in our knowledge of these crops, it is hoped that the comparisons between them will enable more rapid progress in the development of improved propagation systems. For this reason, the three international agricultural research centres with major programs on root and tuber crops, CIAT, IITA and CIP, organized this workshop with financial support from UNDP.

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INTRODUCTION

The Importance of Planting Material in Root and Tuber Crop Production

J. E. Bryan, CIP, Lima, Peru

Most crop specialists agree that the use of good quality seed is the quickest way to increase crop production and productivity. (The term 'seed' is used to denote true botanical seed, tubers, roots, or other plant parts. Since root and tuber crops are almost exclusively multiplied by vegetative propagation, this is the meaning of seed commonly used in this publication.) Without good seed, the impact of other inputs on yield, such as fertilizer and soil preparation, will not be as significant or as economical. In addition, good seed can be adapted to small as well as large farms, and it is responsive even under less favorable climatic conditions.

Many farmers, especially in developing countries, are not yet using good quality seed, despite its obvious advantages. One of the major reasons for this is that farmers are slow to change from the ancient practice of setting aside part of their crop, more or less non-selectively, as seed for the next, to the more recent idea of saving planting material only from the more vigorous and healthy plants. However, in order to produce good quality planting material in small-scale and subsistence agriculture, it is very important that this latter idea becomes ingrained into farmers' practices.

The switch to improved seed means a drastic change for the individual farmer, with many new risks and new ways of thinking. The change is equally significant at the national level. The adoption of improved seeds implies initiating and maintaining complex, sizable, and costly long-range activities, including infrastructures for financing and training both at the scientific and farmer level. Trained manpower at the farmer level is the most critical.

Breeding programs and varietal selection are of little value without the necessary infrastructure to maintain and multiply a new variety to the quantity and quality necessary to make a significant impact on productivity. Governments wishing to motivate farmers to use improved seed, improved varieties, or modern techniques are faced with the need not only to provide educational and credit facilities but also to ensure that the required seed and related inputs are available to the farmers at the correct time.

Good planting material naturally implies freedom from diseases, insects, and other pests, but it also implies physiological quality. This is extremely important when working with vegetatively propagated crops such as potatoes, cassava, yams, and sweet potatoes. In the case of potatoes, there is a 65-year history of reducing diseases and insects in planting materials. However, the importance of physiological quality in planting materials is less well known.

Root and tuber crops, being propagated vegetatively, are inherently more susceptible to the maintenance, increase, and dissemination of both systemic and nonsystemic diseases than are the sexually reproduced crops using true seed as planting material. The systemic diseases—viruses, viroids, and mycoplasma pathogens, as well as several bacteria—are the most devastating in terms of yield loss for the root and tuber crops. Recent progress using thermotherapy and meristem techniques have enabled scientists to remove many of these systemic diseases from planting materials. Increased use of rapid multiplication techniques is enabling scientists to produce large amounts of 'pathogen-free' material. Because most rapid multiplication techniques in root and tuber crops involve the use of aerial portions of the plant, contact with soil and tuber/root portions is broken and most nonsystemic pathogens and pests can be eliminated. However, when replanted in contaminated soils, the plants become reinfected, as is also the case with systemic diseases, but usually reinfection with these is at a slower rate if appropriate precautions are taken.

Crop losses are difficult to define in monetary terms. Individual diseases vary tremendously in their effect on yield reduction. With 100% infection, potato virus X (PVX) normally reduces yield less than 10%. However, the yield of certain susceptible cultivars has been reduced in excess of 25%. Mild strains of potato virus Y (PVY) only reduce yield 25-30%, but severe PVY and potato leaf roll virus (PLRV) can reduce total yield in excess of 60%. This loss varies with plant density, seed tuber size, fertility, and other

agronomic practices, as well as with variety. The bacteria *Pseudomonas solanacearum* can cause 100% crop loss at harvest or prior to purchase by the consumer. Similar losses are reported in the root crops.

Crop losses are caused in several ways. The first and most important is by yield reduction, in which fewer and smaller roots or tubers are produced. As these losses occur below the ground, they are not noticeable until harvest. This is particularly true for the virus diseases and nematodes.

The second type of loss is through rotted, damaged, misshapen, or off-color roots or tubers. These types of losses are often caused by bacterial or fungal pathogens, as well as by insects, viroids, and mycoplasma. Again, these losses are most obvious at harvest.

The third type of loss occurs on the portion of the plant above the ground. The cumulative effect of mild insect infestations, lack of chlorophyll caused by viruses, and mild leaf spots caused by certain fungi are often underrated because they are not serious by themselves.

The last and most obvious type of loss is caused by pathogens killing the plant or causing severe leaf or stem damage. Fungi, bacteria, insects, and certain viruses do the most damage.

Most of the above types of losses can be attributed to infected planting materials. But the effect of planting material quality is not limited to yield losses. It also affects the storage properties of the product and its eating quality. It is therefore appropriate for agricultural programs to devote a significant share of their resources to this important aspect of crop production.

CHAPTER 1. CROP DESCRIPTIONS: IMPORTANCE, GROWTH, PRODUCTION SYSTEMS, AND USES

Potato Production

R. H. Booth and D. Horton, CIP, Lima, Peru

Importance

On a worldwide basis, potato is the most important root crop with an annual production of about 258 million tons compared with 146 million tons of sweet potato, 121 million tons of cassava, 22 million tons of yams, and around 6 million tons of cocoyams (Table 1). Similarly, potatoes are grown in more countries of the world than any other root and tuber crop. In fact, potatoes are grown in more countries than any other single crop, with the exception of maize. Also, potato is the only root crop being considered in this workshop which is produced in significant amounts in developed countries. In the developing countries, however, sweet potatoes and cassava are grown in an equal or larger number of countries. Cassava, yams, and cocoyams are grown almost exclusively in the developing countries (Table 2).

In countries with developing market economies, cassava stands out as the leading root crop with an annual production of 115 million tons (Table 3). Potato follows with 32 million tons, and production of yam, sweet potato, and cocoyam is 22, 15, and 5 million tons, respectively.

Potatoes are grown in all developing regions but in much smaller amounts than cassava. The five most important potato producers in developing regions are India, Turkey, Argentina, Colombia, and Brazil. These five countries account for over 50% of total potato production in the developing market economies but only 7% of world production. The smaller quantities produced in many other countries, however, are important contributions to the diets of many peoples.

Table 1. **Area, production, and yield of root and tuber crops in the world.**

	Cassava	*Potato*	*Yam*	*Sweet potato*	*Cocoyam*
Area (million hectares)	14	19	2	12	1
Production (million tons)	121	258	22	146	6
Yield (t/ha)	9	14	9	12	5

Source: D. Horton; J. Lynam; H, Knipscheer, 1984

Table 2. **Number of countries producing root and tuber crops.**

	Countries (no.)	Potato	Sweet potato	Cassava	Yam	Cocoyam
World	182	130	106	95	43	29
Developed market economies	28	28	6	0	2	1
Developing market economies	141	91	96	92	41	27
Centrally planned economies (European)	8	7	0	0	0	0
Centrally planned economies (Asian)	5	4	4	3	0	1

Source: D. Horton; J. Lynam; H, Knipscheer, 1984

Table 3. **Area, production, and yield of root and tuber crops in the countries with developing market economies.**

	Cassava	Potato	Yam	Sweet potato	Cocoyam
Area (million hectares)	13	3	2	2	1
Production (million tons)	115	32	22	15	5
Yield (t/ha)	9	11	9	7	4

Source: D. Horton; J. Lynam; H, Knipscheer, 1984

Within its origins in the tropics, the potato is generally grown in areas with relatively fertile and well-drained soils, cool temperatures (particularly at night), and adequate rainfall or irrigation. Such conditions are typically found in the tropical highlands such as the Andes, Central Africa, and the Himalayas; in areas with temperate or mediterranean climates such as Argentina, Chile, and Turkey; and in areas with relatively cool night temperatures during the spring, autumn, or winter seasons such as North Africa and the Indo-Gangetic plain.

Production trends

According to statistics of the Food and Agriculture Organization (FAO), world production of potatoes has fallen by approximately 10% over the last two decades while production of all other root crops has increased over this same period. However, these figures are greatly influenced by estimates for China. China is the world's largest producer of sweet potatoes and one of the largest producers of potatoes. In recent years the International Food Policy Research Institute (IFPRI) has conducted extensive research on Chinese agricultural statistics. This unpublished work indicates that the FAO estimates for China greatly overestimate sweet potato production and underestimate potato production. Using the IFPRI estimates of Chinese root crop production would mean that global production of potatoes has remained roughly constant over the last two decades, rather than fallen, as previously believed.

In developed market economies the area seeded to potatoes has fallen by approximately 40% since 1960, while yields have increased by 30%, and total production has fallen by about 20%. On the other hand, in the developing market economies the area under potatoes over the same period has increased by 38%, yields have increased by 45%, and total production has doubled (Table 4). In European and Asian countries with centrally planned economies, the area cropped with potatoes decreased annually by 1% and yields increased by slightly less than 1%, leaving the total production about constant. Within the developing market economies over the last 20 years, the area under potatoes in Africa and Asia increased by almost 7% and 4% per year, respectively, while that in Latin America did not change substantially. Potato yields increased by more than 2% annually in Latin America and Asia, while in Africa yields remained constant. Thus, total potato production increased roughly by 140% in Africa, 80% in Asia, and 40% in Latin America.

The production trends show that over the past 20 years potato production has increased most rapidly in areas where per capita produc-

Table 4. **Percent change in area, production, and yield of root and tuber crops in countries with developing market economies, 1961-1981.**

	Cassava	Potato	Yam	Sweet potato	Cocoyam
Area	32	38	12	0	92
Production	49	101	53	0	58
Yield	13	45	18	0	-18

Source: D. Horton; J. Lynam; H. Knipscheer, 1984

tion levels are low and least rapidly where the potato is already a staple food in the diet. Over this period the increase in per capita production of potatoes in many developing countries has been striking. In fact, the average growth rate of potato production exceeds that of most other food crops in developing countries.

Production costs

In terms of production efficiency, potatoes can produce more edible energy and protein per hectare than practically any other food crop. In terms of energy and protein production per day, the potato also ranks high. However, high potato yields require a large input of energy per hectare. In fact, the energy inputs for potatoes are exceeded only by those for irrigated rice and high-value vegetable crops such as broccoli and cauliflower. The potato is a heavy user of energy derived from both fossil fuels and human labor. Where yields are highest, energy inputs in the form of chemical fertilizers and pesticides account for a large proportion of the total energy input. On a world basis, the potato crop is now the second largest user of chemical pesticides, the first being cotton.

For the present, the potato crop is a high-input, high-output food crop in all world regions. Both potato yields and production costs per hectare are higher in developed countries than in developing countries. But because the yield gap between these groups of countries is greater than the difference in production costs per hectare, potato production costs per kilogram are higher in developing countries.

While the structure of potato production costs varies considerably between countries, the total cost in most countries lies between US $ 1000 and $ 2000/ha. This cost level is considerably higher than that for most other major food crops, including most of the root crops and rice and wheat. In developing countries, production costs for rice and wheat, when

calculated against either energy or dry matter produced, are considerably lower than for potatoes. On the other hand, in some specialized potato-producing countries in the developed world, average production costs of energy or protein from potatoes do not differ greatly from those of wheat.

In future years, it is not likely that the production cost of potatoes per hectare will be significantly reduced, but in many cases yields could be increased substantially with only slight increases in production cost per hectare. This would allow a significant reduction in production cost per kilogram.

Not only is the production cost of potatoes higher than for most other root crops, but the cost structure is also different from that of other root and tuber crops (Table 5). Seed tubers are nearly always the single most costly production input. In available estimates for South America and tropical Africa, seed tubers account for 20-40% of the direct production costs (38% in the specific example given for Peru), in Asia 30-35%, and in Central America around 50%. These high costs for seed tubers clearly justify the many research and development programs emphasizing better production, storage, and distribution of healthy and inexpensive seed. To date, research has concentrated on: rapid propagation techniques, virus and disease detection, physiological quality, storage, and the development and evaluation of alternative seed production and certification schemes. Also, the potential use of true potato seed (botanical seed) is currently being widely explored as an alternative means of reducing production costs.

Labor tends to be the second most important production cost in developing countries, accounting for 15-35% of the input costs in most cases. Inputs of industrial origin—equipment, fuel, and chemical fertilizers

Table 5. **Examples of the production cost structure for potato, cassava, and sweet potato.**

	Cassava (Thailand, 1978)	Potato (Peru, 1980)	Sweet potato (Peru, 1973)
Labor (%)	64	17	45
Equipment (%)	34	11	42
Seed (%)	2	38	8
Fertilizer (%)	—	20	3
Pesticides (%)	—	14	2
Total cost/ha (US$)	100	1700	200
Yield (t/ha)	14	18	12

Source: D. Horton; J. Lynam; H. Knipscheer, 1984

and pesticides—account for a variable proportion of total costs: between 20% and 40% in Asia and Latin America but a very small proportion in Africa. In the U.S.A. and Western Europe, the structure of potato production costs varies considerably from that described for developing countries. Seed and labor only account for 20% and 8%, respectively, whereas inputs of industrial origin account for nearly 75%.

The high potato production costs in developing countries result in high prices to users. In comparison with other root crops in developing countries, the average price of potatoes at US $140/ton is similar to that of yams (US $160/ton) but considerably higher than that of cassava and sweet potato at about US $70-90/ton (Table 6). In addition to showing the

Table 6. **Yield, price, and value of various crops in developing countries.**

Crop	Yield (t/ha)	Price (US$/ton)	Value (US$/ha)
Potato	10.9	142	1550
Yam	9.0	163	1469
Sweet potato	7.1	89	629
Cassava	8.8	70	613
Cocoyam	4.2	123	514
Rice	2.2	170	366
Wheat	1.5	148	217
Maize	1.5	119	177
Sorghum	1.0	123	117

Source: D. Horton; J. Lynam; H. Knipscheer, 1984

Table 7. **Production and value of potatoes in developing countries, 1977 average farm gate prices.**

Rank	Country	Production (million tons)	Value (million US$)
1	India	9.9	1440
2	Turkey	2.9	440
3	Argentina	2.2	340
4	Colombia	2.1	320
5	*Brazil*	1.9	290
6	Peru	1.6	240
7	Egypt	1.1	170
8	Chile	1.0	150
9	Bangladesh	1.0	150
10	Bolivia	1.0	150

Source: D. Horton, World Potato Facts, 1984. CIP, Lima, Peru.

high cost of potatoes, Table 6 also shows the high value of the crop. Table 7 indicates the meaning of this, in economic terms, to leading potato-producing countries in the developing world.

Uses

According to the best available estimates, about 45% of the world potato crop is used for human consumption (fresh and processed), 30% is fed to animals, and 15% is kept for seed purposes. Only about 2% is used for starch production and the remainder, just under 10%, is the FAO estimate of waste.

The production of potatoes specifically for animal feed has been limited almost exclusively to Europe, and today is only practiced extensively in Eastern Europe. In Poland and Russia, the world's two largest potato-producing countries, the portion of the total crop used for fodder is nearly two-thirds and one-half, respectively. Potato production for starch and alcohol is of limited importance in the world. Only in the Netherlands, where more than one-third of the total crop is grown for starch, is potato production for starch of major importance. Other countries producing significant quantities of potato starch include Poland, Russia, and Japan. In developing countries, practically no potatoes are grown specifically for livestock feed or industrial use, although waste tubers are sometimes used for these purposes. Thus, most potato production is used for human consumption.

Few accurate studies of potato consumption trends are available. Those that are indicate broad fluctuations within countries and years which are not reflected in generalized statistics. Such statistics generally underestimate consumption levels considerably. This is possibly due to the significant quantities of potatoes, and of course other root and tuber crops, which are produced for home consumption and so fail to enter into national and international statistics.

With an estimated per capita consumption of 166 kg per year, Poland has the highest consumption level of any country. In Western Europe it appears that per capita potato consumption has stabilized at about 90 kg per year. In the U.S.A., where per capita consumption is considerably lower than in Western Europe, it is still increasing gradually and is presently about 60 kg per capita. Annual potato consumption appears to be more or less stable in Latin America at about 25 kg per capita. In other developing regions, and especially in Asia, per capita consumption is increasing rapidly, reaching about 25 kg in the Near East but only 6 kg in Africa and the Far East.

Since the Second World War, processing of potatoes for human consumption has been a growing industry, particularly in the U.S.A. where now over half the potatoes are consumed in processed forms—primarily frozen French fries, dehydrated instant preparations, and snack foods such as potato chips. By contrast, few of the prerequisites for such potato processing are present in developing countries, where the potato processing industry remains in its infancy. However, ancient and traditional methods of processing potatoes into less perishable food items continue to be practiced in such areas as the Andes and Himalayas. Because of their low cost and simplicity, these methods can provide alternatives to the storage of fresh tubers. There are no accurate estimates of the amounts of potatoes processed by such means, but they are considered to be small relative to total production.

In evaluating the prospects for potato processing in developing countries, modern processing techniques do not appear attractive due to their high cost in terms of capital, energy, and waste. It has been recommended that research and development emphasize processing principles which would produce alternative dehydrated potato-based foods acceptable to low-income consumers. If such processes are kept simple and low in capital and energy requirements, they could be alternatives to the difficult and costly task of storing fresh potatoes through hot periods in order to satisfy continual consumer demand.

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Cassava Production

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Importance

Cassava is almost solely grown in the tropics, where it is planted on a total of 13.4 million hectares of land. This area produces close to 130 million tons of the crop, with an average yield of approximately 9 t/ha. Although about half the total area planted with cassava is in Africa, yields are lower there than in Asia and the Americas, and so total production is approximately distributed as 40% in Africa, 40% in Asia, and 20% in the Americas. In terms of total calories produced and consumed by people in the tropics, cassava is the fourth most important crop after rice, sugarcane, and maize.

Growth and development

Cassava can either be grown from true seed or from stem cuttings. In commercial production it is exclusively grown from stem cuttings; sexual seed is only used in breeding programs or by farmers interested in selecting new clones. Stem cuttings planted in moist soil conditions germinate within 1-4 weeks depending on temperature conditions. Axillary buds in the leaf scars develop rapidly; however, after initial development of all axillary buds, apical dominance restricts the development of the lower buds, resulting in the development of an average of one to three shoots per cutting. While the shoots are developing, a callus forms on the lower end of the cutting and this then produces roots. Roots also develop from around the leaf scars and from the base of the newly developing shoots. Roots start to accumulate starch less than a month after planting, and by 6 weeks after planting several of them have begun to swell and to accumulate starch in appreciable quantities.

Shoots consist of nodal units and internodes, each nodal unit comprising a leaf lamina and petiole, an axillary bud, and the stem. Apical dominance is strong in cassava and development of the axillary buds is normally suppressed, leading to the characteristic growth form of the plant. Certain stimuli, not all of which are known, cause the apex to become reproductive. When this occurs, between two and six (normally two to three) of the axillary buds develop into approximately equal-sized branches. This process continues throughout the plant's life cycle.

The first leaves produced tend to be small, even when fully expanded. As the plant ages, the size of the individual leaves increases for the first 4-6 months, after which it decreases. The rate of leaf formation per apex declines continuously as the plant ages. However, in heavily branching types, this effect is more than compensated by the increased number of active apexes resulting from increases in branching and leaf formation rate per plant. The net result of the changes in leaf formation rate per plant, leaf size, and leaf fall is a rapid increase in leaf area index for the first 4-6 months, followed by a slow decline up to harvest time.

An interesting feature of the growth and development of cassava, which is common in most root crops, is the simultaneous development of the source (the leaves) and the economically useful part (the roots). This contrasts markedly with the grain crops, in which the source is produced first, followed by grain filling.

Cassava also contrasts with the grain crops in that it has no fixed date of maturity. Cassava will continue to produce new leaf area, albeit at a declining rate, and will continue to increase its root yield until it is harvested.

Cultivation systems

Cassava is produced in a very wide range of growing conditions with innumerable different cultivation systems. Most of the world's cassava is grown on small farms; about 30-40% is grown as a mixed crop in association with maize, grain legumes, and a variety of other crops. A limited number of large cassava plantations exist to supply raw materials for starch factories.

Although in general cassava production is not mechanized, in several countries machinery is often used to prepare the land for its planting. The total labor requirement is commonly between 70 and 120 man-days per year, the lower figures generally representing the areas where mechanized land preparation is carried out, and the higher figures where it is not.

Cassava production areas have been broadly classified by CIAT into six different ecosystems (Table 1). The most important of these zones in terms of total production are the lowland tropics, which have a pronounced dry season.

Although experimental yields of 70 t/ha have been achieved and under good conditions farmers have frequently obtained yields of 30-40 t/ha, average world yields are less than 10 t/ha. These low yields are partially due to the fact that cassava is normally grown under marginal agricultural conditions, where it exceeds the yield capacity of most other crops, and also partially due to poor agronomic practices.

Table 1. **Cassava production ecosystems and their main characteristics.**

Eco-system	General description	Mean temperature	Dry season duration	Annual rainfall (mm)
1.	Lowland tropics with long dry season; low to moderate annual rainfall; high year-round temperature	Above 22°C	3-4 mo.	800-1500 (unimodal distribution)
2.	Lowland tropics with moderate to high rainfall; savanna vegetation on infertile, acid soils, moderate to long dry season; low relative humidity during dry season	Above 22°C	3-6 mo.	Above 1200
3.	Lowland tropics with no pronounced dry seasons; high rainfall; constant high relative humidity	Above 22°C	Absent or very short	Above 2000
4.	Medium-altitude tropics; moderate dry season and temperature	21°-24°C	4 mo.	1000-2000 (bimodal distribution)
5.	Cool highland areas; moderate to high rainfall; little seasonal temperature change	17°-20°C	Absent	Above 2000
6.	Subtropical areas; cool winters; fluctuating day-lenghts	Average above 20°C; min. 0°C	Absent	Above 1000

The cassava varieties used, except in a few isolated cases, are traditional land race varieties that have been selected by farmers over many years. In many cases, farmers plant several different varieties in the same field. With the massive increase in varietal improvement efforts in the 1970s, new varieties are now being released in many countries. However, propagation and dissemination of planting material for these new varieties generally is not well organized.

When the roots are harvested, the stems of the mature plants (at least eight months old) are kept by the farmers for use as planting material for the succeeding crop. The material may be planted immediately or stored for up to six months if the harvest period does not coincide with the planting time. Planting material is taken from the woody part of the stems. If it is intended for storage, it is cut into stakes at least 1 m long and laid in the shade or it is placed in bundles with the basal parts buried in the soil in the shade of a tree. The stored stakes produce shoots from their upper ends, which are trimmed off before planting. In southern Brazil, where cuttings have to be stored through the cool winter, they are kept in underground shelters to protect them from frost damage.

Farmers have difficulty in assessing the quality of planting material. They pay attention to its germination and the initial vigor of the new plants, but they usually do not know the nutritional and phytosanitary status of the original cuttings. Even though different planting materials may have similar germination or sprouting percentages and all new plants may appear equally healthy, yields may differ greatly, depending on the nutrition and disease status of the plants from which the cuttings were taken.

Just before planting, the planting material is cut into pieces 10-30 cm long, but occasionally longer. These cuttings are then planted horizontally, vertically, or in an inclined position. In horizontal planting, the pieces are buried 5-10 cm below the soil surface. In vertical or inclined planting, only one-half to two-thirds of the length of the pieces is covered with soil. If ridges or mounds have been prepared, the stakes are planted on the upper part.

From 7000-20,000 stem pieces are planted per hectare. High planting populations are used if the soil fertility is low, if cassava is being grown in monoculture, or if erect, low branching varieties are being planted. The most common population is about 10,000 plants per hectare.

Although cassava is relatively drought-tolerant once established, it requires adequate soil moisture for the first 2-3 months after planting. In areas with a dry period, cassava is normally planted at the beginning of the

wet season, but secondary plantings are often made 2-3 months before the onset of the dry season.

Cassava is usually grown without fertilizer on soils that have inherently low fertility and, in addition, it is frequently the last crop in a rotation before a fallow period. Farmers who use no fertilizer periodically leave the land fallow. The yield of a cassava crop in shifting culture, a system which occurs in much of Africa and parts of Asia and the Americas, or in fallow culture, is closely related to the number of years of fallow and the number of crops that have preceded the cassava crop since the last fallow period. In a few countries, farmers who are short of land and unable to maintain long fallow periods are beginning to apply fertilizer to the cassava crop.

Weed control is one of the most labor-intensive activities of cassava cultivation. Although land preparation provides initial weed control, up to six or seven weedings with a hoe or a machete may be necessary later. However, once the crop is well established, shade from the cassava leaf canopy prevents much competition from weeds.

Most farmers do not use any chemical pest or disease control measures. Use of selected varieties that are tolerant to local disease and pest problems, and practices such as crop rotation and intercropping tend to reduce disease and pest incidence.

Unlike crops such as rice and wheat, cassava can be harvested more or less whenever it is needed. The harvest may begin as early as 7 months after planting in warm areas, or it may be put off until 18 or more months after planting. Long growth periods are common in areas that have cool winters and in highland areas where average temperatures are low. Since the starch content of the roots tends to be greatest when temperatures are low, cassava is commonly harvested in the cooler months. When the rains begin after a long dry season, the starch content drops markedly and harvesting tapers off.

Most farmers prepare cassava for harvest by cutting the tops; this leaves a stump about 30 cm long, which is grasped and used to uproot the plant. If the soil is hard, farmers may tie a pole to the stump to use as a lever. Mechanical harvesters and harvesting aids are in limited use.

Uses

According to data of the Food and Agriculture Organization (FAO), about 65% of total world cassava production is used for human consumption and 21% for animal feed, with lesser amounts for starch and industrial use (Cock, 1982). The cassava used for human consumption is

almost equally divided between fresh roots, normally boiled and eaten in soups and gruels, and a variety of cassava flours. It is estimated that 450-500 million people from 26 tropical countries consume an average of 300 kilocalories of cassava per day, in the form of fresh roots or processed products.

Cassava used for animal feed within the developing countries (11.5% of the world production) is mainly fed directly as fresh cassava on the farm. Thailand, and to a lesser extent Indonesia, export about 7% of the total world production in the form of chips and pellets for incorporation in animal feed in the European Economic Community.

In recent years, much has been made of the use of cassava as a source of fuel alcohol; however, at present only minimum amounts are used for this purpose.

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Sweet Potato, Yam, and Cocoyam Production

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Sweet potato

Importance

Sweet potato, *Ipomoea batatas* (L.) Lam., is a worldwide food crop, and it is also used for animal feed and in industry. It has a high yield potential in comparison with the other major tropical food crops, and therefore should be of considerable socioeconomic and political concern. This yield potential is illustrated by the 53 t/ha produced in 5 months from an improved sweet potato line grown under good management at IITA (Alvarez and Hahn, 1983). Another important feature of the sweet potato is its adaptability. It has been shown to have a greater tolerance to an extended range of edaphic and climatic conditions than most other tropical root crops. Its optimal habitat falls halfway between cassava at one extreme and taro at the other, but it readily extends into the realm of both. It is also tolerant to cold and can be grown at altitudes as high as 3000 m in the tropic zones (Cobley, 1976; Coursey and Booth, 1977).

The tuberous root is the primary product of the sweet potato, and it is eaten as a vegetable. It is used in the industrial food trade as a source of starch and flour and it also has a number of industrial conversion products, which are generally only found in the more developed countries. Both the tuber and vines are used on farms for animal feed, and in the Philippines, Indonesia, and parts of Africa, the more tender leaves and vine tips are used as a potherb (Coursey and Booth, 1977; Purseglove, 1968).

The economic importance of sweet potato has consequences for the farmer, the consumer, and the society (Khan, 1972). For the farmer, higher

yields generally mean a higher quality product as well. Both of these attributes are likely to affect the price and the farmer's total revenue since production costs per unit of resources should decrease as yield and quality increase.

Two classes of consumer are affected: those who use the product for direct consumption and those who use it for producing other goods. The direct consumer could see a stable or reduced cost for the crop, which may affect the amount consumed relative to other staple foods. Also, where there is a higher quality product, the consumer's total satisfaction will be increased. The consumer who uses the raw material for further processing would benefit from a stable source of supply and a higher quality processed product. This in turn could further expand his share of the market through final consumer satisfaction.

Another economic factor of some importance is that most of the world production of sweet potato is consumed locally with very little entering the export trade (Onwueme, 1978; Kay, 1973). Rises in local food prices tend to restrain growth in developing countries and increase relative and absolute poverty. Therefore, it becomes feasible to place a greater emphasis on agricultural production than was justified previously. Successful agricultural development will diffuse the benefits of growth more widely than alternative strategies and will even accelerate national growth where earlier agricultural programs were inadequate for their time. If this is the case, then the economic pressures in the field of agriculture may well have a salutary effect on the pace and pattern of development (Mellor, 1982).

Growth and development

The sweet potato is a dicotyledonous herbaceous perennial vine, but is cultivated as an annual crop on the farm, with a normal growing period of between 3-7 months depending on the environment and cultivar planted. Numerous cultivars exist and extreme variation is found in the form and growth habit. Vines can be twining and trailing, and stems can extend up to 5 m in length. In the tropics, stem cuttings are usually used as planting material and are planted on mounds or ridges. The stems are thin and trail over the soil surface, producing adventitious roots at the nodes. Their color is mostly green but varies from light green to purple. The vascular bundles are bi-collateral, showing phloem on the inside and outside of the bundle. The xylem is in the middle of the bundle with strips of cambium separating the outer and inner phloem from the xylem. The easy rooting of sweet potato stems is probably due to the presence in the stem of the pericycle and endodermal layers.

Leaves are spirally arranged on the stem and vary greatly in shape between cultivars. The petiole has the growth ability to align the leaf surface to the maximum amount of sunlight. The reddish-purple flowers are borne solitarily or on cymose inflorescences on peduncles that grow vertically upward from leaf axils and are usually longer than the leaf petioles. The mature flowers open in the early morning, remain open for only a few hours, then close and wilt before midday of the same morning. The sweet potato requires short-day inducement for flower initiation. Flowers and fruits are common in the tropics, with the amount varying with the cultivar, the environment, and the season. Pollination is through the activities of hymenopterous insects, the most important of which are bees. Pollen tube growth and cross-fertilization occur only between compatible cultivars. Most cultivars are self-incompatible. The seed testa is thick and very hard making it highly impermeable to water or oxygen. Seed germination, therefore, is difficult and irregular but can be induced and made more regular by scarifying the seed through mechanical abrasion or by the chemical action of concentrated sulfuric acid for about three-quarters of an hour. Freshly harvested seed will readily germinate if scarified (Cobley, 1976; Kay, 1973; Onwueme, 1978; Purseglove, 1968).

There is early adventitious root development from the nodes at and near the attachment of the first fully expanded leaf (Togari, 1950). The number of roots formed reaches a maximum 10-15 days after planting. Based on the primary cambial activity and the amount of lignification of cells of the stele, the roots can be grouped as 1) young, 2) fibrous, 3) pencil-form, and 4) storage roots. In all, 10 kinds of roots have been described for the sweet potato (Wilson, 1982).

During early growth, changes in environmental conditions influence the proportion of roots that are formed in each root class. The number of storage roots may be determined as early as 30 days after planting. Cool weather of about 23^{0}C along with an adequate supply of potassium lead to rapid cambial activity and little lignification of the roots, a combination which favors the development of the tuber. Further development is dependent on an increase in the number and size of the cells and on the development of starch granules (Hahn and Hozyo, 1983). There is a slow increase in the number and size of the cells for the first 40 days after planting, followed by accelerated growth up to 60 days after planting. Most cells reach their maximum size by the 60th day. The starch granules follow a similar pattern (Thomas et al., 1971).

Thus, the components of yield of the sweet potato are determined in sequence. The number of storage roots is determined first, then storage size is determined by cell division and expansion, and lastly, the synthesis of

starch granules determines the density of starch in the cells (Togari, 1950). It follows, therefore, that changes in one component of the potential yield, as influenced by environment, will lead to an adjustment by the plant in the components that are subsequently developed (Hahn and Hozyo, 1980; Thomas et al., 1971).

In sweet potato, dry weight accumulates in the economically important tuber while the stems and new leaves continue to grow. Growth rates in the tuber are small initially but increase to a maximum and then decline with the onset of maturity (Hahn and Hozyo, 1983).

The leaves are the main source of assimilate for the total dry weight of the crop. Yield, therefore, depends on the extent of the leaf area developed, the rate at which it works, and the length of time it persists. Since new leaves are continuously produced until harvest, the leaf area maintained is due almost entirely to the activity of apical meristems and to the growth and longevity of the leaves produced. After the growth of the tuber has begun, a portion of the current assimilate must be partitioned for the growth of new leaves in order to maintain the leaf area needed for continued production of dry matter (Hahn and Hozyo, 1983).

Cultivation systems

"The most important human-influenced adaptation of sweet potato has been its integration into agricultural systems, the diversity of which is only hinted at by the variations of environments. It is a comparatively easy crop to grow, and in the tropics it exhibits no strict seasonality, so that it can be combined in mixed fields with other tubers or roots, vegetable species and even grain . . . It is a constant provider of farinaceous staple, and is often integrated into indigenous cultivation cycles with a secondary role as a feed for livestock, often occupying inferior land." That quote from Yen (1982) clearly indicates the utility of the sweet potato in numerous diverse cultivation systems. It is widely grown in tropical, subtropical, and warm temperate areas under systems ranging from highly intensive mechanized cultivation to subsistence farming. A wide range of cultivars are used that differ greatly in their adaptability. However, optimum growth occurs at about 24°C or more, coupled with abundant sunshine and warm nights. The sweet potato is tolerant to periods of drought but needs 500 mm or more of rain throughout the season. Sandy loam soils that are well-drained are best, with yields being reduced by varying degrees on less ideal soils (Kay, 1973).

The three major methods of land preparation for sweet potatoes are ridges, mounds, or flat surface preparation. Of these, ridge planting is the

most generally accepted method. It has been well demonstrated that higher yields are obtained on higher ridges to a maximum ridge height of about 36 cm. In each situation, the optimum ridge height depends on soil type and the sweet potato cultivar being grown (Onwueme, 1978).

The sweet potato cropping systems around the world are determined by local conditions, and in more sophisticated farming operations, by the dictates of economics. In some tropical areas rainfall patterns allow for two crops of sweet potato a year whereas in the drier areas only a single planting is possible.

Uses

Sweet potatoes are primarily used for human consumption. Generally, they are consumed directly, the main types of preparation being boiling, baking, roasting, or frying. In cultures where leaves are consumed as a vegetable, they are usually eaten boiled or as a component of a soup or stew. The leaf is more nutritious than the tuber, being richer in protein, minerals, and vitamins.

In the processed form, the tubers are prepared in numerous ways for human consumption. They are made into flour and starch, or they are canned, frozen, or dehydrated. For industrial uses, the tuber is a source of starch, glucose syrup, alcohol, acetone, lactic acid, vinegar, and pectin (Kay, 1973; Onwueme, 1978; Purseglove, 1968).

The tuber and plant tops also are a source of animal feed. The tuber is fed directly or in some processed form, and leaves are fed to livestock as fresh fodder or in the form of silage.

Yams

Importance

Yams are one of the major components of the starchy staple intake for a large number of people living in the tropic zone and have much regional importance in West Africa, Southeast Asia, the Pacific Islands, the Caribbean Basin, and tropical Latin America (Kay, 1973; Onwueme, 1978; USAID, 1974). In times of food scarcity, wild types are sometimes used to alleviate hunger. Some yams contain organic compounds used to produce steroid chemicals in the manufacture of pharmaceuticals. The size of the global harvest, about 19 million tons annually, makes the crop of great importance to the world's food supply. Yams are of great ethno-agricultural significance in the West African region where a considerable

amount of ritualism has developed around their production and utilization (Onwueme, 1978). Most of the world production of yams is consumed within the country of origin with little entering international trade, and is therefore important to the domestic economies of such countries (Kay, 1973; Onwueme, 1978).

Growth and development

Cultivated yams are vines and are trained on some type of support. The vines vary greatly in length, growing from 3-10 m under good management. There is considerable variation in the shape, size and color of the leaves. Generally, the lamina is simple and lacking marginal serrations. Leaves may also be lobed or made up of three leaflets. Cultivated yams seldom flower and many cultivars do not flower at all. When there are flowers, they are very small and white to brown in color. Normally, the male and female flowers occur on separate plants. The yam fruit is a dehiscent capsule, trilocular in shape, with the junctions of the locules extended out into flattened wings. The tuber grows from a corm-like structure located at the base of the vine as do the main feeder roots. The many cultivars vary greatly in tuber characteristics: size, number per plant, shape, texture of the flesh, and taste.

Tuber growth begins with the onset of meristematic activity at the junction of the stem and root. The resulting mass of cells develops a growing point and the tuber begins to elongate. The growing point, which is distal to the tuber point of attachment, contains the primary meristem. The primary meristem continues to divide and produce more cells, which enlarge and become filled with starch. During its growth out from the point of attachment, the primary meristem leaves a thin strip of meristematic cells beneath the cortex. Parenchymatous cells beneath the epidermis become meristematic, produce cork cells, and isolate the cells external to them. The process is repeated so that the mature part of the tuber is covered by several layers of cork. Tuber maturity is generally reached 8-11 months after planting (Cobley, 1976; Kay, 1973; Onwueme, 1978).

Cultivation systems

In primitive farming, yams are usually the first crop on the land after clearing the bush for cultivation. In West Africa, a common rotation consists of bush fallow-yam-maize-cassava-bush fallow. There is frequent intercropping with melons, chilies, maize, okra, spinach, and other vegetables. The best planting materials are small, whole tubers. The production of seed yams is becoming popular and profitable for farmers

specializing in their production. Yam production using minisetts and microsetts as a vegetative seed source is gaining in popularity. (See Chapter 5.) The setts may be planted on flat ground, in trenches or holes, on mounds or ridges, or in raised beds. After planting, stakes are provided for vine support in order to maximize yields. However, selection and evaluation from the IITA yam germplasm collection has recently identified lines that produce high yields when the vines are grown on the ground without staking (Alvarez et al., 1983).

Uses

The yam tuber is a starchy staple food eaten as a vegetable. Preparation is by boiling, baking, roasting, or deep frying in oil. A popular West African preparation is pounded yam, for which the cooked tuber is mashed in a mortar into a stiff glutinous dough termed "fufu" and eaten with a stew. In a processed form, yam flour, yam flakes, and yam chips are made. The pharmaceutical industry uses the yam as a source of steroids (Kay, 1973; Onwueme, 1978).

Cocoyams

Importance

Colocasia spp. and *Xanthosoma* spp. are commonly referred to as cocoyams among other names. (*Colocasia* spp. are often called taros, with two predominant types: eddoe and dasheen. A common name for *Xanthosoma* spp. is tannia.)As with yams, the importance of cocoyam is that it is one of the starchy staples of people in the tropics. As a food crop it is grown in much the same regions as yam, sweet potato, and cassava. The world harvest of cocoyam is about 4 million tons annually and most is consumed in the country of origin, with very little entering international trade.

Growth and development

Cocoyams are essentially warm weather lowland crops. The best yields are at a mean temperature above 21°C with an annual rainfall exceeding 2000 mm. Among the eddoe and dasheen types, the eddoe types are more tolerant to drier conditions while the dasheen types do best under flooded conditions. Tannia does not tolerate waterlogging well, and so it grows best on deep, well-drained soils.

Eddoe types have a relatively small corm surrounded by large, well developed cormels. The dasheen types have a large central corm and fewer,

more compactly clustered cormels of a smaller size. Tannia has a corm at the base of the plant and this produces a number of lateral cormels.

Propagation is by vegetative means using small corms, cormels, stem cuttings, or pieces of these. The rapid increase in shoot growth soon after planting slowly declines after about 6 months. Both taro and tannia follow this general pattern. With taro, this decline is observed as a reduction in leaf number and size. The shortening of the leaf petiole is seen as a general decrease in plant height in the field. Throughout the growing season there is a continual turnover of leaves, with the older leaves dying as new ones appear.

Corm formation begins about 3 months after planting. Corm and cormel growth is slow initially but increases later in the season when shoot growth is slowing. The corms mature 6-18 months after planting. The cormels arise from the axillary buds on the corm. Both the corms and the cormels show considerable variation in size, shape, flesh color, acridity, and taste among the various cultivars (Cobley, 1976; Kay, 1973; Onwueme, 1978; Purseglove, 1968).

Cultivation systems

Taro is grown under flooded lowland conditions similar to that required for rice. Tannia and upland taro are grown as dryland crops. For flooded taro, level land is required and preparations follow the same pattern as for rice, i.e., plowing, discing and harrowing, and puddling for minimum percolation of impounded water. The operations are either manual or mechanized depending on locality and technical level of the farm practices. For taro or tannia grown in an upland situation, land preparation involves clearing, plowing, harrowing, and sometimes the formation of furrows. Planting on the flat ground is the most common method, although ridges or beds are sometimes used. In traditional farming, planting is done on low mounds often similar to those prepared for yam or cassava, or on flat, unprepared land. Growing cocoyams as an intercrop is also a common practice (Kay, 1973; Onwueme, 1978).

Uses

The edible corms and cormels of cocoyams are rich in starch and consumed in a way similar to yams, sweet potatoes, or cassava. Preparation is by boiling, baking, or deep frying in oil. In West Africa, *fufu* is made from boiled corms and cormels. In the Pacific Islands area, the manufacture of *poi* is an established industry. The fresh or cooked corms and cormels can be milled into flour after drying. The leaves and petioles,

especially when young, are used as a vegetable. Except for the roots, all parts of the cocoyam can be used as a feed for livestock. Industrial uses include mucilage for paper and pharmaceutical makers, a source of alcohol, and a fermented drink (Cobley, 1976; Kay, 1973; Onwueme, 1978; Purseglove, 1968).

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CHAPTER 2. STATUS QUO OF SEED PRODUCTION

Current Practices in the Production of Seed Potato

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Introduction

The potato-producing countries of the developing world, for a variety of reasons, have not been able to adopt modern seed production technology; seed costs are still high, while quality is low. Most of these countries, with the exception of the Andean area, have relied on imports from countries better able to produce high-quality seed. Since the formation of OPEC and spiraling costs of petroleum in the 1970s, many governments trying to keep their budgets down have demanded that seed potato imports be reduced drastically or stopped altogether. Thus, scientists in developing countries are under pressure to catch up with seed potato production technology generated by Europe and North America. Most of these countries have little or no history of seed certification in potato or other crops, and they are lacking adequate infrastructure to adopt and support advanced technology. CIP and other institutions have made a tremendous effort in the past decade to train scientists in seed production techniques, certification, and the related fields of pathology, entomology, nematology, and physiology. This effort, accompanied by governmental inputs, is beginning to pay dividends.

However, there are still many problems. The present technology of the countries in the northern hemisphere was not developed nor adopted in a few years. It has evolved over time. Also, the needs of temperate-zone agriculture are not necessarily the same as those of tropical or subtropical agriculture. The technology needed to meet these needs likewise may differ.

Seed production programs

The technology exists to produce large quantities of planting material for potatoes that will realize 90% or more of the yield potential of most varieties. However, where it is needed the most, in developing countries, only 20-25% of the yield potential is being produced. Seed production programs are varied, but they can be put into general groups, as described below.

1) No program; local varieties produced by farmers and distributed on an informal basis. No trained personnel are utilized.

2) All seed imported; minimum infrastructure needed: someone to choose the variety, place the order, and attend to distribution to local ware growers. This is often done by the private sector. A low-quality seed is often imported.

3) Seed imported and some multiplied once. The multiplication is usually informal with farmers saving some of the seed tubers in order to plant the succeeding crop. This works very well where two crops are grown in the same year. Some infrastructure may be needed to select fields with the best seed for wider distribution.

   This system gives best results if only a small amount of medium-quality seed is imported and almost all of the harvest is used for planting the succeeding crop. A trained person is needed to help with selection of the best material and remove plants with the most severe diseases. This system can reduce imports by about 50%.

4) High-quality seed imported and multiplied twice before sale to ware growers. More infrastructure is needed and, in addition, field inspections and more roguing are necessary. Selection of production areas with low vector activity is desirable. Virus identification abilities and small laboratories may be needed.

5) High-quality seed imported and multiplied for three years. Inspection services and marketing or distibution systems are needed, as well as pathologists and laboratories.

6) A full-fledged program. If three multiplications have been successful, a complete program should be considered. This can take one of two paths:

   - Small amounts of very high-quality seed may be imported and multiplied five to six generations prior to sale to ware growers. A full team of inspectors with certification regulations is needed.

Virologists and other pathologists with laboratory facilities, as well as a highly-developed marketing system, are indicated. Highly-trained farmers to grow seed are essential.

- The import of a few tubers or use of local varieties may be maintained indefinitely. A clonal selection system for producing prebasic and basic seed by scientists or highly competent private growers is needed. A tissue culture section is optional, but a greenhouse and laboratories are essential. Competent scientists, inspectors, and seed growers also are needed.

Developing countries at present are in various stages of these steps. Most areas of North Africa are multiplying imported seed once and moving into two multiplications. South Sahara Africa and Asia vary between 100% import to a full program. In Latin America, there are all types and combinations of these programs. The successful ones took time to train the last link in the multiplication chain—the farmer producing the seeds. They have also been successful in making the potential users of the seed produced aware of the benefits of high-quality planting materials.

Seed production techniques

Several types of production techniques can be used to produce improved seed stocks in potatoes. The examples given below each have many variations depending on national needs.

Farmer's seed plot technique

This method uses a positive selection process (saving tubers from the best plants as opposed to negative selection, which is removal of diseased and undesirable plants and their tubers). The system works best for small farmers with less than 3 ha of potatoes. Its use enables the farmer to produce improved seed for his own use through a planned process of selection from his own seed stocks. The best plants in an existing field are marked by staking during the growing season. These plants are harvested and stored separately from the unmarked plants and used the following season to plant a seed plot. The process is repeated each year by selecting the best plants in the current seed plot for the new seed plot. The remaining tubers of the current seed plot are used as seed for the farmer's normal potato crop. No roguing is required although its use would improve the method's efficiency. The major requirement is ability of the grower to recognize symptoms of yield-reducing diseases.

This method will help to develop farmers as seed growers if the national program decides to utilize more sophisticated seed production techniques.

Negative selection or straight roguing

This is a common seed production method widely used by seed growers. It is simple and effective. Diseased and other undesirable plants are removed from the seed potato field as soon as symptoms of diseases are expressed. The removal (roguing) requires that all plant parts, tubers, stolons, and vines are carefully removed from the field in air-tight bags and destroyed. The method, although simple and effective, is often impractical in developing countries because of the farmers' reluctance to eliminate any plant that may produce some food. The system is most effective with persistent virus diseases such as potato leaf roll virus (PLRV).

Clonal selection

This is done by initially selecting high-quality tubers within a variety (clones), and then multiplying each clone's progeny separately for three or more generations. Any evidence of disease (especially nonpersistent, contact, or latent virus) results in the discarding of the entire clone. The method requires the use of antisera techniques for most efficient detection of latent viruses. Low-yielding clones should be eliminated even if no diseases are present.

Rapid multiplication techniques and in-vitro plantlets

The methodologies of these techniques are given in detail in Chapter 5. They fit ideally into the clonal selection system, but because this initially requires very large numbers of each clone, each being of a high health standard, clonal selection is usually based on plant type and yielding ability.

Clonal selection and rapid multiplication, while adaptable to farmer seed growers, are often best carried out by governmental institutions, with later multiplications being carried out by the farmer producing the seeds.

Use of true potato seed (TPS)

The use of botanical seed or TPS has many advantages over tuber seed. Seed health is much higher, transport and storage are minimal, and no edible parts are planted. The use of TPS is still in an experimental stage. At present three methods of using TPS are available: 1) direct seeding, 2) transplanting, and 3) direct seeding or transplanting in beds at a high density (100 plants/m^2) to produce small, healthy tubers for field planting.

Open-pollinated or hybrid seed can be used to produce TPS. Hybrid seeds usually give higher yields than open-pollinated ones, but they are

much more costly to produce. Desirable parents often have poor flowering and seed set when grown in areas with short days and high temperatures. TPS has a huge potential, but it will be some time before this potential is reached.

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Current Practices in the Production of Cassava Planting Material

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Introduction

Cassava stakes for use in vegetative propagation have been obtained in a very simple manner for thousands of years by taking stem cuttings from mature plants. This work is usually done by unskilled workers. Furthermore, cassava planting material is not produced from what is normally a commercially utilizable part of the plant, but from waste material discarded in the field. It is probably for these reasons that, in general, stake production is still practiced at a technologically very low level. These practices, however, give rise to a number of problems leading to low productivity of the crop. This paper reviews some of the current practices in stake production and points out some elements necessary for improvement.

Selection of stakes

This section should probably more accurately be entitled 'non-selection of stakes' since a conscientious selection of mother plants according to nutritional and health status, followed by a careful selection of stakes from these plants, is hardly ever done in traditional production systems..

The more common practice is instead to first cut down all tops at root harvest and then obtain stakes from stems scattered over the field. There is no opportunity at this stage to discriminate between diseased and healthy plants or between well-developed, well-nourished plants and poorly-developed, nutrient-deficient plants.

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Furthermore, in traditional systems, hardly any selection is made with regard to the maturity of the stake. This means that along with stakes of adequate maturity (recognized by a relation of total-to-pith diameter of between 2:1 and 3:1), a large number of either too young, i.e., succulent stakes, or too old, i.e.,very lignified stakes, are selected. This leads to plant loss and a patchy, uneven sprouting of stakes.

In many cases, stakes are obtained when stems have been cut for a week or more and thus have been exposed, in the field, to both dehydration and infestation by pathogens and insects, passing a serious risk on to the new plantation right from the start. Even worse, circumstances often oblige farmers to store cassava stems for several months before stakes are cut for planting. Although some attempts generally are made to protect the stems from full sunlight and thus from desiccation, no chemical protection against fungal pathogens or insects is normally provided, and the sprouting during storage depletes the stems of carbohydrate which the stakes then lack when the new crop starts to grow (Leihner, 1983).

Cutting and preparation

Cutting tools

Axes, knives, machetes, and saws of all kinds are used to cut stakes. Overly heavy tools often damage the stakes, which are then readily infested with soil-borne pathogens and insects after planting. Medium-sized machetes are best suited for hand cutting stakes but they are seldom available to farmers. Motorized circular saws are mostly used for stake cutting in large-scale operations. While being efficient in cutting large numbers of stakes in a short period of time, this tool also carries the risk of disseminating systemic diseases present in some stakes to all the rest. Manual cutting, however, allows the tool to be disinfected after cutting the stem of each plant before starting on the next one. In mechanized planting, a planter machine is fed with pre-cut stakes, or a planter-cutter machine is fed with long stems which it cuts. The freshly cut stake is often sprayed with fungicide and then deposited into the ground by the planter.

Cutting methods

A great variety of cutting methods are presently practiced worldwide. In one of the common methods, the long stem is placed on a base made of wood or some other material and then cut with a heavy, short axe or knife, or with a machete. The cut in this case may be slanted or rectangular but in all cases, bark and bud damage is frequent around the cut end when the cassava stem rests on a base. Another frequent way of cutting consists of

holding the long stem in the air and separating the stake from it by one single cut. In this way, the cutting angle is slanted. While avoiding physical damage to the stake, the slanted cut induces an undesirable rooting pattern to the stake, concentrating root formation at the stake tip. This occurs with either vertical or horizontal stake planting. While not being of great significance to total root yield per se (CIAT, 1980; Leihner and Castro; 1979), an uneven distribution of roots around the cut end of the stake may lead to less anchorage and more falling over of plants, as well as to a greater number of irregular, small roots.

Stake length

As with cutting methods, farmers use a great variety of stake lengths in commercial plantings. Stakes as short as 10 cm with only two to four buds may be used by some, whereas others cut and plant stakes of 40 cm or more. Short stakes do not appear to have a negative effect on root yield when growing conditions are optimum (Leihner, unpublished, 1983). However, under less than optimum field conditions, short stakes with their small carbohydrate reserves and low vigor are likely to produce weak plants which cope less well with rough soil conditions, drought, or weeds; their low bud number also poses a risk for establishment (CIAT, 1975; Toro and Atlee, 1981). Poor stake quality together with small stake size may therefore be a frequent cause for uneven stands in farmers' fields and result in low yields. Overly long stakes, on the other hand, may produce more top growth compared to root growth, with a low harvest index and root yield as a consequence. Also, long stakes mean the use and transport of more stake material than necessary, which increases the cost of planting. For these reasons, stake lengths between 20 and 40 cm are probably the most efficient.

Mukibat system

The traditional and rudimentary methods of selecting and preparing cassava planting material stand in contrast to a very careful and elaborate system known as the Mukibat system. A well-selected *Manihot esculenta* stake is used as a stock onto which a *Manihot glaziovii* scion is grafted. One *M. glaziovii* scion generally has one cassava stake attached to it, but may have three to four (Satrawi system). Planting material selected for grafting, the grafting process itself, and the planting are all carried out with great patience and care, and yields are said to be much higher than with normal cassava culture (Guritno and Soetono, 1979). However, it remains to be seen what yield might be obtained from a normal cassava culture which has been raised with the same investment in time and care as a Mukibat culture.

Handling before planting

Transport

The majority of cassava planting material is transported in the form of long stems to facilitate handling and reduce moisture loss. Bundles are often tied up and carried by animals or trucks from the place of production to the site of utilization. Besides the fact that in this way diseases or insects and mites are often introduced into an area where they had not been before, any method of transportation causes mechanical damage. Transportation is therefore avoided as much as possible by experienced farmers. At one time, transport of cassava planting material was prohibited in central Colombia and the farmers themselves strictly prevented planting material from being carried from one department to the other. In this way, they were able to eradicate cassava bacterial blight (CBB) from the area and prevent it from entering again. Farmers thus may restrict transportation of planting material to within the farm or at most, to an exchange of stakes from one farm to the other.

Chemical treatment

Although cassava is an important crop in many tropical countries, it is rarely managed in the intensive way other food or cash crops are. Thus, the use of agricultural chemicals for cassava is very limited or even nonexistent. Chemical treatment of stakes for pest control and protection against soil-and air-borne fungi after planting is not a common practice among cassava producers. Many farmers simply do not know about this simple and inexpensive way of stake protection. In other cases, names of appropriate products are unknown or the products themselves are unavailable. In this area, therefore, great progress can be achieved by making information and appropriate chemical inputs available to farmers (Lozano et al., 1977).

Conclusions

Cassava planting material is obtained in a very simple manner from low-value raw material and probably for this reason no refined stake production technology has developed among farmers. Hardly any selection of stakes is practiced; healthy and diseased, weak and vigorous, mature, immature, and overmature stakes are all used alike. Cutting is often done with inappropriate tools, either too light or too heavy, and damage is frequent. The cutting angle can also be important, as irregular,

undesirable rooting patterns have often been observed in stakes cut on a slant. Most cassava growers use stake lengths between 15 and 40 cm, which is adequate. Sometimes, however, stakes are either too long or too short, both practices reducing crop productivity. In post-harvest handling of stakes, transportation is minimal and normally does not constitute a problem, but chemical protection of planting material is still largely unknown and practiced by very few farmers. This review would suggest that in order to improve stake production technology, the primary considerations are selection of stakes for healthiness and adequate maturity, non-damaging cutting practices, the use of appropriate stake lengths, and chemical protection of the stakes.

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CHAPTER 3. PHYSIOLOGICAL AND SANITARY PROBLEMS IN SEED PRODUCTION

Physiological Problems in the Production of Seed Potato

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Introduction

The physiological condition of seed potatoes is an important characteristic that influences the success of emergence and the growing pattern in a potato crop. Planting seed tubers which are not in the right stage of physiological development can result in reduced yields and even complete crop failures. By selecting tubers of the appropriate physiological age, a farmer can manipulate the time of crop maturity—early, medium, or late. The physiological condition of seed potato tubers is influenced by both growing conditions and storage practices.

Physiological aging

Starting with its initiation, a potato tuber continually develops both morphologically and physiologically. The physiological state of a tuber is referred to as its physiological age, which is expressed in biological rather than chronological terms. For example, on a certain planting date, the chronological age of different seed tubers may be the same but their physiological age may differ considerably due to the effects of different growing or storage conditions.

The physiological development of seed potatoes, although influenced by the tuber itself, is primarily related to sprout development. After initiation, the potato tuber develops physiologically through the stages of 1) dormancy, 2) apical dominance, 3) multiple sprouting, and 4) senility.

Dormancy

Following initiation of growth, a potato tuber is usually dormant for a certain period. That is, it does not sprout even under favorable environmental conditions. The true dormancy period is the time between tuber initiation and the initiation of sprouting, but in many potato production situations, dormancy refers only to the post-harvest period. It is extremely risky to plant seed tubers while they are still dormant. This practice results in delayed and irregular crop emergence and, in extreme cases, the tuber will rot in the soil before sprouting. The length of the dormant period is influenced by variety, previous growing conditions, storage temperature, tuber condition, and maturity. Tuber dormancy may vary from nearly zero to several months depending on variety. Length of the dormancy period is not related to the maturity class of a variety or to the subsequent rate of sprout growth.

Due to accelerated physiological processes, the dormancy period of seed tubers is reduced when stored at high temperatures. However, in some varieties a fluctuating storage temperature is even more effective than constant high temperature in shortening the dormancy period.

Mechanically injured or diseased tubers commonly have a reduced dormancy period. Thus, cutting seed tubers may promote earlier sprouting. Where only the post-harvest dormancy period is being considered, it is clear that younger, immature tubers will usually have a longer residual post-harvest dormancy period than older, mature tubers.

Apical dominance

Sprouting commences following the break of dormancy. Frequently, the apical eye begins to sprout first and this may suppress sprout growth in the other eyes. This phenomenon is termed apical dominance. Planting seed tubers in this condition results in a crop with single stems. This may reduce yields unless a higher seed rate is used to reduce plant spacing and re-establish the required higher stem density. Expression of apical dominance varies among varieties and it can be influenced by storage conditions and management, as discussed in Chapter 6.

Multiple sprouting

Following the initiation of growth by the apical sprout, other lateral buds begin to initiate growth and additional sprouts are formed to produce the multiple sprouting stage. The time lapse between apical dominance and multiple sprouting depends on variety and storage conditions. Similarly,

the final number of sprouts produced is characteristic of the variety. At the beginning of the multiple sprouting stage, a tuber is said to be physiologically young, and at the end of this period it is relatively old. The multiple sprouting stage may last for many months provided the tubers are stored at moderate temperatures. Storage at high temperatures reduces this period. Storage in diffused light helps to maintain short and vigorous sprouts and so prolongs this period. The multiple sprouting stage is the optimum physiological stage for planting.

Senility

With increasing physiological age, sprouts begin to branch profusely and become long and weak. In general, such seed tubers should not be desprouted even when sprouts have become excessively long, as the tubers may have lost their sprouting capacity. Often desprouting results in the formation of weak 'hair sprouts'. Such physiologically old tubers are too weak to produce vigorous plants in the field. With excessive physiological age, small tubers are sometimes formed on the sprouts either before planting or, commonly, after planting physiologically old seed in poor conditions. This latter phenomenon is known as 'little potato disease'. Senility is delayed when seed tubers are produced and stored under cool conditions. Although different varieties react differently, a given stage of physiological aging is generally arrived at sooner following production and storage under hot conditions.

Effect of physiological age on crop production

The physiological age of seed tubers not only influences sprouting behavior as described above but also crop stand and development (Table 1). Plants from physiologically old seed tubers develop their stand and yield potential rapidly, however, such a crop matures early and total yield

Table 1. **Influence of physiological age on crop development.**

	Physiologically young seed	Physiologically old seed
Emergence	late	early
Tuber initiation	late	early
Foliage production	high	low
Tuber number	high	low
Crop maturity	late	early
Yield potential	high	reduced

remains limited. Plants from physiologically young seed develop slower, but since the crop grows longer, the total yield potential is higher.

Thus, when the available growing period is limited due to climate, cropping pattern, or socioeconomic reasons, it is advisable to plant physiologically older seed tubers, as a higher yield may be obtained from the early harvest. Conversely, when the available growing period is long, maximum yields may be obtained by planting physiologically younger seed tubers (Figure 1).

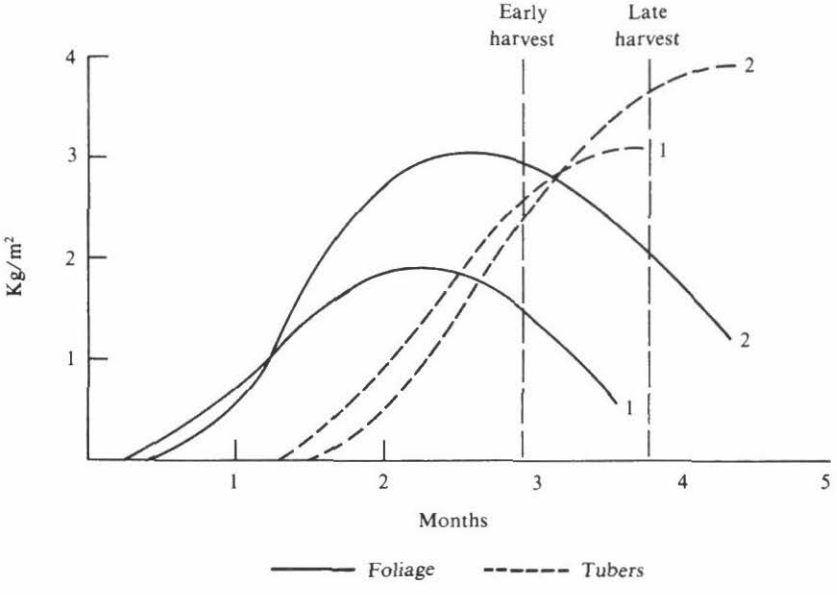

Figure 1. *Difference in growth pattern on an early-maturing crop (1) and a late-maturing crop (2). At early harvest the highest yield is obtained with growth pattern (1) and at late harvest with growth pattern (2).*

Manipulation of physiological age

Although the physiological development of seed tubers is greatly dependent on variety, it can also be influenced by growing conditions and storage practices.

Growing conditions

Within traditional potato-growing climates, the physiological age may be influenced slightly by selection of growing sites and management of soil conditions. It is believed that the physiological aging process is somewhat accelerated by a hot growing climate, light soil structure, low soil moisture, and low soil nitrogen fertility. However, as observations of potato growth over a wider range of climates become more numerous, it has been found that physiological factors linked with environmental conditions at the location of tuber origin can override the normal expression of physiological age. For example, emergence and tuber initiation has been observed to be earlier, and foliage development and total yield to be greater, in seed tubers produced under cool growing conditions rather than those produced under very hot conditions. The exact physiological nature of these origin-linked phenomena are not fully understood.

Storage practices

Physiological aging during storage depends mainly on the length of the storage period and the storage temperature. Both these factors can be combined in the mathematical product 'day degrees'. Thus, the longer a tuber is stored and the higher the storage temperature, the higher is the accumulated number of day degrees, and the more physiologically advanced are the tubers. However, there is some disagreement among researchers about whether the calculation of accumulated day degrees should commence at tuber initiation or tuber sprouting. Also, the day degree model is not adequate for explaining the origin-linked differences in performance as described above.

As the effect of physiological age on yield varies with variety, origin of seed tubers, and growing conditions, it is not possible to design specific management practices for all situations as these will vary according to local conditions and needs.

Size of seed tubers

In addition to the physiological aging process, a further physiological consideration in the production of seed tubers is that of optimum tuber size. This is important due to its effect on the quantity of seed and, thus, the cost required to produce a ware crop. A requirement for a certain seed tuber size can influence the storage and production practices used for producing a seed crop.

Optimum tuber size is a complex subject and will not be given detailed attention in this paper. Simply to illustrate some of the factors involved, an example is given in Table 2 in which a crop is being produced from seed tubers of different sizes. The goal is a stem population of 24 main stems/m^2 with a row spacing of 75 cm. If the expected number of stems produced per seed tuber given in this example is correct (thereby producing approximately the same yield per hectare from all tuber sizes), and if the price per ton of tubers of the different sizes is the same, then it would be more economical to use seed tubers of a medium size.

Under existing field management practices, the anticipated number of stems developing from small seed tubers is generally low, as used in the example of Table 2. This considerably increases both the risks of failures and the total weight of seed tubers required. However, research has shown that with some additional care, higher stem numbers can be established from even very small tubers and this could, therefore, make their use highly economical.

Recent findings have in fact shown that under medium soil temperatures (15-20°C), even very small seed tubers, down to only 5 g, can produce excellent crops with more than one main stem per plant at seed rates of

Table 2. **Approximate seed requirements for different seed tuber sizes for a population of 24 main stems/m^2.**

Seed tuber size (mm)	25-28	28-35	35-45	45-55
Ave. seed tuber weight (g)	15	22	45	80
Spacing between seed tubers (cm)	5.5	14	25	33
Expected stem no. per seed tuber	1	2.5	4.5	6
Seed tuber no. per m^2	24	10	5.3	4
Seed tuber no. per ha	240	100	53	40
Seed tuber weight per ha (t)	3.6	2.2	2.4	3.2

only 0.5-1.0 t/ha. This opens up the further possibility of using true potato seed (TPS) or other rapid propagation systems to produce large numbers of these small tubers and, thus, to reduce seed tuber costs even further. As the area required to produce large numbers of small tubers from TPS is small, health factors can be rigorously controlled. By such means a high health standard can be assured in small tubers produced from TPS, whereas the small tubers from commercial seed tuber crops frequently carry disease, which is another factor influencing their low productivity in traditional seed tuber production systems.

Conclusion

It can be seen that consideration of specific aspects of seed tubers, in terms of size and physiological age, can aid in reducing their cost. Reduced seed tuber cost would reduce the cost of consumer potatoes, and hence increase their consumption in many developing countries.

Physiological Problems in the Production of Cassava Planting Material

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Introduction

The production of cassava stakes for planting material has been a rudimentary process for thousands of years and only recently have scientists begun studying some of the problems related to it. Genotypic characteristics, plant age, tissue age within the plant, and plant nutrition are among the factors playing a role in cassava stake production. A comprehensive research program is necessary to find out how these and other factors influence stake production and to determine management practices for cassava in order to produce optimum stake yields. This paper provides preliminary information on some of the physiological aspects determining the performance of cassava stakes.

Genotypic influences

The two varietal characteristics which potentially most affect stake production of a cassava genotype are its general vigor and its branching habit (Leihner, 1983). While overall vigor determines the amount of top growth and consequently the number of stems available for stake cutting, the branching habit determines the availability of primary and secondary stems, which are the parts mostly used for planting material.

An in-depth study was conducted to examine the growth habit, stake number, and stake production efficiency of four cassava genotypes. Total top growth at 12 months after planting was low with the non-vigorous, late branching cultivar M Col 22, intermediate with two more or less erect, vigorous hybrids (CM 516-7 and CM 849-1), and high with the very vigorous, early branching cultivar M Mex 59 (Figure 1). There were also

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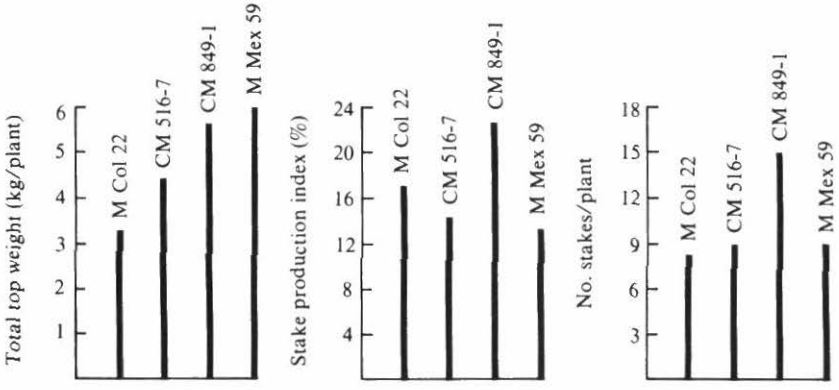

Figure 1. *Total top growth, stake production index, and number of stakes produced per plant of four cassava genotypes 12 months after planting (CIAT, 1983).*

large differences in the efficiency of the different genotypes to produce stakes, as measured by the stake production index (SPI = stake fresh weight over total top weight multiplied by 100). The two erect growing genotypes (CM 849-1 and M Col 22) showed greater efficiency than the non-erect genotype (M Mex 59). The hybrid CM 516-7, which grows more or less erect, has an enormous foliage retention capacity leading to a low SPI compared to CM 849-1 and M Col 22. M Col 22 produced only half the total top growth of M Mex 59, yet still produced approximately the same amount of stakes per plant.

Plant age

One of the unknowns about cassava planting material is the effect of plant age. For this reason, a study with four genotypes was initiated, taking harvests from 6 to 14 months after planting at 2-month intervals. Over the 8-month observation period, top growth continued in all four genotypes, with the greatest amount of stem and foliage produced by M Mex 59 and the smallest amount by M Col 22 (Figure 2).

The SPI, indicating the efficiency with which cassava tops can be used in stake production, increased up to 12 months of age and declined thereafter in M Col 22, CM 516-7, and CM 849-1 (Figure 3). M Mex 59 reached maximum efficiency at 8 months of age, after which the SPI declined. The latter cultivar also showed the lowest SPI, on average, whereas the two erect growing genotypes, M Col 22 and CM 849-1, had the highest stake

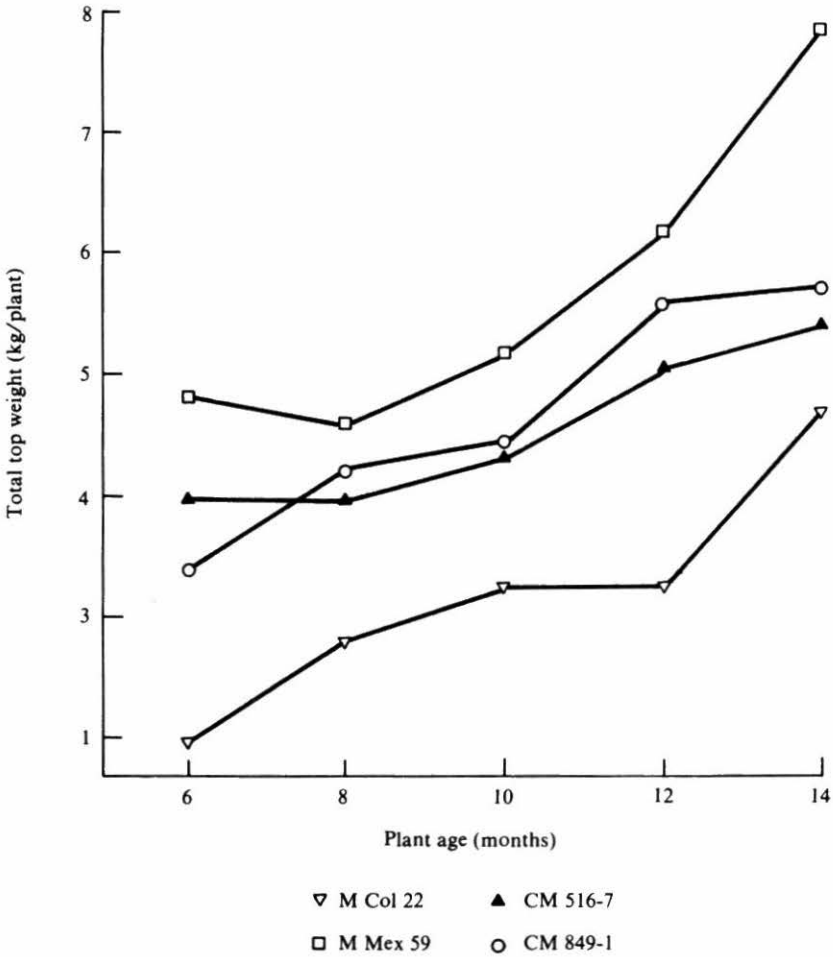

Figure 2. *Total top growth of four cassava genotypes from 6 to 14 months after planting (CIAT, 1983)*

production efficiency over most of the 8-month period. As a result of continuously increasing top growth, and an initial increase followed by a decrease in the SPI, the number of stakes per plant initially increased and then leveled off or declined (Figure 4). The hybrid CM 849-1, which demonstrated outstanding stake production efficiency, also produced the greatest amount of stakes in absolute terms, whereas the other three genotypes did not differ greatly in stake number produced per plant.

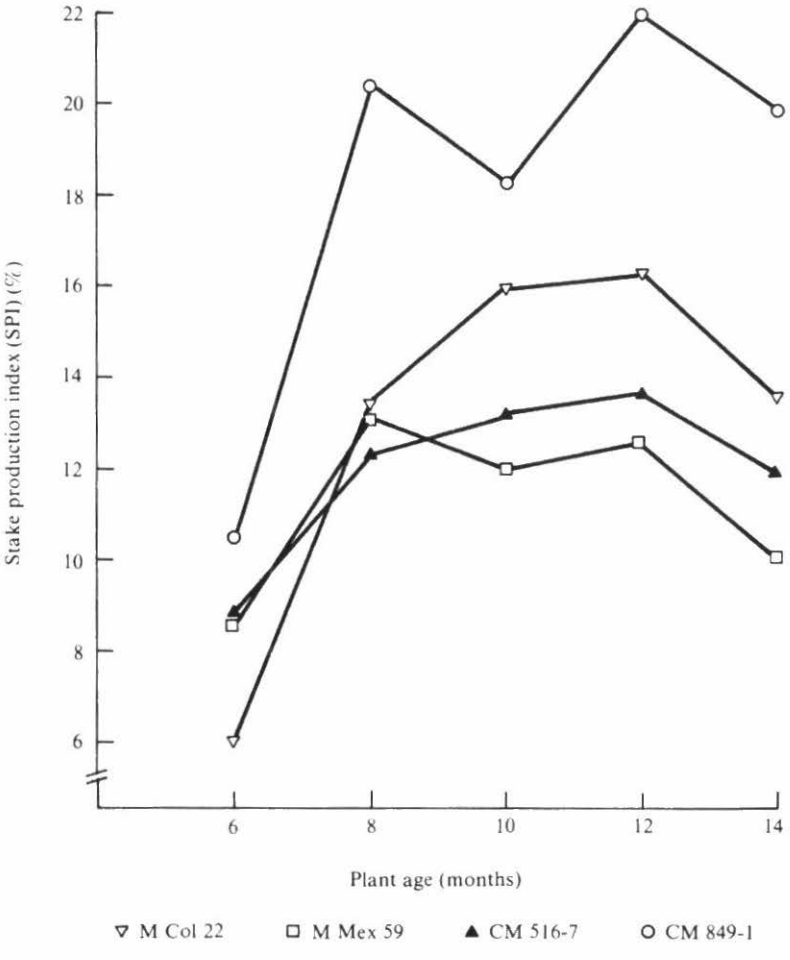

Figure 3. *Stake production index (SPI) of four cassava genotypes from 6 to 14 months after planting (CIAT, 1983).*

Stake quality, as expressed by the amount of dry matter in the stakes, was influenced to some degree by plant age but also showed response to climatic conditions, especially rainfall. Stake dry matter increased from its initial value to a maximum before the rainy season at 8 months in CM 516-7 and 10 months in M Col 22, M Mex 59, and CM 849-1 (Figure 5). There was a marked decrease in dry matter during the rainy season (12-month sampling), followed by strong increases during the subsequent dry spell. These latter changes probably reflect the plant water status more than its age.

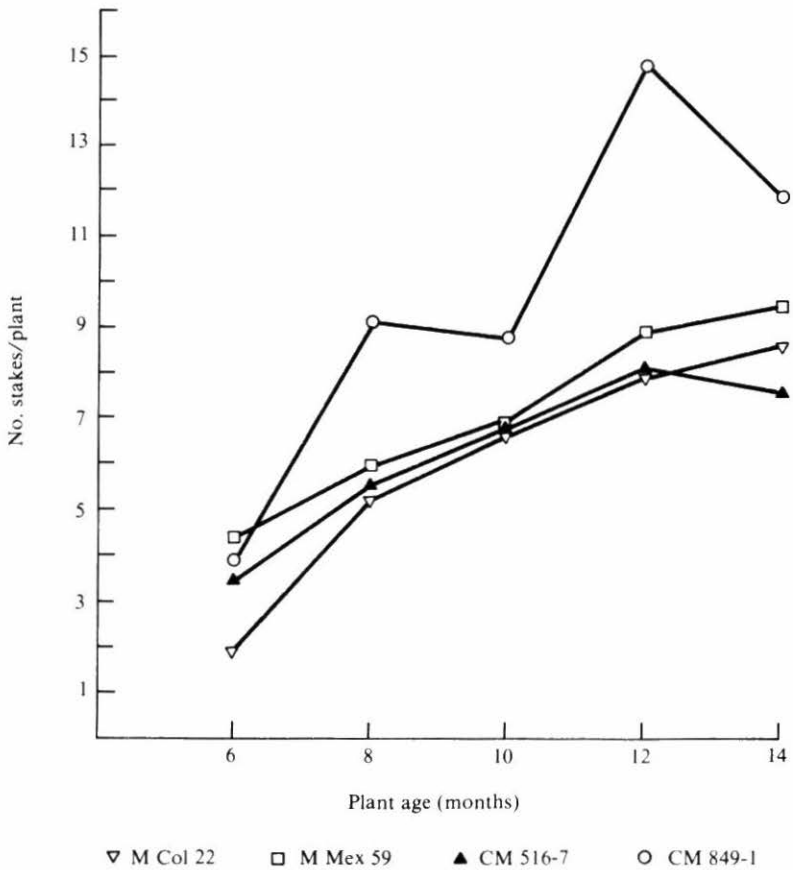

Figure 4. *Stake number per plant produced by four cassava genotypes from 6 to 14 months after planting (CIAT, 1983).*

Root starch concentration was highest at 10 months (Figure 6), while stake production efficiency was highest at 12 months (Figure 3). However, root production continued to increase beyond 10 months (Figure 7); stake production continued to increase with age in some varieties but not in others (Figure 4). The hybrid CM 849-1 demonstrated that a very early stake and root production is possible with some clones. At only 6 months of age, this cultivar reached a stake production of almost four stakes per plant and a stake production efficiency of over 10%, together with a yield of 27.3 t/ha of roots containing 37% starch.

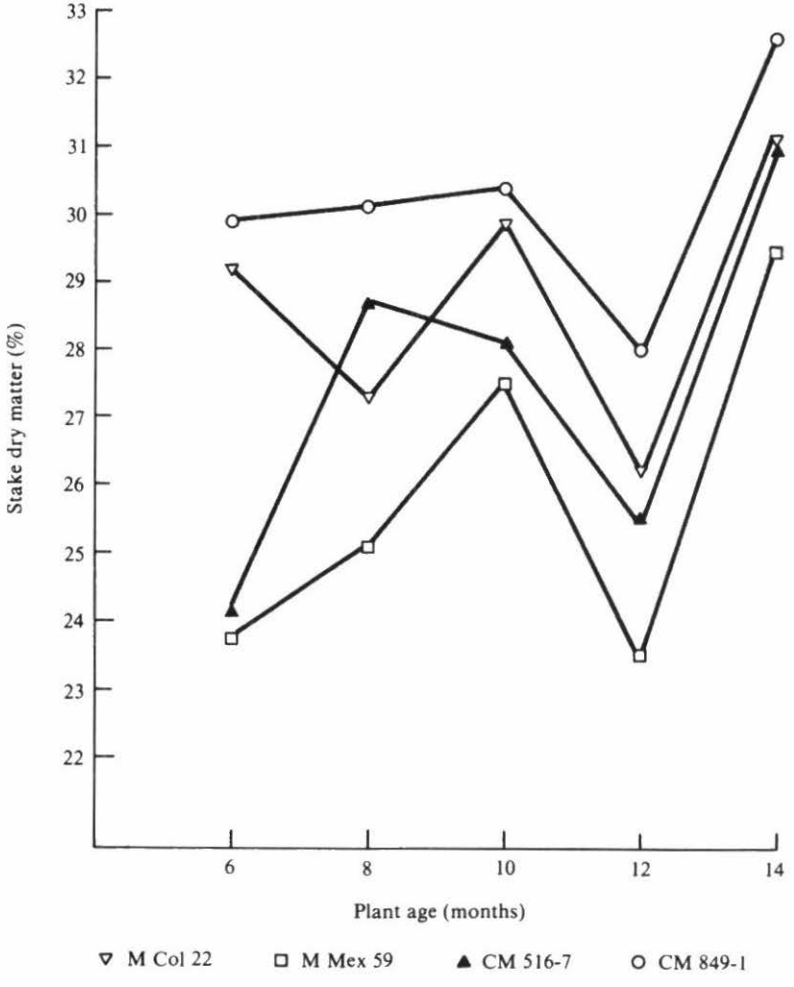

Figure 5. *Dry matter in stakes of four cassava genotypes from 6 to 14 months after planting (CIAT, 1983).*

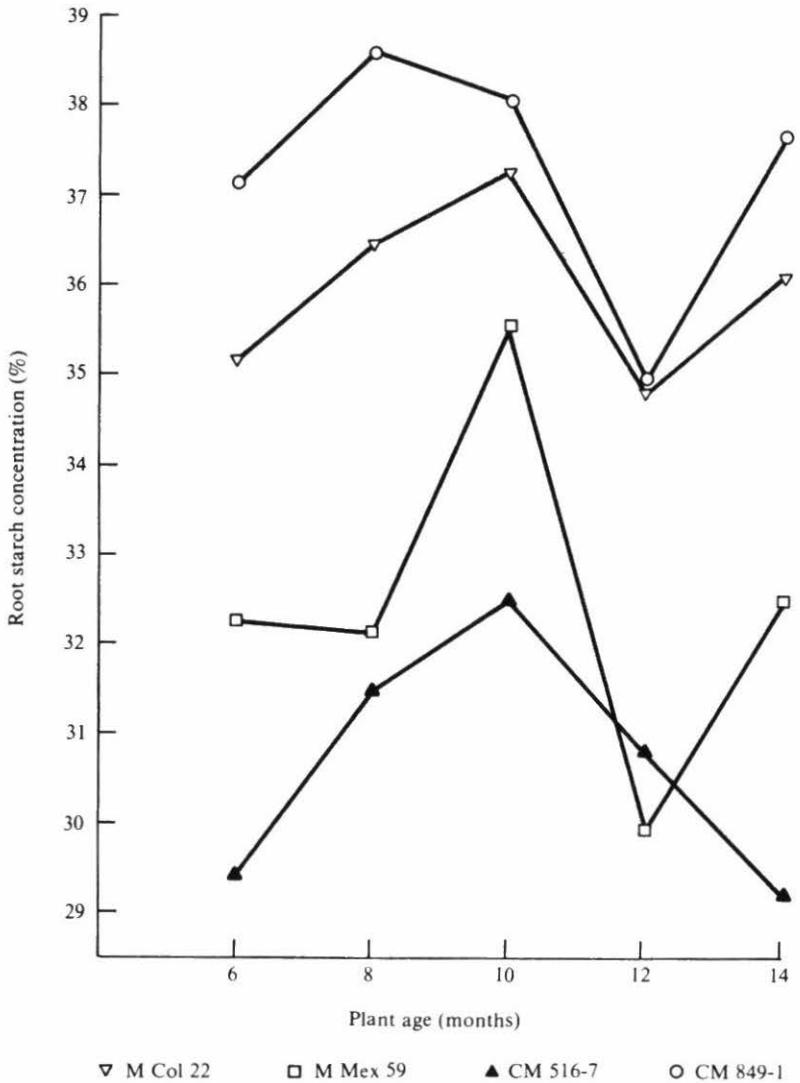

Figure 6. *Root starch concentration of four cassava genotypes over an 8-month growing period (CIAT, 1983).*

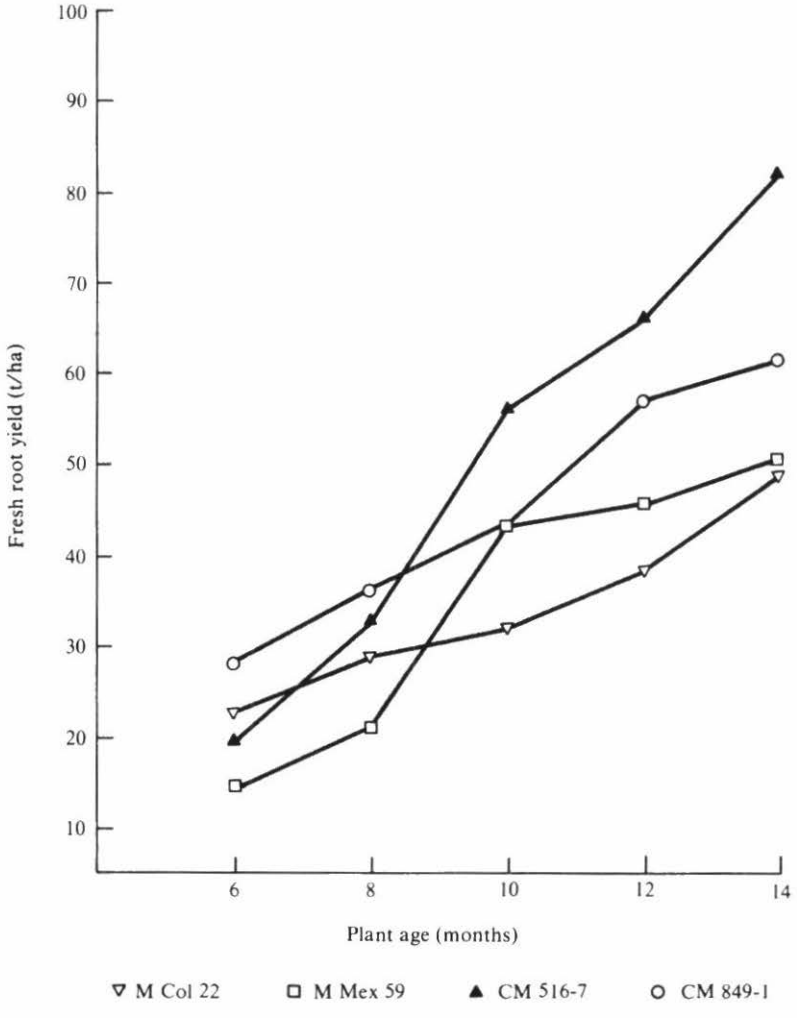

Figure 7. *Fresh root yield of four cassava genotypes from 6 to 14 months after planting (CIAT, 1983).*

Tissue age

The stems resulting from the initial sprouts of the planting piece are called primary stems and represent the oldest tissue of the plant, whereas secondary and tertiary stems resulting from the branching process are formed later and represent younger tissue. An experiment was conducted

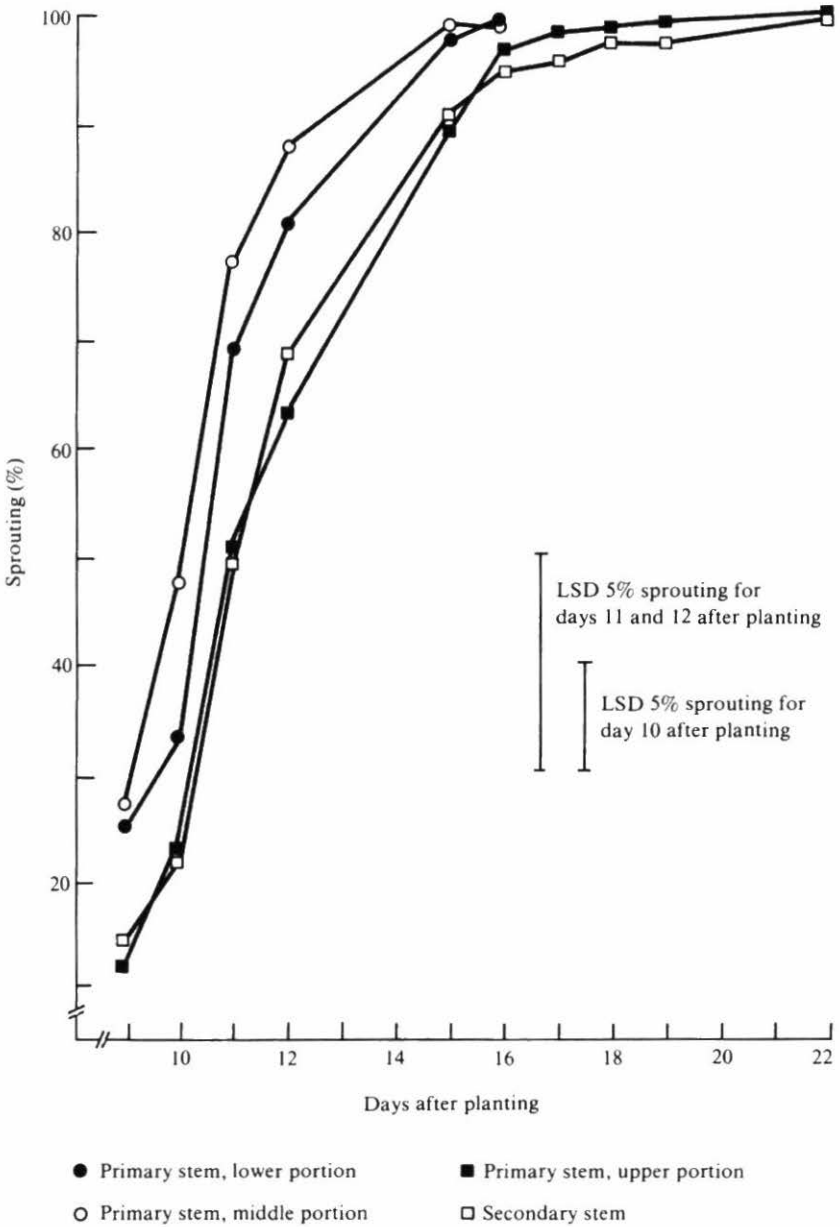

Figure 8. *Effect of stake tissue age on the sprouting process in cv. M Mex 11 (CIAT-Palmira, 1981).*

to evaluate the influence of tissue age (stakes from primary and secondary stems) on sprouting and yield of a subsequent cassava crop. There was a considerable difference in sprouting speed among the stakes of different ages: stakes from the middle and lower part of the primary stems, i.e., the older stakes, sprouted much faster and more vigorously than stakes from the upper portion of primary stems and from secondary stems, i.e., the younger stakes (Figure 8). While no differences existed between the groups of stakes with regard to percent of final sprouting, plant height, or total top fresh weight, there was a difference between commercial root weights: stakes from the youngest tissue gave a significantly greater commercial root yield than stakes from the oldest tissue (Table 1). The same tendency was observed with regard to total root yield, however, differences among treatments were not statistically significant.

Table 1. **Effect of stake tissue age on sprouting, growth, and root yield[a].**

Stake age and origin	Final sprouting (%)	Plant height at harvest (cm)	Total fresh weight		
			Tops (t/ha)	Roots (t/ha)	Commercial roots (t/ha)
Very old:					
lower part					
primary stem	100 a	234 a	34.3 a	15.9 a	11.2 b
Old:					
middle part					
primary stem	100 a	239 a	32.3 a	16.7 a	12.0 ab
Intermediate:					
upper part					
primary stem	100 a	241 a	32.9 a	17.5 a	12.3 ab
Young:					
lower part					
secondary stem	100 a	240 a	32.9 a	21.3 a	16.9 a

a. Means followed by the same letter are not significantly different by Duncan's multiple range test ($P = 0.05$).

Planting density

During early growth, cassava plants tend not to interfere with each other, even at greater than normal planting densities. The number of sprouts per plant, which form the primary stems, is therefore almost unaffected by planting density. However, at higher planting densities, the

greater number of primary stems per unit area leads to increased competition among these stems at later growth stages. As a result, individual stems stay thinner and a lower production of stakes per plant with adequate size, maturity, and bud number is obtained (Figure 9). On the other hand, higher planting densities increase the total number of plants per unit area sufficiently to more than compensate for the decrease in number of stakes per plant. In the end, higher planting densities do increase the total amount of stakes produced per unit area, mean stake fresh weight being somewhat adversely affected (Figure 10). Similar experiences with the use of increased planting densities to produce high-quality cassava planting material have been reported from India (Mohankumar, 1980).

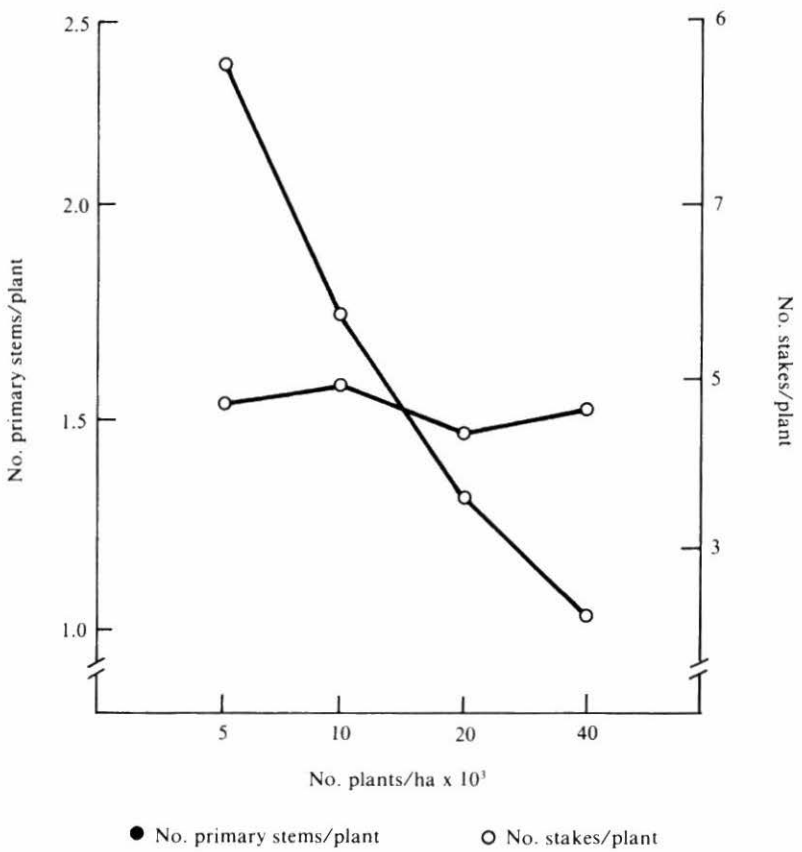

Figure 9. *Effect of planting density on number of primary stems and number of stakes per plant in cv. M Ven 77 (CIAT-Carimagua, 1982).*

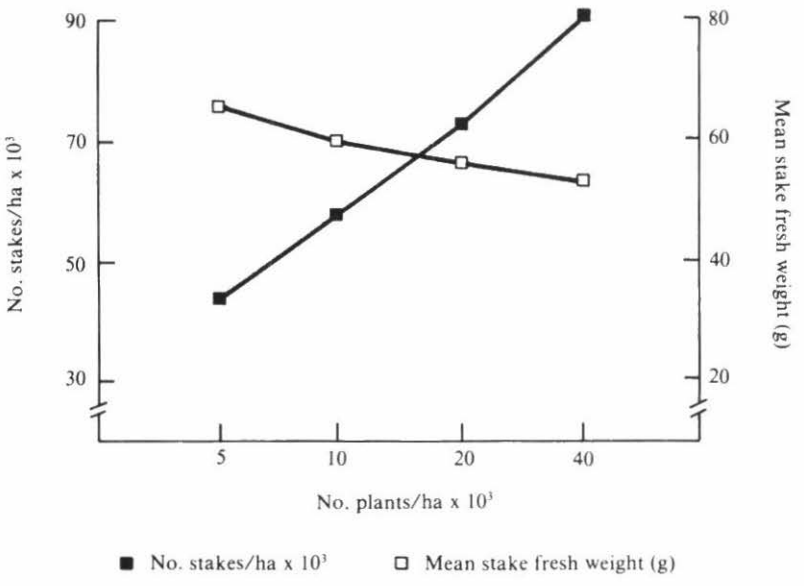

Figure 10. *Effect of planting density number of stakes per hectare and sake fresh weight in cv. M Ven 77 (CIAT-Carimagua, 1982).*

Plant nutrition

A detailed analysis of the effects of fertilization with nitrogen (N), potassium (K), and phosphorus (P) was possible with experiments conducted both in Quilichao and Caribia, Colombia. It was observed in a stake production trial at Caribia that N fertilization had a large influence on the total top fresh weight of variety M Col 22. As expected, an increased N level promoted the formation of stems and foliage, which almost doubled in weight in plants grown with 300 kg/ha N fertilizer compared to those with no added N (Table 2). However, stake number per plant was only slightly increased at N levels up to 150 kg/ha and showed a decline at 300 kg/ha. Similarly, stake production efficiency as expressed by the SPI decreased markedly at the highest N level. It appears logical that at high N rates, stake production would decrease both in absolute numbers and relative to total top growth, since N mostly favors the growth of foliage and immature stems. The high stake production in both numbers and efficiency without N is explained by less elongation of stems, which caused an increase in the number of stakes with five or more buds, and therefore a higher proportion of the entire top was available as planting material.

With more elongated stems, more stakes had to be discarded due to insufficient bud numbers.

No such variation of the above parameters was observed as a response to K fertilization. Total top weight, stake number per plant, and the SPI were stable across all K levels, showing that K does not normally have a strong influence on the vegetative growth of cassava, even in a soil deficient in that element (Table 3).

Table 2. **Influence of N fertilization on quantity and efficiency of stake production and on other growth and yield parameters[a].**

N level (kg/ha)	Stakes/plant	Stake production index (%)	Total fresh weight		Harvest index (%)
			Tops (t/ha)	Roots (t/ha)	
0	3.9 ab	8.5 a	26.5 c	28.5 b	52 ab
50	3.1 b	5.6 a	30.1 bc	33.0 ab	52 ab
100	3.3 ab	7.5 a	28.9 bc	39.0 ab	57 a
150	5.3 a	8.0 a	40.1 ab	40.6 a	50 ab
300	2.7 b	4.0 a	46.9 a	41.3 a	47 b

a. Means followed by the same letter are not significantly different by Duncan's multiple range test ($P = 0.05$).

Table 3. **Influence of K fertilization on quantity and efficiency of stake production and on other growth and yield parameters[a].**

K level (kg/ha)	Stakes/plant	Stake production index (%)	Total fresh weight		Harvest index (%)
			Tops (t/ha)	Roots (t/ha)	
0	3.8 a	7.6 a	29.3 a	38.8 a	57 a
42	3.4 a	7.8 a	25.2 a	37.5 a	59 a
83	3.6 a	7.6 a	29.4 a	37.4 a	57 a
125	3.8 a	7.3 a	29.0 a	40.3 a	58 a
250	4.0 a	7.5 a	27.2 a	40.9 a	60 a

a. Means followed by the same letter are not significantly different by Duncan's multiple range test ($P = 0.05$).

At CIAT-Quilichao where the experiment with increments of P was conducted, P deficiency is known to be limiting to plant growth. Applications of this element had the expected positive influence on total top fresh weight of variety CM 523-7 up to the P level of 132 kg/ha (Table 4). A slight decline in top fresh weight was observed at 264 kg P/ha. Stake number per plant and the SPI were best at a P level of 44 kg/ha, however, neither parameter showed a great deal of variability in response to P.

Data from these three experiments show that applications of N and P up to intermediate levels promote a balance between stem and foliage growth favorable to the production of planting material, whereas K appears not to have any influence on either quantity or efficiency of stake production.

Table 4. **Influence of P fertilization on quantity and efficiency of stake production and on other growth and yield parameters[a].**

P level (kg/ha)	Stakes/plant	Stake production index (%)	Total fresh weight		Harvest index (%)
			Tops (t/ha)	Roots (t/ha)	
0	8.2 a	28 ab	18.3 b	43.4 b	70 a
44	8.8 a	30 a	21.3 ab	49.5 a	70 a
132	8.1 a	26 b	24.0 a	52.2 a	69 a
264	8.5 a	26 b	23.7 a	51.9 a	69 a

a. Means followed by the same letter are not significantly different by Duncan's multiple range test ($P = 0.05$).

Conclusions

There appears to be a large difference among cultivars in their ability to produce planting material. This ability is, within certain limits, rather independent of total top growth but is influenced greatly by the distribution of top growth among parts not useful for stake production (foliage and young, herbaceous branches), and parts that are suitable for stake production. The ratio of suitable stem material to total top dry weight is particularly high in cultivars with a late branching, erect growth habit, since primary and secondary stems make up a large proportion of total top growth in these cultivars, and these are the parts used most for stake production. Cock et al. (1979) have found that such cultivars also have a characteristically high root yield.

Stake production increases with plant age, reaching an optimum in some cases and continuing to increase in others. A limiting maximum plant age for stake production does not appear to exist. The efficiency of producing stakes also increases with plant age, showing an optimum at 12 months under CIAT conditions. The greatest increase in stake production efficiency occurred between 6 and 8 months of age, rising from very low levels at 6 months to rather high levels at 8 months. These high levels did not change much at later stages. Thus, a minimum plant age for stake production under CIAT conditions usually is 8 months (Alguacil and Leihner, 1983). On the other hand, hybrid CM 849-1 demonstrated sufficient earliness to produce acceptable stake and root yields with even younger plants.

Besides plant age per se, the age of tissue within the plant appears to have an influence on the performance of the stakes in a subsequent crop. Stakes coming from the lower and middle portion of primary stems (older tissue) are normally thick and have large carbohydrate reserves. This leads to fast sprouting and vigorous early growth. Stakes from younger tissue sprout more slowly, but they produce higher commercial and total root yields. While the reason for this is not well understood, it seems possible that plants from younger stakes achieve a more efficient dry matter distribution towards the roots, resulting in higher harvest indices and root yields.

Data provided in this paper on the effect of planting density on stake production suggest that it is feasible to use higher than normal planting densities if an increased stake production in limited space is desired. Plant populations should probably not exceed 40,000/ha in order to avoid drastic reduction in root size.

Considering the information on the effect of soil fertility presented here, it is evident that plant nutrition interacts with genotypic characteristics in modifying growth habit, and consequently stake production ability. The proportion of stems useful for stake production was in a favorable balance with total top growth under natural soil fertility levels or with low to intermediate levels of applied fertilizer. The efficiency of the plants to provide propagative material diminished under high fertilizer levels due to more foliage production, a higher proportion of thinner branches, and longer internodes. Under limited soil fertility conditions, this shift to more top growth was mainly promoted by N and to a lesser degree by P; K had the least influence. Therefore, good natural soil fertility or a modest fertilization on poor soils should be adequate to optimize stake production.

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Sanitary Problems in the Production of Cassava Planting Material

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Introduction

The production of cassava propagating material is associated with sanitary problems induced by pathogens (fungi, bacteria, mycoplasmas, viruses, and viroids) and pests (insects and mites) when appropriate control measures are not taken. These sanitary problems reduce the quality of the propagating material, which is reflected in low yields (Table 1). They also represent a quarantine risk in areas where the infected/infested propagative material is introduced.

Cassava is normally vegetatively propagated. Current vegetative systems for propagation are stake planting, shoot or leaf rooting, and meristem culture. The first is used by growers, and the second and third are commonly used in experimental stations. The sanitary problems in each system are many, and only by following careful and efficient control measures is it possible to avoid such problems in cassava production and improvement programs. This paper will discuss these problems and their control.

Problems in stake production

The sanitary problems of stake production are pathological and entomological, and can appear at different levels of severity. Stake quality and quantity are influenced by pathogens, insects, and mites, all of which attack the plants during the growth cycle. These sanitary problems can be quite complex, and may appear before the preparation of cuttings (before harvesting), during storage time, and after stake planting.

Table 1. **Yield, percent yield reduction, and number of cuttings per plant in the native clone Secundina in relation to cutting source and type of selection[a].**

Treatment	Cutting source	Yield (t/ha)		Yield reduction (%)	Number and quality of Cuttings/plant	
		Fresh root weight	Starch		Good	Poor
1	From meristem culture; selected cuttings	34.0 a	7.9 a	0	6.2 a	2.8 ab
2	From farms without symptoms of mosaic; selected cuttings	19.6 b	6.2 b	18.3	3.6 bc	4.9 ab
3	From farms without regard to mosaic symptoms; selected cuttings	18.2 b	5.8 b	24.2	3.8 b	4.4 ab
4	From farms with mosaic; selected cuttings	14.7 c	4.5 c	38.7	3.2 bcd	3.5 b
5	From farms without regard to mosaic symptoms and without selection of cuttings	7.3 d	2.4 d	69.5	3.4 bcd	5.5 a

a. Means followed by the same letter are not significantly different by Duncan's multiple range test ($P = 0.05$).

Pathology

Pathological problems affecting cassava plants are able to induce total losses in susceptible clones, especially during the rainy seasons. Short of total losses, reduction in root and stake production can be considerable, with the consequent loss of stake quality.

Before harvest

The stem of cassava is attacked by various pathogens which induce internal or external rots and cortical or epidermal lesions (cankers, xylem discoloration, etc.); others invade the stem tissues systemically without leaving visible symptoms (viruses, mycoplasmas, bacteria). Based on their location and presence, the pathogens attacking cassava stems can be grouped as either systemic or localized.

Systemic pathogens are vascular and cortical or epidermal causal agents which invade the host systemically without leaving visible signs in the mature portion of the stem. Vascular pathogens may be viruses and mycoplasmas (Lozano et al., 1977; Jayasinghe et al., 1983a), bacteria (Lozano and Sequeira, 1974a), and fungi (CIAT, 1982 and 1983). Cortical or epidermal pathogens include bacteria (Lozano and Bellotti, 1978a and 1978b) and fungi (Zeigler et al., 1983). Because of the systemic nature of these pathogens, a high percentage of the plants coming from diseased cuttings are also diseased. These plants may constitute the source of primary inoculum in a new plantation, and it is by the introduction of such plants that systemic pathogens are disseminated from different regions, countries, and continents (Lozano, 1977).

Localized pathogens are nonsystemic agents (causes of bacterial stem rot, anthracnose, concentric ring leaf spot, some basidiomycetes, etc.) that invade only a part of the stem. These pathogens generally leave cankers of light brown to black necrotic areas on the epidermis of the stem. Other pathogens (such as the causal agent of bacterial stem rot) also invade the pith region, which turns reddish-yellow to dark brown in color (Lozano et al., 1977). These groups of pathogens enter the stem through wounds produced mechanically or by insects, or by invading the leaf petioles, penetrating them directly or through the stomata. Others enter directly into the stem, rapidly invading the green portion. The degree of invasion decreases as the stem becomes lignified (Lozano et al., 1977).

During storage

Stakes can be stored for quite a long time (more than 12 weeks) if climatic conditions (temperature, light, relative humidity) and biotic stresses (pathogens, insects, mites) are controlled (CIAT, 1978; Leihner, 1983). High relative humidities favor the spread of pathogens from small lesions and pathogen infection from propagules located on the epidermis. *Glomerella cingulata, Fusarium* spp., *Diplodia manihotis*, and species of various ascomycetes and basidiomycetes have been found (Lozano et al., 1977 and 1981) infecting the stakes after a few days of storage at relative humidities above 80% (CIAT, 1978).

After planting

Soil-borne pathogens which commonly attack hosts such as forest trees and other crops often attack cassava as well. These include *Rigidoporus lignosus, Rosellinia necatrix*, and *Amillariella mellea* in forest trees; *Fusarium* spp. and *Rosellinia* spp. in perennial crops such as coffee, bananas, and plantains; and *Rhizoctonia* spp., *Sclerotium rolfsii*,

Whetzelinia sclerotium, *Phytophthora* spp., and *Pythium* spp. in herbaceous crops with short growing cycles such as cotton and beans. Attack by these pathogens occurs once the stakes have been planted, initiating at the cut ends, through entry into the epidermal wounds, at the base of the shoots, or in the rootlets. Losses from such pathogens can be up to 90% (Lozano and Booth, 1974; CIAT, 1978; Lozano et al., 1977).

Entomology

Before harvest

Several insects and mites can affect both the production and quality of planting material during the pre-harvest cycle. These include mites of the *Mononychellus* complex, thrips, mealybugs, scales, shoot flies, fruit flies, and stemborers (Bellotti and Schoonhoven, 1978).

Studies at CIAT-Palmira and other sites show that mite attacks can reduce stake production by 28% on resistant clones and 79% on susceptible clones. The *Mononychellus* mite attacks the apical part of the cassava plant causing a reduction in plant height and vigor (Byrne et al., 1983).

Thrips, especially the species *Frankliniella williamsi*, also attack the growing point of the cassava plant; reduction in stake production has been measured at 57% (O. Vargas, personal communication). Thrip damage is distinguished by severe distortion of cassava leaves; brown wound tissue appears on the stems and petioles, and internodes are shortened. Growing points may die, causing growth of lateral buds which may also be attacked, giving the plant a witches'-broom appearance. Subsequently, the quality of planting material is also reduced.

Shoot fly damage has been observed in most cassava growing areas of the Americas. Several species are reported, with *Neosilba perezi* and *Lonchaea chalybea* being the most important. Adult flies oviposit several eggs between the unexpanded leaves in the growing points or in a small cavity made in the tissue by the ovipositor. The young larvae tunnel in the soft tissue, eventually killing the growing point. This retards plant growth, breaks apical dominance, and causes germination of lateral buds, which may also be attacked. Younger plants are more susceptible, and repeated attacks may cause stunting. This can result in more prolific branching, and consequently a decreased number of desirable stakes. Studies at CIAT showed a reduction of more than 50% in desirable stakes when shoot fly attack occurred during the first 2 months of plant growth.

Although fruit flies (*Anastrepha manihoti* and *Anastrepha pickeli*) prefer to oviposit in the fruit, they have been observed causing severe damage to the stems. Oviposition occurs about 10-20 cm below the apex, but in the young, tender stem tissue. After hatching, the white-yellow larvae bore up or downward in the stem pith regions. Larval tunneling in the stem results in brown galleries in the pith area. A bacterial pathogen (*Erwinia carátovora* pv. *carátovora*), often found in association with fruit fly larvae, can cause severe rotting of stem tissue. As a result of severe attacks, growing points may collapse and die, retarding plant growth and encouraging growth of lateral buds (Lozano and Bellotti, 1978a). This secondary rotting can cause a 70% reduction in production of healthy planting material. A 16% decrease in stake germination was observed when severely damaged planting material was used.

Mealybugs (*Phenacoccus herreni, P. manihoti*, and *P. gossypii*) and scales (*Aonidomytilus albus* and *Saissetia* spp.) attack and damage the stems of growing plants. This damage reduces both the quality and quantity of stakes produced. Studies at CIAT with cuttings heavily infested with *A. albus* resulted in a 50-60% loss in germination.

There are several stemborers that can cause severe damage to cassava stems. The two most important species appear to be *Chilomina clarkei* (Lepidoptera: Pyralidae) and *Lagochirus* spp. (Coleoptera: Cerambicidae). Several species of the genus *Coelosternus* (Coleoptera: Curculionidae) are reported attacking cassava stems, primarily in Brazil. Larvae of *C. clarkei* appear to be of most importance since adults will oviposit all along the stem, resulting in numerous tunnels throughout the wood and pith regions. Studies in the Colombian Llanos showed a 53% loss in the production of clean planting material due to *C. clarkei* attack. Adults of the *Lagochirus* species appear to oviposit primarily around the basal portion of the stem, which results in fewer damaged stakes. A new species of Cerambicidae stemborer identified as *Lepturges* has been found attacking cassava stakes. At present, populations are low. The egg-to-adult period is approximately 60 days. This species has also been identified attacking cassava in the state of Pará in Brazil.

During storage

In many cassava growing areas, stems of the cassava plant are stored for varying lengths of time between harvest and planting. Stake storage usually occurs during the dry season while the farmer awaits the rainy season to initiate planting. The dry season is favorable for population increases of several cassava pests that can attack and severely damage

stored stakes. Major pests that can cause losses in planting material during storage are scales, stemborers, and termites.

Cassava stems highly infected with the white scale *Aonidomytilus albus* were stored at CIAT for a one-month period. Scale populations increased and germination was subsequently reduced by 43%. Unstored stakes with the same population of scales resulted in only a 4% reduction in germination (CIAT, 1978).

Several stemborers can attack cassava stems during storage. These include *Lagochirus* spp., *Coelosternus* spp., *Chilomina clarkei, Eulecriops manihoti*, and a *Lepturges* sp. Cassava stem cuttings left untreated in the field for only 8 days resulted in a 65% infestation by *Lagochirus araneiformis* at CIAT. Treated stems were not infested.

Termites are also responsible for storage losses. In studies at CIAT nearly 50% of stored propagating material was lost due to termite feeding.

After planting

Several pests can attack and severely damage recently planted cassava cuttings. These include termites, cutworms, white grubs, and stemborers.

Termites attack mainly in the tropical lowlands. In Colombia termites have been observed causing considerable losses in germination, as well as causing death of young plants in several cassava growing areas. Germination losses of 15-30% have been recorded.

Cutworms such as *Agrotis ipsilon* feed on roots and underground parts of the stem, causing loss of planting material. The bark and buds may be completely stripped. Losses as high as 50% of the stakes have been observed in cassava fields in Colombia. Cutworm attacks are sporadic but occur more frequently when cassava follows maize or sorghum, or is planted adjacent to these crops.

Damage to cassava stakes caused by grub feeding is reported from several parts of the world. Although several species are reported, a *Phyllophaga* sp. and *Leucopholis rorida* appear to be the most important. White grub damage is characterized by the destruction of the bark and buds of recently planted stakes, and the presence of tunnels in the woody part. These infestations may result in rotting and death of the stake. Studies with *Phyllophaga* at CIAT show that germination can be reduced by 95% in experimental plots.

Stemborers such as *Lagochirus* spp. and *C. clarkei* can damage recently planted stakes. Females can oviposit in the exposed portion of the stakes

above ground. The resulting tunneling by the larval stages can cause a loss in germination or death of the young plants.

Problems in shoot and leaf rooting

The speed at which cassava has been traditionally propagated through the use of mature stem cuttings has been multiplied several thousand times by employing shoot and leaf rooting techniques (Cock et al., 1976; Roca et al., 1980), thereby solving one of the greatest disadvantages of cassava in relation to other crops. Sanitary problems, especially pathological, are common if appropriate control measures are not followed. These are summarized below.

Viral and mycoplasmal diseases cannot be prevented by rooting shoots or leaves. The spread of these diseases is feasible if cuttings are obtained from diseased mother plants, since several hundred plantlets can be obtained per cutting with these two techniques. Similarly, knives can also be easily infested after cutting infected shoots or leaves; infested knives can mechanically transmit viral and mycoplasmal diseases to healthy shoots or leaves during their preparation for rooting.

The rooting media (water, sand, vermiculite, etc.), when infested, can maintain fungal and bacterial pathogens for a considerable period of time (Cock et al., 1976; Roca et al., 1980). These usually penetrate the host through the cuttings of the shoots or leaves during the rooting period. Mycelia growth, tissue maceration, and discoloration of the stem base are common symptoms when shoots or leaves are diseased.

During the transplanting operation, rootlets of the plantlets obtained by shoot or leaf cuttings can be damaged, leaving wounds where soil-borne pathogens (either bacteria or fungi) can penetrate and invade the plantlets. As a consequence, losses in establishment can be expected, especially when infected soils are used. CIAT has recorded losses higher than 60% in trials.

Problems in meristem culture

The meristem culture technique reduces the risk of pathogen dissemination through vegetative propagative material. However, there is a certain probability that pathogens (especially viral and viroidal) will be able to pass with the meristem explant to the generated plants. For this reason several virus indexing tests have been developed in cassava (Lozano and Jayasinghe, 1982), as in other crops, in order to minimize the risk of pathogen dissemination.

During the development of the technique, fungal and bacterial contaminations can occur. This is commonly due to a deficiency in the sterilization of the material and reagents used, lack of appropriate equipment for obtaining sterile environments necessary for the manipulation of the material, and operational carelessness which facilitates contamination. Similarly, when plantlets are generated and transplanted to new media and to the field, infection due to bacterial and fungal pathogens is also possible if appropriate care is not taken (Roca, 1979 and 1982).

Control measures

The control measures described below could avoid sanitary problems in the production of cassava propagating material.

Pre-harvest control

The propagating material of cassava should be collected from plantations apparently free from systemic diseases. More than one inspection should be made prior to collection of such material in order to determine the apparent sanitary condition of the plantation. Such inspections should be made during the optimum climatic conditions for either disease or insect/mite developments. For example, inspections should be made during the middle to the end of the wet seasons for diseases such as cassava bacterial blight, superelongation, and *Diplodia* stem rot; and during the optimum conditions established for whitefly-transmitted diseases, such as low temperature periods for Caribbean mosaic disease. Before collection, the vigorously growing healthy plants should be identified (Lozano and Jayasinghe, 1982).

Importing or exporting cassava stakes from any country or any geographic region is not recommended. Vegetative material should be introduced only as meristem cultures, but only after sufficient tests have been carried out to determine the sanitary conditions of the introduced material. Meristems should be taken from shoots arising from cuttings taken from healthy plants grown on plantations free from frog skin disease, mosaics, bud proliferations, and stunted plants. It is also suggested to avoid thermotherapeutical and chemical treatment which may incur the risk of inducing viral mutations or viral biotype selection (CIAT, 1982). Such treatments, however, could be done for cleaning within an experimental station. As far as possible, introduced material should be absolutely healthy. If frog skin disease is present in a region, grafting with a susceptible variety is advisable, as well as performing a

partial electrophoretic test of introduced plants (Jayasinghe et al., 1983b). If mosaic diseases are present in the region, grafting sensitive varieties with imported material is advisable (CIAT, 1982). Any suspected material should be eliminated by autoclave (120°C and 20 atmospheres of pressure) or burnt. All introduced material should be observed carefully and periodically; at least three periodic bioassays should be carried out, in addition to any other available test which can help in the detection of systemic diseases of cassava. It should be considered that mosaic-carrier varieties exist in cassava which do not show any visible symptoms, but which can easily be affected and be the focus of dissemination of diseases when introduced into clean areas (CIAT, 1982). These diseases could be a threat to the regional varieties and even to other crop species. Since information available on systemic diseases of cassava in relation to their identification, detection, and epidemiology is very limited, the introduction of cassava vegetative material should be limited and a clone should be imported only when necessary.

For the production of propagative material (either sexual or asexual), a portion of the cassava plantation should be protected from both pathogen or pest damage to insure the production of good quality seeds or cuttings. A 10-20% portion of the plantation (depending on the cultivar planted) can be protected with systemic and/or contact pesticides such as benomyl (systemic fungicide that controls anthracnose and superelongation), captan (contact fungicide that controls anthracnose and *Diplodia* stem rot), dimethoate, propargite (Omite), and other selective pesticides to guard against mites, thrips, mealybugs, whiteflies, and stemborers. Damage due to shoot and fruit flies can be reduced significantly by two pesticide applications during the first two months of plant growth.

For the production of propagative material, the cultural practices of the plantation should be adapted to the specific characteristics of each ecological zone. Such cultural practices should include plot selection, soil preparation, healthy planting material, weed control, periodic inspections, elimination of plant debris, crop rotation, planting during the appropriate season, well-planned spacing of plants, and a good supply of nutrients and water. The best biological control against the most common pests of cassava in the region should be developed, as well as a program to select and use the most resistant genotypes to abiotic and biotic problems existing in each edaphoclimatic zone (Lozano and Bellotti, 1980).

In-storage control

See Chapter 6 for a discussion of problems associated with storing cassava stakes.

Post-planting control

To prevent soil-borne problems after planting the stakes, the following recommendations should be considered.

a) Do not plant cassava after the removal of forest, perennial, or woody crops because severe root rot problems can appear due to pathogens or pests that affect these plant species as well as cassava (Lozano and Bellotti, 1980).

b) Prepare soil as for any other crop. As cassava is susceptible to flooding and to pathogens favored by this condition (i.e., *Phytophthora* and *Pythium* spp.), soil drainage must be adequate for the quantity and distribution of rainfall in each edapho-climatic zone (Lozano and Bellotti, 1980).

c) Plant in accordance with the terrain; satisfactory root formation and distribution result from appropriate positioning of the stake in the ground. Good root development leads to vigorous plants, which are more resistant to biotic problems (Lozano and Bellotti, 1980).

d) Plant in the appropriate season. Considerable losses in establishment due to failure in rooting or bud sprouting can occur if planting is done during the hottest season of the year in areas with high average temperatures. This may be caused by the effect of soil temperature on horizontally planted stakes; when planted vertically or obliquely, air circulation cools the extreme upper portion of the stake, reducing the effect of hot soils (Lozano and Bellotti, 1980).

e) Take precautions against the most common entomological problems that affect stakes after planting in the Americas:

Stemborers. Several insecticides were compared for effectiveness of stemborer control. Aldrex 2% at 0.02 cc/liter of water was far superior to the other insecticides in a 5-minute stake dip. Insecticide stake treatments can be made at least 2 weeks after cutting and still effectively control stemborers.

Termites. This pest is sometimes a problem in certain cassava growing areas where it attacks stored planting material and growing plants. Several combinations of stake treatments were tested to determine effectiveness in controlling termites. The best combination was captan and carbendazim (2 g/liter of water each) in a 10-minute stake dip and later application of 0.025 g (a.i.) aldrin dust around each stake. A fungicide/insecticide combination is necessary

because where only aldrin was dusted on the ground at planting, termite attack after 150 days was only 13% but stake death was 34%; when the combination fungicide/insecticide was applied, stake death and termite attack after 150 days was 5% for each.

Cutworms. Attacks of cutworms are sporadic but occur more frequently when cassava follows maize or sorghum, or is planted adjacent to these crops. Cutworms attacking at ground level may be controlled effectively with poison baits (10 kg of bran or sawdust, 80 g (a.i.) trichlorfon 80%, and 500 g sugar or 1 liter molasses with enough water for adequate consistency of the mixture). Underground cutworms can be controlled by applications of aldrex dust 2.5% at 1.250 g (a.i.)/ha.

White grubs. White grubs can be controlled effectively with aldrin dust 2.5% at 1.250 g (a.i.)/ha applied to the soil in the last disking. Insecticidal dip treatments for cuttings are not effective. A muscardine fungus, *Metarhizium anisopliae*, is pathogenic to grubs. This microbial control agent must be incorporated during land preparation. Diseased grubs have been found under natural conditions, and several larval parasites of the grub have been identified, including several species of *Dielis*. Parasitism in one study reached 26%.

Control in shoot and leaf rooting

Asepsis is the key to the prevention of problems in shoot and leaf rooting. Asepsis includes: clean propagative material (disease-free shoots or leaves); clean rooting media (sand, vermiculite, soil, gravel, etc.); clean tools used during the preparation and planting of propagative material; and clean water used as media, watering, or spraying. The propagative material should be taken from healthy plants. The media, tools, seedling beds, containers, and water should be sterilized either by dry or wet hot treatments (Cock et al., 1976; Roca et al., 1980). Technicians should also wash their hands with soap and water before initiating any operation. Any plant with disease symptoms should be eliminated as soon as the symptoms are observed.

Control in meristem culture

To avoid sanitary problems, a careful sterilization of tools and reagents is required. Technicians should wear sterile clothes and work in sterile environments while transferring meristems and culturing. Diseased cultures or plantlets should be eliminated and containers sterilized. Thermotherapeutical treatments to mother plants before meristem cultures

(Roca, 1979), followed by specific diagnostic tests (CIAT, 1982) should be used in order to reduce the risk of viral or viroidal contaminations.

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CHAPTER 4. SPECIAL TECHNIQUES FOR PRODUCING HIGH-QUALITY SEED

Virus Elimination in Potato and Cassava

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Introduction

The control of bacterial and fungal diseases is to some extent possible through the application of chemicals which specifically affect the pathogen's metabolism. However, this is impossible in the case of viruses and viroids because these pathogens utilize the host's metabolism for multiplication. Therefore, chemicals which may affect virus multiplication usually exert high toxicity on the host cell metabolism.

Virus spread in the host plant

The spread of virus particles in the plant mainly occurs through the vascular system, with some viruses being completely restricted to the phloem. The rate of movement in the vascular system is high and was determined for potato virus X (PVX) and tobacco mosaic virus (TMV) to be on the order of 1-8 cm per hour (Capoor, 1949). In addition to this type of transport, a passive movement of virus particles from cell to cell takes place through the channels which connect the cells to each other, the plasmodesmata. The driving force for this movement is protoplasmic streaming, which has been calculated to move at a rate of 5-15 microns per hour, much slower than the rate in vascular tissues.

The mechanisms of virus spreading cause the uneven distribution of virus particles in the plant (Limasset and Cornuet, 1949) and are the underlying bases for the success of meristem culture using *in vitro* techniques.

Meristem culture

The apical dome of a shoot's apical meristem contains the truly meristematic cells and is surrounded by leaf primordia and primary leaves. Since the more differentiated vascular tissues occur away from the meristem (towards the older tissues of the stem), the vascular elements of the leaf primordia are still very incipient, and they have not yet made contact with the main strand of the vascular system in the stem. Therefore, virus particles which may be present in the vascular system can reach the meristematic region of the apex only through cell to cell movement. This is one of the main reasons that virus concentration decreases acropetally towards the meristem of the apical bud as well as the axillary buds in a virus-infected plant. Whether other factors, such as the production of virus-inhibitory substances by the meristematic cells or the effect of hormones in the culture medium, play a role in the elimination of viruses by meristem culture has not conclusively been proved.

Isolation of the apical part, called the meristem tip, under aseptic conditions, and its culture on an adequate aseptic medium, leads to the development of plantlets; this development, in principle, follows a pattern similar to that in the entire plant: the cells of the meristem continue to divide and the differentiation of tissues continues. The nutrition of the excised portion of the plant is supplied by the artificial medium. This technique, called meristem culture, was first applied some 30 years ago on dahlias, and it is used to produce pathogen-free plants.

Bacteria and fungi can easily be eliminated since they are not entering the meristem tip. Of course, if the surface sterilization of the bud was insufficient or the tools were not well sterilized, bacteria and fungi will grow in the meristem tissue since the culture medium for the meristems is also ideal for the growth of most of these micro-organisms. However, as long as sterilized conditions are used and portions are excised in which the incipient vascular elements have not yet reached the main vascular strands, bacterial and fungal pathogens will present no problems.

Thermotherapy

Experiments carried out with different virus-host systems have shown that treatment of plants with elevated temperatures (thermotherapy) leads to a reduction in virus concentration in the plant (Kassanis, 1950; Quak, 1977). Different reasons have been given to explain this phenomenon, but it is probably not one alone, but a combination of reasons that cause virus reduction. Competition for sites to synthesize nucleic acids and proteins

between the fast-dividing host cells and the virus particles may lead to a change in the balance between synthesis and degradation of virus particles. In addition, the nucleic acid of the virus, the carrier of its genetic information, is usually protected from the attack of degrading enzymes by a coat consisting of many protein subunits. At elevated temperatures the linkage between these subunits becomes weaker, and temporary holes may open and permit the attack of nucleases, so leading to the inactivation of viruses and a decrease in virus concentration.

When thermotherapy has been applied to potato tubers, reduction of virus concentration has been observed (mainly of potato leaf roll virus, PLRV), but no virus eliminations were achieved except for PLRV. The same is the case with cassava stakes exposed to elevated temperatures (CIAT, 1983). But thermotherapy applied to the whole plant as well as to sprouted tubers, followed by meristem culture, has been successfully used for elimination of viruses in potato (Stace-Smith and Mellor, 1968; Pennazio, 1971). While this method is in use for many vegetatively propagated crops, the detailed conditions have to be determined experimentally for each crop and each plant part to be treated.

It should be stressed that the plant regenerated from meristem culture has to be tested for virus freedom in spite of the fact that the combined methods of thermotherapy and meristem culture increase the probability of virus eradication.

Chemotherapy

As an alternative to thermotherapy, chemotherapy has recently shown promising results in both potato and cassava. A nucleoside analogue, virazole, known for its broad spectrum against animal DNA and RNA viruses has shown good results when applied to the potato plant as a spray or in hydroponic culture, followed by meristem culture. Preliminary results of culturing meristem tips in the presence of 100 ppm virazole in the medium are very promising.

In the case of cassava, promising results have also been obtained, but lower virazole concentrations are used, 20-40 ppm being the highest concentrations that can be applied.

Routine elimination schemes in potato and cassava

Thermotherapy is routinely used at CIP to eliminate viruses in potatoes. Optimal eradication rates have been obtained when the plant was decapitated before thermotherapy. A temperature regime of 36°C for 8

hours, under continuous light of high intensity (10,000 lux) improves elimination rates (Roca et al., 1978). If possible, plants are treated over 4 weeks. Throughout this time, axillary buds grow rapidly. Meristems are isolated from apical buds as well as axillary buds, and cultivated *in vitro*. After about 6-8 weeks, plantlets regenerate from the meristems.

The routine procedure for cassava at CIAT is very similar to that for potato at CIP. Potted stakes with dormant buds are exposed to a thermotherapy of 40°C in the day and 35°C at night, with a 12-hour photoperiod. These conditions prevail for 3-4 weeks during which time sprouting occurs vigorously; then meristem tips are excised and cultured. Plantlets develop after 6-8 weeks.

For potato as well as cassava, developing plantlets are propagated *in vitro*. In cassava the propagated plantlets are transferred to pots and then samples are taken for virus testing.

It was found that when *in vitro* plantlets of both crops were transferred to the sterilized soil they needed a high phosphorus fertilizer. These plantlets are only handled using disinfected tools or hands, and pots and soil are sterilized.

Effectiveness of routine procedures

As in other host-virus systems (Kassanis, 1957; Accatino, 1966) the success of virus elimination is correlated to the size of the excised portion, both in cassava and potato. The smaller the excised portion, the higher the probability for virus eradication. This seems reasonable in the light of the earlier discussion on meristem culture.

On the other hand, at least in the case of potato, very small portions are difficult to cultivate or complex media are necessary, leading to callus formation before plantlet development. For cassava at CIAT, as well as for potato at CIP, a portion containing the apical dome and one or two leaf primordia are usually excised.

The efficiency of virus elimination by meristem culture in potato has been reported to be dependent on the virus. The viruses which are restricted to the vascular bundle such as PLRV are usually easy to eradicate. There is a gradual increase in the difficulty to eradicate viruses: PLRV > PVA > PVY > PMV > PVX > PVS (Kassanis, 1957; Accatino, 1966). Applying the above routine thermotherapy procedure, an almost 100% elimination rate has been obtained, except for the potato spindle tuber viroid (PSTV).

Using the thermotherapy system described for cassava, 100% healthy plants have been obtained from starting material infested simultaneously with frog skin and mosaic diseases (CIAT, 1983).

Application of thermotherapy needs special facilities and equipment, such as incubators or similar equipment which can be manufactured by a local workshop. When these facilities are not available, meristem tip culture alone may lead to pathogen-free plants at a lower frequency.

Elimination of PSTV

Using the thermotherapy procedure described above for potato, PSTV cannot be eliminated. This viroid consists of a one-stranded RNA, which is ring-shaped and twisted in the form of a supercoil. In this form it is very resistant to attacks by nucleases. It has been shown that elevated temperature favors the multiplication of the viroid (Sanger and Ramm, 1975). Therefore, a first test for PSTV is carried out at the end of the thermotherapy period.

To eradicate PSTV, a method has been developed based on the observation that in plants grown at low temperature, the concentration of the viroid is low (Lizarraga et al., 1980). Therefore, plants were grown at 8°C for 4 months, after which apical domes were excised and cultured. From the plantlets regenerated, 30% were free of PSTV. A clear relationship between explant size and eradication success was observed with improved eradication at small apical dome size (Lizarraga et al., 1982).

The described method is not suitable as a routine technique, since it is very time-consuming and costly. But it may be useful in specific cases in which a valuable clone is thoroughly infected and clean material cannot be obtained.

Testing plants regenerated from meristem culture

As mentioned before, testing plants from meristem culture is very important. For potato, testing is carried out *in vitro* and again later when the plants have been moved to the greenhouse. The methods are a combination of serology, observation of samples in an electron microscope, inoculation on indicator hosts, and polyacrylamide electrophoresis for PSTV.

For cassava, plants are currently tested in the greenhouse using serology for mosaic-type diseases, electrophoresis for frog skin disease, and grafting for latent diseases.

Conservation of pathogen-free material

Samples of clean material are maintained *in vitro* to allow new propagation of disease-free plants to be made at any time. The probability of recontamination with pathogens *in vitro* is extremely low. For both cassava and potato, conditions have been developed which allow the storage of *in vitro* plantlets for 1.5-2 years without transfers (Roca et al., 1982; Estrada et al., 1982).

Conclusions

Methods are available for both potato and cassava which provide high eradication rates of pathogens. Since CIAT and CIP are distribution centers for genetic material, their clones should have the highest sanitary status possible. This may not be the case in a national seed program, and modifications with respect to thermotherapy and testing are reasonable.

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Virus Elimination in Sweet Potato, Yam, and Cocoyam

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Sweet potato

Sweet potato virus diseases such as mosaic virus, feathery mottle virus (Mori, 1971; Mori et al., 1969), internal cork virus (Mori, 1971; Nielsen, 1960), sweet potato virus disease (Frison and Ng, 1981), and some unidentified viruses (Over De Linden and Elliot, 1971; Alconero et al., 1975) were eliminated from sweet potato plants by meristem culture alone or in combination with thermotherapy. The procedure for obtaining these virus-free sweet potato plants is described below.

Culture method

Sweet potato roots are harvested from the field, cleaned, planted in pots, and grown in the greenhouse. When the sprout is about 30 cm high, both apical and lateral buds are excised for culturing. After surface sterilization first with 70% (v/v) ethanol for 5 minutes, and then with a 5% filtered solution of calcium hypochlorite containing a few drops of Tween 20 for 20 minutes, the buds are rinsed with three changes of sterile distilled water. Meristems with one to two leaf primordia, about 0.3-0.4 mm in length, are excised with the aid of a dissecting microscope under a microflow transfer cabinet. The meristems are then transferred to glass tubes containing 5 ml of the culture medium. The capped cultures are incubated in a culture room maintained at 26-29°C. A 12-hour photoperiod is provided by daylight fluorescent tubes with 5,000 lux light intensity at plant level.

The medium is modified from that of Murashige and Skoog (1962) by adding 3% sucrose, 80 ppm adenine sulfate dihydrate, 0.2 ppm indoleacetic acid (IAA), 0.5 ppm benzylaminopurine (BAP), and 0.7% agar. The pH of

the medium is adjusted to 5.7 ± 0.1 by adding drops of 0.5 N sodium hydroxide or 0.5 N hydrochloric acid before sterilization at 121°C for 15 minutes.

Plantlets with three to four nodes are obtained 6 weeks after inoculation and transplanted from the tubes onto Jiffy peat pellets. They are kept in a high-humidity chamber in an isolation room. After 1-2 months, symptomless plants are grafted onto *Ipomoea setosa* seedlings, an indicator plant used for sweet potato viruses such as russet crack, internal cork, yellow dwarf (Hildebrand, 1966), and sweet potato virus disease (Frison and Ng, 1981), for observation of symptoms. Grafting is done three times at 2-month intervals. Electron microscope (EM) observation and serologically specific electron microscopy (SSEM), if available, should be carried out on the leaf extract of the sweet potato and indicator plants.

Yam (white and water yams)

In vitro culture of yams for pharmaceutical purposes has made great progress. However, far less work has been done on food yams. Meristem culture incorporated with hot air pretreatment of the mother plants has been used to eliminate several viruses (CARDI, 1981; Mantell and Haque, 1979). The development of the yam meristems *in vitro* is very slow; it takes about five months before a plantlet can be transplanted to soil (Mantell and Haque, 1979; Ng, unpublished). This may be due to the small size of the buds and consequently smaller meristems. Blackening of the culture medium may also be one of the factors for slow growth. Heat treating the mother plants for a prolonged period may allow the use of a bigger piece of the meristem tip for culturing, thus shortening the time to obtain plantlets without decreasing the ratio of virus-free plants produced. Further studies need to be carried out on shortening the development of yam cultures. A method to obtain virus-tested yams from meristem culture is given below.

Culture method

Yam roots are cut into planting size after the dormancy period and planted in pots in the greenhouse. After 1-2 months, they are moved to a growth chamber set at 35°C for both day and night temperatures and a 12-hour light cycle. Two weeks after heat treatment (extension of this treatment is suggested), terminal buds are excised and disinfected following the method described for sweet potatoes. Meristems with two to three leaf primordia are excised and transferred to glass tubes containing 5 ml of the culture medium, and then capped and incubated in the culture room as for sweet potatoes.

The Murashige and Skoog (MS) basal medium is used with the addition of 3% sucrose, 0.2 ppm napthaleneacetic acid (NAA), 0.15 ppm bencylaminopurine (BAP), 0.04 ppm gibberellic acid, 80 ppm adenine sulfate dihydrate, and 0.7% agar. The pH of the medium is adjusted to 5.1 ± 0.1 before sterilization.

Plantlets are obtained 5 months after incubation with two transfers to new culture media. They are then transplanted onto Jiffy peat pellets and grown in the humidity chamber. Later they are replanted into pots for observation of disease symptoms.

Virus indexing can be done by enzyme-linked immunosorbent assay (ELISA) techniques and SSEM if antisera are available, or by means of inoculation of sap samples to *Nicotiana benthamiana* (Rossel and Thottappilly, 1982).

Cocoyam (taro and tannia)

Dasheen mosaic virus (DMV) was eliminated from cocoyams using the meristem culture technique (Hartman, 1974; Ng, unpublished). Two types of bacilliform viruses in taro which cause diseases known as *alomae* (death of taro) and *bobobe* (curled or folded leaf) were also eradicated using meristem culture (Jackson et al., 1977). Virus-tested plants can be obtained by the following method.

Culture method

Cocoyam shoot tips are obtained from the corms of field grown cocoyams after removal of the petioles, and trimmed to a shape of 2 cm long and 0.5-1 cm wide. They are then washed with a mild solution of 'teepol' (1% v/v) in a container for 1 minute and rinsed well with tap water. Next they are treated with 70% ethanol for 4 minutes, followed by a 7% filtered solution of calcium hypochlorite with a few drops of Tween 20 for 20 minutes. After rinsing with three changes of sterile distilled water, the shoot tips are removed aseptically and trimmed with the aid of a dissecting microscope under a microflow transfer cabinet. Meristems with two leaf primordia are excised and transferred to the culture medium. The cultures are incubated under the same incubation conditions described previously except that the liquid cultures for taro are placed on a gyrorotatory shaker set at 70 rotations per minute (rpm) for the whole incubation period.

The medium for taro meristem culture consists of MS basal medium with the addition of 3% sucrose and 80 ppm adenine sulfate dihydrate in liquid form. For tannia meristem culture, the MS basal medium is used

with the addition of 3% sucrose, 200 ppm casein hydrolysate, 0.1 ppm NAA, 0.5 ppm BAP, and 0.7% agar.

The pH of the media is adjusted to 5.7 ± 0.1 before sterilization. The sterile media are then poured into 60-ml screw-capped universal plastic containers (pre-sterilized). Containers with the soil medium for tannia are filled to 15 ml and containers with the liquid medium for taro are filled to 10 ml.

Taro and tannia plantlets are obtained 5 weeks and 8 weeks after inoculation, respectively. They are transplanted to pots in the isolation room for observation of dasheen mosaic virus (DMV) symptoms. Leaf sap samples can be used for electron microscope observation, and SSEM can also be carried out. Another method of detection is to inoculate a plant used for DMV testing, *Pholodendrom sellum*, or healthy cocoyam seedlings with the plant samples.

Virus-tested plants can then be multiplied using vine cuttings (Akoroda and Okonmah, 1982), root pieces (Alvarez and Hahn, 1983; Okoli et al., 1982), and *in vitro* culturing before beginning large-scale production of planting material.

Conclusions

The aims of freeing vegetatively propagated plants from virus infections by thermotherapy and/or meristem culture are to produce virus-free plants for use in studies on the effects of viruses, to provide the basis for the commercial growing of clones, and to allow safe national and international distribution of clonal material.

It should be kept in mind that the elimination of viruses does not bring about immunity; reinfection can be expected when the plants are exposed to disease and their vectors. Therefore, measures should be taken to prevent massive reinfection. The nuclear stock of plants can be maintained in insect-proof screenhouses with a very high degree of protection, or they can be maintained *in vitro*, in which case reinfection is completely avoided. However, if this involves a callus stage, the increased mutation rate should not be ignored. If the stock is maintained in a screenhouse, it should be frequently indexed individually, so that reinfection can be detected in time. The commercial planting materials should be randomly tested to qualify for certification. The development of sensitive virus indexing methods, such as ELISA and SSEM tests, will certainly give a very high assurance of freedom from the tested viruses.

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CHAPTER 5. RAPID PROPAGATION TECHNIQUES

Rapid Propagation Techniques for Potato

J. E. Bryan, CIP, Lima, Peru

Introduction

Five methods of rapid multiplication techniques for potatoes are briefly described below. The first four are covered in detail in the CIP bulletin "Rapid Multiplication Techniques for Potatoes," 1981, by Bryan, Meléndez, and Jackson. Slide sets and illustrated guide books giving detailed methodology are also available in English, Spanish, and French versions. The fifth method is not yet published.

All rapid multiplication techniques are labor-intensive and costly. The extra cost is usually more than offset by improved health and increased seed production in less time. Generally, 7-10 times more seed is produced in the same time than by conventional methods. Because most rapid multiplication techniques use aerial portions of the plant, contact is broken between tubers, soil, and the cuttings. This eliminates most nonsystemic diseases carried in soil and tubers. However, if proper sanitation methods are not followed, the techniques favor spread of contact-disseminated pathogens.

Three of the methods entail rooting the cuttings in sand or other media, for which the use of rooting hormones can be beneficial. A well-drained rooting medium is essential. Rooting is optimum at 20-23°C, and growth of cuttings is best at 23-26°C. Therefore, the best overall production temperature is about 23°C.

Stem cuttings

The best available tubers, well-sprouted, are planted. When the stems are 20-30 cm high, the apical growing point of each stem is removed. This

removal stimulates development of axillary buds at each leaf/stem axis. When these new growths are about 15 cm long (about 20 days) they are removed and placed in 5-cm squares in the rooting medium. The rooted cuttings are ready to transplant to the field in 15 days. New cuttings will have grown on the mother plant during this time and the second harvest will also be ready then. Most varieties produce three to four harvests of cuttings, depending on the number of stems per plant. Each mother plant gives about 35 cuttings and each cutting yields five to eight tubers in the field, giving an increase ratio of 1:175-280.

Sprout cuttings

Tubers are alternated in light and dark to control sprout length and internodal distance for the production of the size needed. They are held at a constant 90-95% relative humidity to promote primordial root development. Sprouts are removed and cut into segments, each with at least one node. The tiny cuttings are rooted in sand and are usually ready for transplanting to the field in about 20 days. Two harvests can be made from each tuber with up to 60 cuttings per harvest, each cutting yielding five to eight tubers in the field. This gives an increase ratio of 1:600-950 per tuber.

Single-node cuttings

Mother plants for single-node cuttings are usually derived from other rapid multiplication techniques. When the plants have five to seven leaves, the stem is cut off, except for one strong leaf. The stem is cut into segments, each segment having one leaf with a node. These are rooted in sand and are ready to transplant in about 15-20 days. The mother plantlet that was left with one leaf has in the same 15 days produced another stem from the node at the leaf. This stem is then removed, again leaving a second strong leaf and the process continues. Five or more harvests can be made from each mother plantlet. The later harvests usually yield two or three stems each, so that an average of nine stems is obtained from one mother plant over five harvests. Since each stem yields an average of five segments, each mother plant can produce about 45 plantlets. Figuring an average of five tubers per plantlet gives 225 tubers from one mother plant (9 stems/mother plant x 5 cuttings/stem = 45 plantlets x 5 tubers/plantlet = 225 tubers).

The sprout cutting technique can be used first to obtain 120 cuttings from two harvests of a mother plant. These 120 cuttings then serve as mother plants for single-node cuttings, each then giving the average 45 plantlets described above. In this case, 27,000 tubers are obtained from the

initial tuber used for sprout cutting (120 x 45 = 5400 plantlets x 5 tubers/plantlet = 27,000 tubers). Another route could be followed by using the 5400 plantlets as mothers for single-node cuttings, thereby yielding 243,000 new plantlets (5400 x 45) which should produce 1,215,000 tubers.

Leaf bud cuttings

Leaf bud cuttings are similar to single-node cuttings but are harvested from almost mature plants. The stems are removed and cut into segments leaving a mature leaf and lateral bud. These are placed in moist sand. A small tuberlet forms and is ready to harvest in 30 days. Tuberlets kept should weigh at least 1 g.

Tuberlets are stored at 4°C and 95% relative humidity for 3-5 months and planted when they sprout. Using tuberlets weighing 1-3 g planted on an 80 x 15 cm spacing in the field, a yield of 15-20 t/ha is expected.

Sprout cuttings, single-node cuttings, and stem cuttings give the highest increase ratios when used in combination. Leaf bud cuttings cannot be taken from plants that have produced stem cuttings or single-node cuttings. These four rapid multiplication techniques offer a choice of methods that do not require sophisticated facilities.

In Vitro plantlets

The multiplication rate of *in vitro* plantlets goes to infinity and is only limited by space and manpower. (The method of producing *in vitro* plantlets is not treated in this paper.) These tiny plantlets are difficult to transplant directly to the field. If they are to go to the field, CIP would, at this time, recommend transplanting in trays and later transplanting from the trays to the field. CIP has found that the best results can be obtained by transplanting to beds at high density, about 100 plantlets/m^2, to maximize large numbers of 5-20 g tubers. These tubers are then multiplied in the field. Use of large plantings of *in vitro* plantlets is still in the research phase.

Rapid Propagation Techniques for Cassava

James H. Cock, CIAT, Cali, Colombia

Introduction

The inherently slow propagation rate of cassava delays the testing of new varieties and their subsequent release to farmers. Over the years a number of more rapid techniques for propagation have been developed (Chant and Marden, 1958; Wholey, 1974; Kloppenburg et al., 1972; Cock et al., 1976; Sykes and Harney, 1972; Pateña et al. 1979). CIAT has refined these methods and developed two basic rapid propagation techniques. The first of these, multiple shoot production from two-node cuttings, is moderately rapid and can be carried out with a minimum of infrastructure. The second technique, using the axillary buds of green stems, is considerably faster but requires better infrastructure and more skillful handling of the plant material. Nevertheless, both systems are simple and require no highly sophisticated equipment for their operation. The two systems are described in detail in the following sections.

Multiple shoot system

Woody cuttings of cassava sprout 1-3 weeks after being planted in a moist medium. The shoots or sprouts consist of nodal units each of which comprises a node, an internode, an axillary bud, and a leaf. The basis of this rapid propagation technique resides in the fact that the upper part of the shoot can be cut and rooted while the axillary buds in the basal part of the young shoot sprout and produce new shoots (Wholey, 1974). The new shoots can in turn be cut and rooted and so on. The main limitations to the rapidity of this technique are 1) the process can only be started when woody lignified tissue is available, and 2) the new shoot production only

continues while nutrient and carbohydrate reserves exist in the original woody cuttings.

Installations

Multiple shoot propagation does not require any sophisticated equipment; however, simple propagation chambers and rooting chambers are required. The propagation chambers (Figure 1) are designed to maintain the original cuttings in a high-humidity environment. The canals in the base are filled with water and the plastic covers are placed over the center of the canals. The design of the propagation chambers and the construction materials can be varied according to the availability of local materials.

The rooting chamber (Figure 2) consists of a work table with a plastic canopy with flaps that can be opened or shut to give access to the work table. The surface of the table should be white, and the roof height should be approximately 1.5 m above the work table (to reduce the temperature in the chamber). As in the case of the propagation chamber, locally available materials can be chosen and used for construction.

Figure 1. *Propagation chamber for multiple shoot system.*

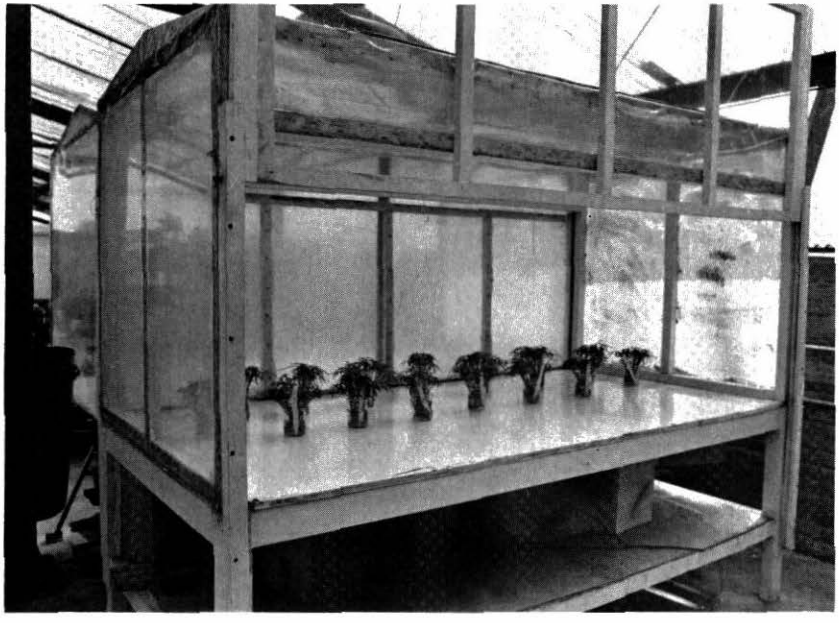

Figure 2. *Rooting chamber for multiple shoot system.*

Method

The soil should have good drainage and be reasonably fertile. Sterilization is done by spraying the soil surface of each chamber with 10 liters of 10% Formol dispensed with a watering can. Alternatively, 1 pound (680 g) of methyl bromide per chamber can be used for adequate sterilization. After sterilization, the soil is covered for 5 days with a plastic sheet and then left uncovered for 5 more days before planting.

A healthy, mature plant is required to produce the mother cuttings used in this propagation system. Woody parts of the stem are cut into two-node cuttings using a hacksaw held firmly in a vice. The stems are cut by rubbing them along the hacksaw blade, which should be cleaned and disinfected with 1% hypochlorite after each 20 cuttings. The two-node cuttings are then immersed in a fungicidal and insecticidal mix (e.g., 0.3% Manzate + 1% malathion for 5 minutes), and planted in lines in the propagation chamber where they are covered with soil to a depth of about 1 cm. When planting the cuttings, it is important that the shortest distance between two leaf scars is in the apex position (the phyllotaxy of cassava is such that leaf scars are not opposite each other).

Once the cuttings have been planted, the soil is watered to field capacity and the plastic cover is placed on the chamber. Depending on ambient temperature, shoots will emerge from 1-3 weeks after planting. When the new shoots reach a height of 5-10 cm, they are cut 1 cm above soil level with a razor blade or sharp knife that has been disinfected in 1% hypochlorite. The shoot is then cut again immediately below the lowest axillary bud and all except the two or three uppermost leaves are cut off. Immediately after this the shoot is placed in a beaker containing cold boiled water. This step washes off the latex that exudes from the cut surface and is extremely important for the success of the system.

The shoots are then transferred to 500-ml beakers or similar containers (up to 80 shoots per container) and placed in the rooting chambers. If temperatures are very high or solar radiation is intense, the chambers should be partially shaded (e.g., 50% reduction in incoming radiation). After approximately 1 week callus tissue forms on the basal cut and roots begin to form. When these roots are still less than 1 cm long (about 2 weeks after placing in the rooting chambers) the shoots are directly transplanted into the field (Figure 3). If transplanting is delayed until the roots are

Figure 3. *Plantlet from multiple shoot system ready for transplanting in the field.*

longer, they will be damaged and the success rate drops markedly. The rooted shoots are planted deep so that the soil level is just below the lowest leaves. For the first 3 weeks after transplanting, it is essential to maintain the soil near field capacity.

Axillary bud system

In traditional cassava propagation systems, the cycles are of 8 months or more because the propagules have to become lignified, and this only occurs as plants mature. The axillary bud system, however, permits green, unlignified material to be used as propagules, thus greatly shortening the propagation cycle while also allowing almost all of the axillary buds to be used, not just those on the lignified part of the stem.

Installations

Axillary bud propagation requires a rooting chamber that is a little more sophisticated than that used for the multiple shoot system. The most important aspect of the chamber is the misting system. In a 2 x 1 m chamber, two misters with a capacity of 50 liters per hour (or somewhat less) are adequate. The design of the rest of the chamber can be seen in Figure 4. Wires are strung 20 cm above the bench surface at 5-cm intervals to support the leaves and buds.

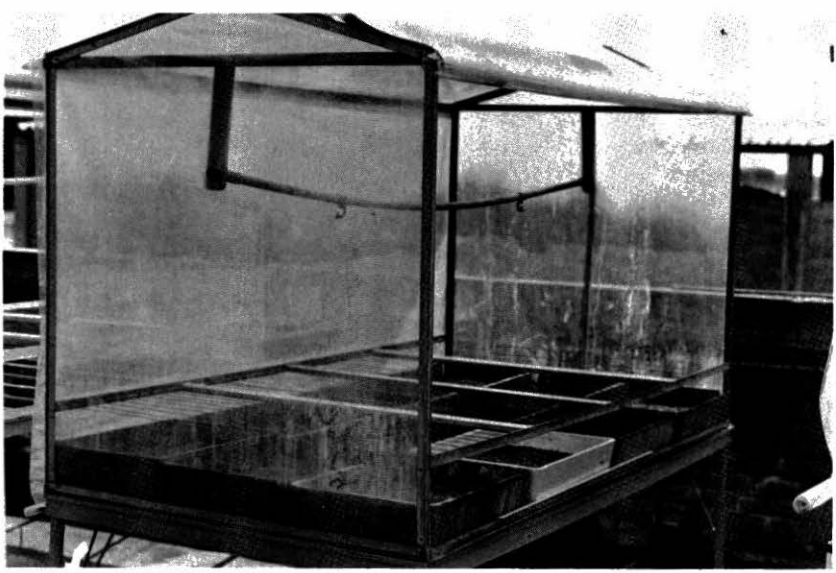

Figure 4. *Rooting chamber for axillary bud system.*

Method

Small trays are filled with coarse sand or gravel that has previously been sterilized. Healthy mother plants 3-4 months old are selected in the field. With a sharp, sterilized knife, each leaf with the accompanying axillary bud and a small heel of stem tissue is cut from the plant to form the propagules. The leaf lobes are then cut so that the leaf forms a rosette in order to reduce the transpiration losses (Figure 5). The propagules are immediately placed in water to wash the latex off the cut surface of the heel, and then put into the rooting chambers. Small furrows are made in the gravel or sand and the heel is placed in these furrows. The axillary buds are not covered. The mist is left running continuously. After 1-2 weeks small roots are formed on the cut surface of the heel and the petiole abscises. When the shoots present an appearance similar to that in Figure 6, they are ready for transplanting. They can be transplanted directly into the field, however, better results have been obtained at CIAT by transplanting first into peat pots or plastic bags filled with a well-drained soil for about 1 week before field transplanting. Within 3-4 months after transplanting in the field, new mother plants are available to repeat the process.

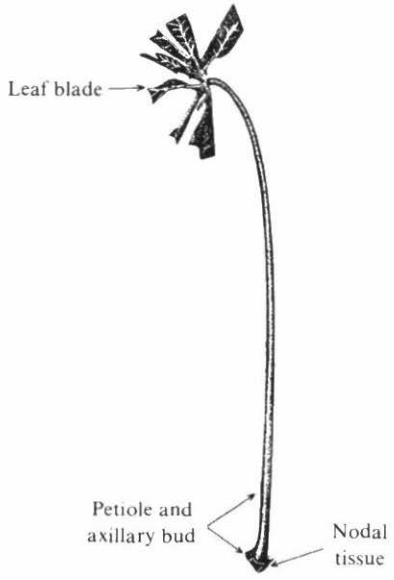

Figure 5. *Propagule from axillary bud system ready for rooting chamber.*

Figure 6. *Plantlet from axillary bud system ready for transplanting.*

Discussion

The two methods described greatly increase propagation rates. Starting from a mature mother plant, it is possible to produce 12,000-24,000 commercial stakes in one year with the multiple shoot method, as compared to 100-400 using traditional methods. The axillary bud method is even more rapid, producing 100,000-300,000 commercial cuttings from a 3-4 month old mother plant.

The systems described here have been used successfully under the conditions of CIAT-Palmira. Modifications may be necessary under different conditions. For example, when average temperatures are less than 20°C, rooting will be much delayed, and when average temperatures are above about 25°C, it may be necessary to shade the propagation and rooting chambers.

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Rapid Propagation Techniques for Sweet Potato, Yam, and Cocoyam

S. Y. Ng, IITA, Ibadan, Nigeria

Introduction

Among several methods for multiplication, only the *in vitro* rapid multiplication method is described in this paper. Explant materials used for *in vitro* culturing are usually the shoot apex and nodal segment (nodal cutting). There also appears to be a possibility of using tuber discs (1 cm^2) of the subepidermal tissue for multiplication (Gunckel et al., 1972; Ng, unpublished).

In vitro culture

The shoot apex and node cuttings are surface-disinfected with the same process used in disinfecting materials for meristem culture (see Chapter 4) except that the calcium hypochlorite concentration is increased to 10%. The culture media are as follows:

1) Sweet potato: Murashige and Skoog (MS) basal medium plus 3% sucrose, 0.1 ppm benzylaminopurine (BAP) and 0.8% agar; 10-ml portions of the sterile medium are poured into 30-ml plastic culture tubes.

2) Yam: MS basal medium plus 2% sucrose, 50 ppm L-cysteine, 0.5 ppm kinetin, 0.5 ppm naphthaleneacetic acid (NAA), and 0.7% agar; 5-ml portions of the medium are dispensed into each of the glass test tubes and sterilized at 121°C for 15 minutes.

3) Cocoyam: It is advisable to further multiply the cocoyam plantlets regenerated from the meristem *in vitro* before one or two of them are

transplanted for virus indexing. Then, if the plants are negatively indexed, they can be rapidly multiplied using the plantlets that originated from the same meristem as well as the negatively indexed mother plants. MS basal medium plus 3% sucrose is used for both taro and tannia, the latter having in addition 0.8% agar; 10 ml of the sterile media are poured into a 60-ml plastic culture container. The pH of all media is adjusted to 5.7 ± 0.1 before sterilization.

The cultures are incubated under the conditions described in Chapter 4, irrespective of liquid or solid media.

Plantlets with an average of 4.2 nodes can be obtained from sweet potato one month after culturing. Each node then can be dissected and transferred to a new culture medium for further multiplication. This means that sweet potato has a multiplication rate of 4.2 per month. In yams, the multiplication rate is about 4 per month. It was estimated by Mantell et al. (1978 and 1979) that about 65,000 yam plantlets can be obtained from a single node in 6 months. The multiplication rate for taro is 20 per 3 months, and about 10 per 3 months for tannia.

Field cultivation

Plantlets are usually obtained in 20-30 days after the second culturing. At this stage, they are transplanted from the tubes to Jiffy peat pellets and kept in a high-humidity chamber. Two weeks after transplanting, the nylon nets of the Jiffy pellets are removed and the plants are transplanted to black plastic bags with sterile soil and kept in the shade for 3-4 weeks before being transplanted into the field. There is always the risk of reinfection when they are planted in the field, but this can be reduced by suitable isolation and strict hygiene. However, the plants still have to be regularly checked by indexing. The harvested seed tubers can then be distributed to the farmers.

References

References used in this section are the same as those given for Ng's paper in Chapter 4 entitled Virus Elimination in Sweet Potato, Yam, and Cocoyam.

Rapid Propagation of Yam by the Minisett Technique

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Introduction

The technique described in this paper is covered in more detail in Bulletin No. 2 of the National Root Crops Research Institute, October, 1982, by Okoli et al.

Edible yams (*Dioscorea* spp.) are usually propagated vegetatively. Whole tubers (weighing between 100 and 1500 g), called seed yams, may be planted to establish a new crop. Sometimes, two to six pieces, called setts, are cut from a tuber and used to establish new crops. As much as 3 tons of seed yams may be required to establish 1 ha of yams.

The yield expected is hardly more than four times the weight planted. This low multiplication rate in yams is a handicap for breeding, because when tubers are selected from a hybridization program, it takes a long time to multiply enough planting material for evaluation in uniform trials. Thus, there has been the need for developing methods to rapidly multiply selected yam clones for evaluation and for distribution to farmers, and also to reduce the seed input in the production of yams.

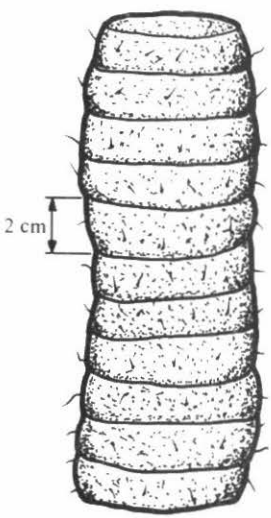
In order to overcome these problems, the minisett technique of producing seed yams has been developed. A minisett is here defined as a sett less than one-quarter of the minimum size (100 g) of yam sett usually planted.

Method

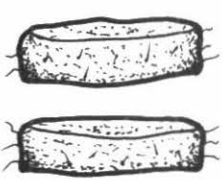
The minisetts are prepared from fairly cylindrical tuber pieces from which discs 2 cm thick are cut. Four minisetts, each weighing 25 g, are

obtained from each of these discs by cutting along two perpendicular diameters of the disc (Figure 1). The minisetts are then dusted with Aldrex T (a fungicide/insecticide) at an application rate of 10 g Aldrex T per 150 minisetts, and are planted the following day.

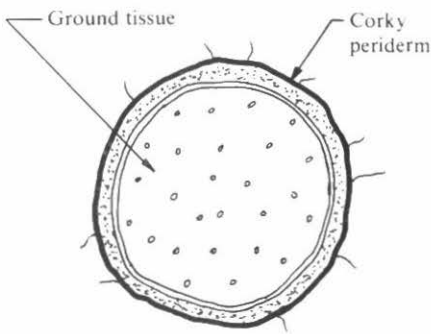
The minisetts can either be planted directly into the field or presprouted in a germination chamber before transplanting into the field. The presprouting method requires a germination chamber made of concrete walls, filled to a depth of 15 cm with river sand kept constantly moist, and covered with a polyethylene sheet.



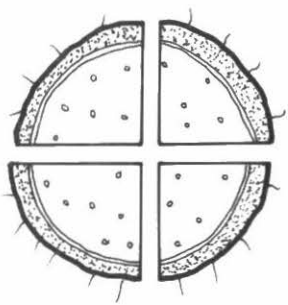
(a) Cylindrical piece with 2-cm marking



(b) Longitudinal section of 2-cm disc



(c) Transverse section of 2-cm disc



(d) Four minisetts cut from disc

Figure 1. *Preparation of minisetts for planting.*

The minisetts are planted in the field at a density of 40,000/ha. They take between 4-8 weeks to establish themselves (Figure 2), depending on the species of yam used. If presprouted, most transplanted propagules survive. The only disadvantage of presprouting is that it is labor-intensive.

The readiness with which a yam tuber sprouts is dependent on the physiological age of the tuber (Onwueme, 1975). Therefore it is better to use mature, stored seed yams that have had their dormancy broken to establish seed yam plantations.

To obtain uniform sprouting in a plantation, it may be advisable to group minisetts from the head, middle, and tail portions of the parent tuber and plant them separately, as it is known that the tail and middle setts sprout less quickly than the setts derived from the head in normal-sized setts (Coursey, 1967).

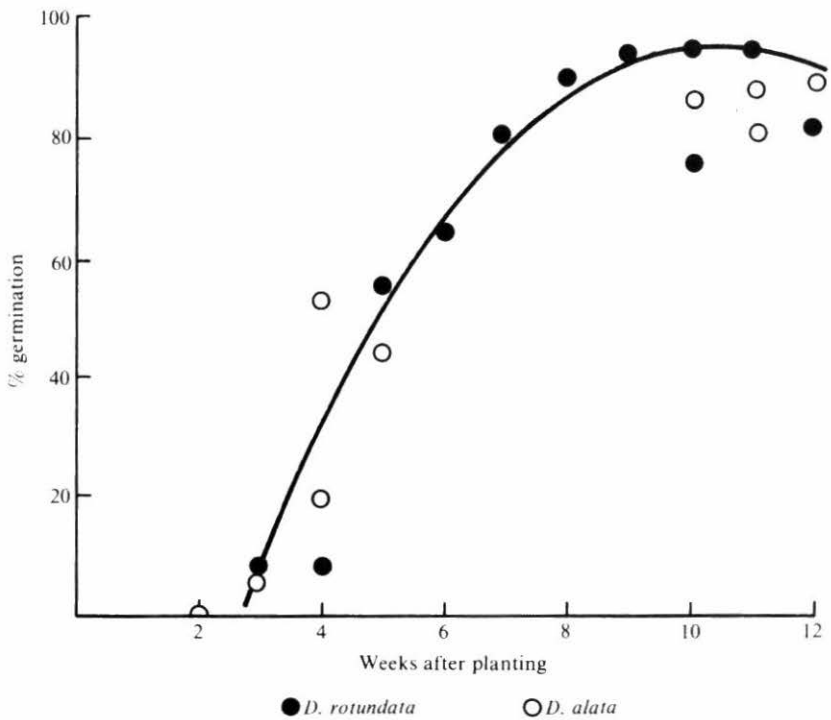


Figure 2. *Mean percent germination of directly sown yam minisetts.*

Discussion

The 25-g minisetts used in this method would require 1 ton of planting material per hectare when planted at a density of 40,000/ha. The expected yield is 13.6 t/ha of seed yams/ha (mean size of the seed yams produced is 340 g). In normal practice, farmers use 4 t/ha of planting material to produce the same yield. It is possible with this method to use much less than 1 ton of planting material; with certain species and possibly varieties such as *D. alata*, minisetts weighing 10 g or less could be used for producing seed yams. One study showed that the smallest size sett that can be sprouted is less than 3 g (National Root Crops Research Institute, 1981).

The number of tubers weighing more than the average (200 g) produced from minisetts is dependent on the species or variety. This aspect needs to be related to physiological parameters that influence yield such as leaf area index, leaf area duration, and net assimilation rates.

The technique described here for rapid multiplication of yam materials exploits the fact that yam, unlike potato (*Solanum* spp.) has no bud initials and any part of the surface of a healthy yam tuber is capable of producing a sprout when placed under favorable conditions (Onwueme, 1973).

Yields of up to 1 kg/plant have been obtained from true seed weighing about 0.002 g/seed. The minisett technique is based on the same principle, i.e., that with minimum food reserves, propagules could have a yield potential similar to that produced by true seed. Although more work needs to be done on the cultural management that will produce the optimum yields, the minisett technique offers a great promise for massive seed yam production in the future.

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CHAPTER 6.
SEED STORAGE

Seed Potato Storage

R. H. Booth, CIP, Lima, Peru

Introduction

This paper is restricted to the storage of potato seed tubers and does not treat the storage needs or problems of true potato seeds (TPS) or other propagating material.

In many respects the storage requirements of all potato tubers, whether destined for use as seed, for direct consumption, or for processing, are the same. Two obvious examples are the avoidance of pest and disease damage and excessive shrinkage and weight loss. Pests and diseases such as potato tuber moth, late blight, pink rot, dry rot, and bacterial soft rots, which all cause gross destruction of stored tubers, are clearly of equal importance regardless of final use. However, the relative importance of certain pests and diseases changes according to the final use of the stored tubers. Of particular importance to stored seed tubers are those pests and diseases which cause eye blindness and which attack young sprouts, such as potato skin spot and *Rhizoctonia*. Of equal importance to the storage of seed tubers is the control of diseases which are tuber-transmitted from one generation to the next and result in either constant degeneration and lower yields or the formation of disease foci for infection of the subsequent growing crop.

Particular attention should be paid to the dangers of severe virus buildup and spread during the storage of seed tubers (potato leaf roll virus and potato virus Y). Young potato sprouts are particularly attractive and susceptible to attack by aphids. This is especially true when seed tubers are stored in buildings with no temperature control and during periods when little alternative vegetation for insect attack is available, e.g., during winter

or dry periods. Where aphid infestation of sprouts occurs in stores, the buildup and spread of severe viruses, particularly potato leaf roll, can be very extensive and so diminish the effectiveness of expensive propagation and field control measures. Thus, in all types of seed stores management, attention must be focused on pest and disease control. Too often the storage phase of the total production cycle is regarded as a 'dormant' phase and little attention is given to the tubers until preparation for planting. This passive approach can frequently result in expensive surprises in the subsequent crop.

The importance of shriveling or water loss in stored seed tubers largely depends on whether they are for sale or for home planting. Since seed potatoes are sold by weight, any loss of moisture during their storage will decrease revenue at the time of sale. On the other hand, if seed tubers are for home planting, some moisture loss, even up to about 20%, is of little importance provided that the tubers are planted in a well-prepared and moist seed bed.

Control of sprout development

Special considerations for the storage of seed tubers are those which influence sprout development. Many aspects of sprout development are characteristic for a given variety; thus, while it is possible to discuss general requirements, specific storage needs and management practices should be determined for each variety.

Seed storage methods and management must provide the desired development of sprouts prior to planting in terms of both number and size. The desired sprout development will vary according to variety, purpose for which the crop is being grown, soil conditions, expected growing conditions, and many other factors which fall beyond the scope of this presentation.

The number of sprouts per tuber, which determines the number of main stems per plant in the field, is influenced by variety, tuber size, and degree of apical dominance or physiological age of the seed. If a potato tuber is stored at a temperature that promotes a short dormant period, the young buds at the apex start growing while growth of the older buds is suppressed. This is known as apical dominance. The degree of apical dominance in a given variety is influenced by storage conditions, especially by temperature (Figure 1). Planting tubers with apical dominance results in the development of single-stemmed plants, and unless this was anticipated and a very high seed rate is used, the result is low yields and the

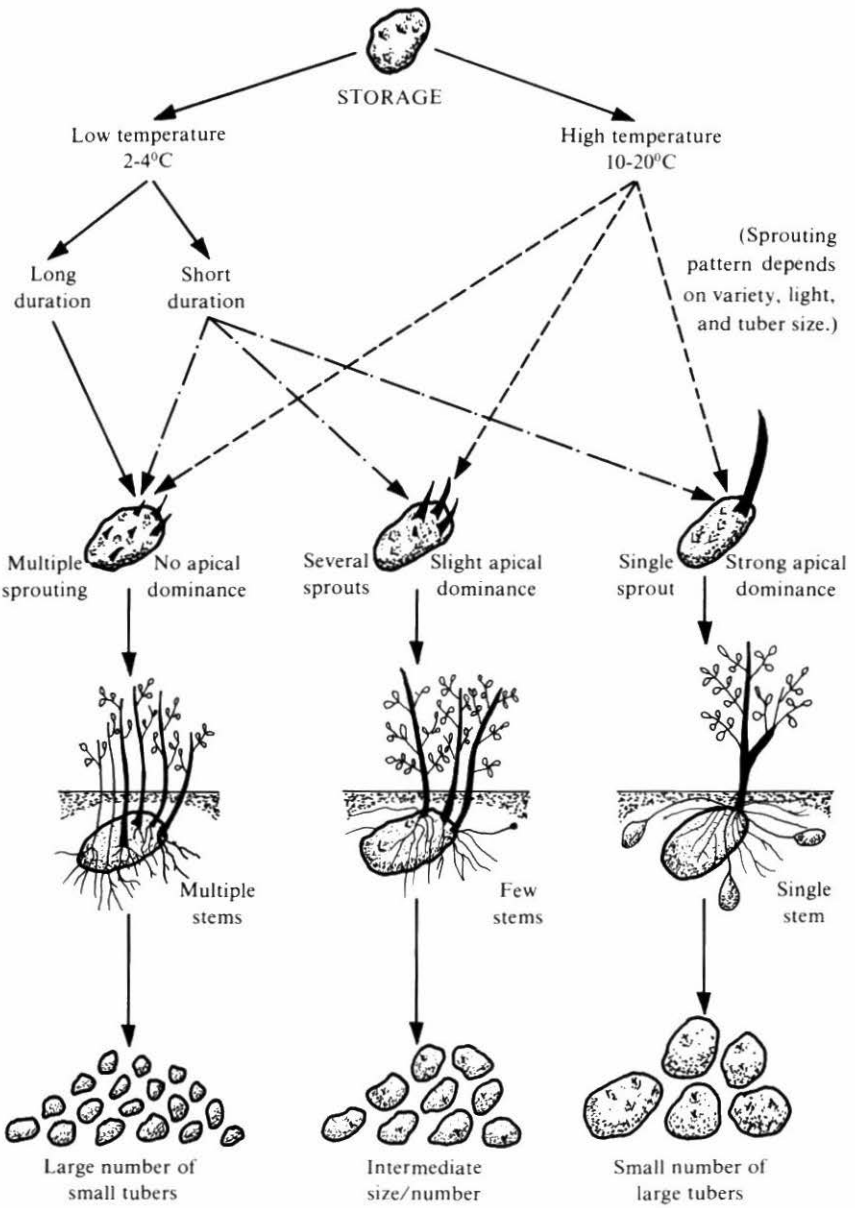

Figure 1. *Apical dominance in potato. (Effect on total yield depends on planting density, soil fertility, and growing conditions.)*

development of a small number of tubers which tend to grow very large. In several areas of the world, the planting of such physiologically young seed is responsible for low yields as much or more than the health of the seed tubers used.

If the storage conditions are controlled so as to suppress apical dominance, then the proper number of main stems, usually three to five, will normally develop. This pattern yields the maximum amount of tubers of suitable market size.

Thus, the important question is what storage practices are available to manipulate the physiological aging of tubers. First, where control of storage temperature is available, the seed tubers may be held at about 4°C beyond the end of the natural dormancy of the particular variety until a few weeks before the required planting date. They are then stored in light (natural or artificial) at about 15°C which stimulates multiple green sprouting.

Where manipulation of storage temperature is impossible, as is commonly the case in most developing countries, apical dominance may be partially controlled manually. After storage at uncontrolled and commonly fairly high temperatures, sprouts will begin to grow following the end of the variety's natural dormancy period. The degree of apical dominance or number of sprouts produced will largely depend on the specific sprouting characteristics of the variety. In varieties which show strong apical dominance, the apical sprouts can be removed by hand. This promotes many other eyes to sprout but, unless undertaken carefully, can promote excessive moisture loss. Another physical method of 'breaking' apical dominance is to cut the seed tuber into one or more parts, each part producing seed pieces with reduced apical dominance. However, the practice of seed cutting, unless skillfully practiced, is risky and can result in increased virus spread and rotting of seed pieces.

Another way to reduce apical dominance is to store seed tubers in diffused light, either natural or artificial. Exposure to diffused light always increases the number of sprouts per tuber, but in varieties with very strong apical dominance, this may not be adequate to provide the required number of sprouts at planting time and may need to be linked to some desprouting.

Storage of seed tubers at uncontrolled and high storage temperatures not only promotes apical dominance but also stimulates excessive sprout elongation when storage occurs in dark buildings. As with apical dominance, excessive sprout elongation may be controlled by low-

temperature storage. Where such control is not available, sprout elongation may be retarded by storage in diffused light.

Thus, to some extent, the use of diffused light can replace the need for expensive low-temperature storage of seed tubers. The technique has long been used as a pre-planting treatment in Europe and in recent years it has become widely accepted in a number of developing countries as a low-cost alternative to cold stores. The advantages of storing seed tubers in diffused light as opposed to in the dark at uncontrolled temperatures are, thus, a very considerable reduction in sprout elongation, and a reduction in apical dominance, resulting in an increased number of short, vigorous sprouts. Additionally, the tuber greening which results from exposure to light has been shown to increase tuber and sprout resistance to certain diseases, e.g., *Rhizoctonia* and bacterial soft rots. This better condition of seed tubers results in a faster, more uniform emergence, which is commonly reflected in yield increases of up to 25%.

Design of storage buildings

The use of natural diffused light for the low-cost storage of seed tubers considerably influences the design and construction materials of a storage building. Entrance of diffused light through transparent walls is ideal because of improved light distribution. Also, because heat gain into buildings per unit area is greater through the roof than through the walls; optimum light penetration is obtained in long, narrow buildings that minimize roof space and maximize wall space. Construction materials will depend on local availability, costs, and climate. A simple frame of round bamboo timber over a leveled earth floor is recommended. The roof should be well-insulated with large overhangs to provide shading for the walls so as to prevent direct sunlight from falling on the stored tubers for prolonged periods. Thatch roofs are ideal for this purpose. Transparent walls can be either wire, nylon, or plastic open mesh screening in warm areas; in cooler regions, polyethylene, rigid corrugated plastic, or glass-fibre sheets can be used. Spaced poles of timber, cane, or bamboo are other alternatives. Where broad-span existing buildings are modified for tuber storage, sky lights and windows will need to be introduced if full advantage of space is to be made.

In small-scale stores (up to 5-6 tons) using natural diffused light, seed tubers can be stored on simple slatted shelves to a maximum depth of two or three tubers to permit light access to all tubers. Spacing between shelves is largely determined by the width of the building: additional spacing is required to allow good light penetration in wider buildings. In small stores

with a width of 1.5 m, a spacing of 25-30 cm between shelves is suggested. Within larger stores, individual shelves should not exceed 1.5 m in width to avoid handling difficulties. Approximately 75-100 kg of seed tubers may be stored per square meter of shelving. Seed tubers can also be stored in seed trays, which increase costs, but have many advantages in reducing tuber handling and are particularly useful where many varieties are being stored.

Generally, construction costs of stores using diffused light are low, but the cost of shelving or seed trays can be a major factor in determining the economics of this simple storage method. It is ideally suited to small farmers in traditional potato growing areas. Further research is required to determine the extent to which the method can be used to store seed tubers through prolonged periods with temperatures continuously above 25°C. Where large quantities of seed tubers are to be stored—in excess of 100 tons—the costs of shelving or seed trays may equal or exceed the costs of more sophisticated low-temperature bulk storage methods.

In stores where internal temperature can be partially controlled, but not enough to control sprout development, artificial light may be used to advantage. Artificial light is best used by suspending or supporting fluorescent light tubes vertically between shelves or stacked seed trays.

Storage and Regeneration of Cassava Planting Material

*Dietrich E. Leihner, CIAT, Cali, Colombia**

Introduction

Farmers try to avoid storing cassava planting material whenever possible. They know that cassava plants raised from stored stakes are weak, or the stakes may not sprout at all. This paper describes research conducted to identify factors related to stake deterioration during storage and the control of such factors through appropriate stake management practices.

Water loss and viability

Cassava stakes dehydrate during storage, particularly when they are stored in open air, exposed to the sun. The rate of moisture loss is determined by plant-related factors such as the moisture content of the stake and the degree of lignification at harvest, as well as by environmental factors such as radiation, temperature, and relative humidity. Moisture loss in storage is faster in short stakes than in long stakes. One storage study showed that when short stakes were stored for two weeks, the sprouting percentage dropped drastically from 85% to 30%. This coincided with a drop in stake moisture content below 60% (Leihner, 1983). The same decline in sprouting percentage, although less drastic, was observed with long stakes only when storage lasted longer than two months. The drop in sprouting percentage again coincided with moisture in the stems falling below 60%. It was therefore concluded that moisture in cassava stakes under storage must stay above 60% if viability is to be retained. This

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finding is in accordance with data obtained by Wholey (1977). Although moisture percentage can only be determined in the laboratory, there is a field method to check on stake freshness. Stakes are cut or scratched with the fingernail; if latex emanates from the lesion, it is a safe indication that the planting material is still viable.

Pathological deterioration during storage

When cassava stakes are stored, a variety of microorganisms and insects start to infest them, causing deterioration of the stem and bud tissues. This reduces both vigor and viability of the planting material. Earlier work at CIAT has shown that microbial deterioration can be reduced by a chemical treatment of stems prior to storage (CIAT, 1979; Lozano et al., 1977). This practice was tested in a trial on the Colombian north coast under extremely favorable conditions for microbial stake deterioration. The interaction of stem position and storage duration with this practice was also studied in the trial. Long stems of the cassava cultivar M Col 1684 were stored with and without fungicide treatment (benomyl and captan, 3000 ppm each) in both vertical and horizontal positions for 30, 60, and 90 days. Prior to planting, stem samples were subjected to a pathological and entomological examination. Without the fungicide treatment prior to storage, there was an increasing infestation of external and systemic saprophytic and pathogenic fungi, both in extent and number of species, as the storage duration increased (Table 1). Storage position did not visibly influence infestation. On the other hand, stakes that received a fungicide treatment prior to storage showed very little infestation and that which occurred was restricted to the nonsystemic genera and localized at the cutting ends.

With respect to insects, the pest on the majority of the stakes was a scale which could not be identified since no live specimens were collected. To a minor degree, cassava mealybugs (*Phenacoccus* sp.) and a beatle (*Collosternus* sp.) were observed. The degree of infestation was visibly reduced on the material which had undergone chemical treatment, although no insecticide was used.

The four groups of planting materials, stored with and without fungicide in both vertical and horizontal positions, showed clear distinctions with regard to sprouting percentage after different storage durations. While sprouting observed 60 days after planting was hardly below 100% when stakes had received the chemical treatment, there was a significant reduction in sprouting percentage without treatment (Figure 1). The reduction in sprouting increased as storage duration increased. There was

Table 1. **Fungal infestation of cassava planting material (cv. M Col 1684) during different periods of storage with and without chemical treatment at Caribia.**

	Storage position	Duration of storage (days)	Fungi observed Systemic	External
With treatment (benomyl and captan, 3000 ppm each)	Horizontal	30	-	*Curvularia*
		60	-	*Fusarium*
		90	-	*Colletotrichum* (on sprouts)
	Vertical	30	-	*Fusarium* *Aspergillus*
		60	-	*Fusarium*
		90	-	*Curvularia*
Without treatment	Horizontal	30	-	*Fusarium*
		60	*Diplodia*	*Fusarium* *Diplodia*
		90	*Diplodia*	*Fusarium* *Colletotrichum* *Diplodia*
	Vertical	30	-	*Fusarium*
		60	*Diplodia*	*Fusarium* *Diplodia* *Aspergillus*
		90	*Diplodia*	*Fusarium* *Diplodia*

no difference between vertical and horizontal storage position when stakes had been treated. However, without the treatment, an initial tendency of the horizontally stored material to sprout better was observed, but the trend was reversed as storage duration increased.

Effect of long-term storage

After identifying stake moisture retention and chemical protection from microbial infestation as decisive aspects in the conservation of cassava planting material, standard storage practices were defined to prevent dehydration (placement of stems in a shady environment that is not too dry) and microbial infestation (treatment with 3000 ppm each of benomyl and captan). Using these practices in a subsequent study, it was possible to obtain fully viable planting material and complete crop establishment even after 170 days of storage. Nevertheless, observations of early development of plants grown from stored stakes showed that initial growth and vigor

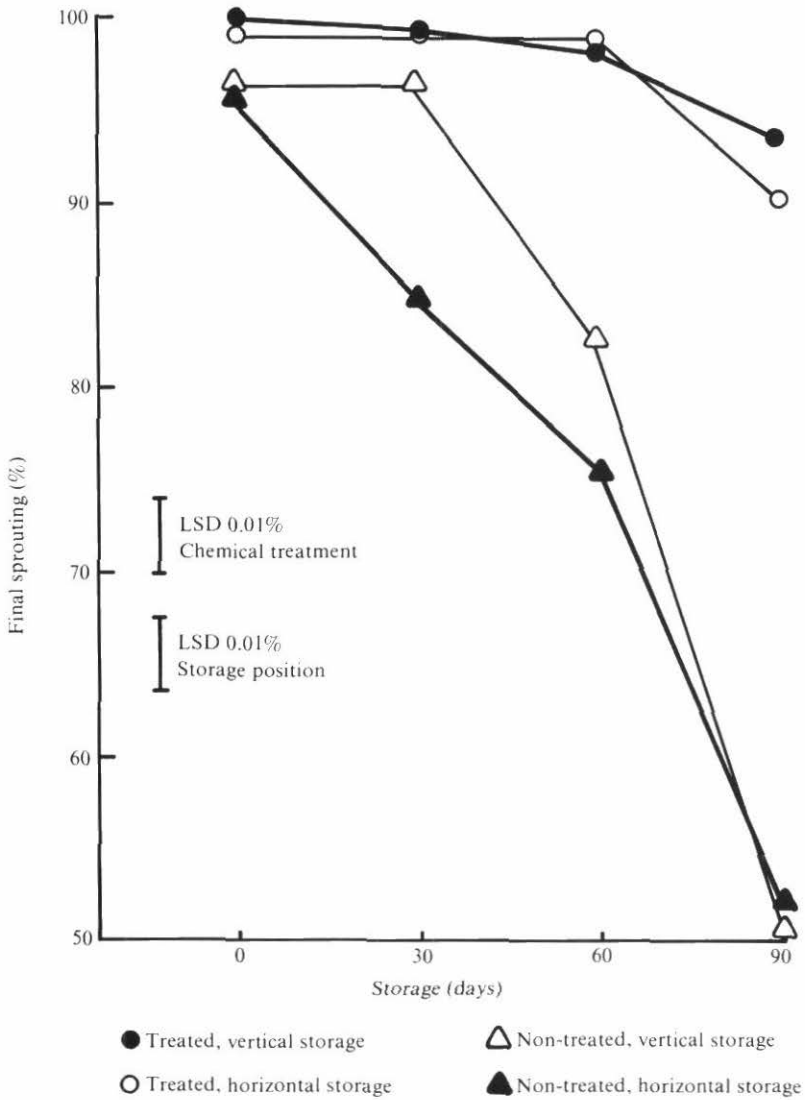

Figure 1. *Final sprouting percent of cassava (cv. M Col 1684) stored under different conditions for 0, 30, 60, and 90 days.*

was reduced as storage duration increased. However, observations of parameters such as mean leaf size at later stages showed no response to storage length (Sales Andrade and Leihner, 1980).

Restoration of early vigor

Despite optimum storage conditions, long storage duration can be expected to bring about some losses in moisture, carbohydrates, and nutrients, which would partially account for reduced early vigor. In order to restore early vigor to see if improved crop productivity would result, a simple water soaking treatment was given to stakes which had been stored for 201 days. As the soaking time increased from 15 to 255 minutes, sprouting vigor was improved, reaching almost the level of fresh stakes with the longest soaking period (Figure 2). However, this recovery of early vigor did not result in greater root yield (CIAT, 1982). When correlations were calculated between parameters quantifying early vigor against total and commercial fresh root yield, they were rather low and mostly not significant, indicating that early vigor alone was not effective in increasing thickened root production.

In another soaking treatment, stakes stored for 201 days were soaked in a 1% solution of a commercially available protein derivative designed for early plant nutritional support (a bioactivator). These stakes were

Table 2. **Effect of soaking cassava stakes in water or nutrient solution for different periods of time after a 201-day storage[a].**

Duration of treatment[b] (min)	Plant height at 60 days (cm)	Weight of tops at harvest (t/ha)	Commercial roots (no./plant)	Total root yield (t/ha)
Soaking in water				
0	41 d	44.1 abc	7.0 abcd	41.5 ab
60	52 bc	39.4 c	6.6 cd	37.6 bc
240	49 c	40.4 bc	6.8 bcd	39.3 abc
fresh	64 a	49.7 a	7.6 ab	40.6 abc
Soaking in nutrients				
0	48 cd	45.2 abc	6.8 bcd	40.6 abc
60	47 cd	47.0 ab	7.5 abc	43.4 a
240	54 bc	45.5 abc	7.9 a	44.6 a
fresh	58 ab	50.2 a	6.5 d	35.6 c

a. Means followed by the same letter are not significantly different (P = 0.05).
b. After the water or nutrient soaking, all materials were subjected to a 15-min standard pesticide treatment.

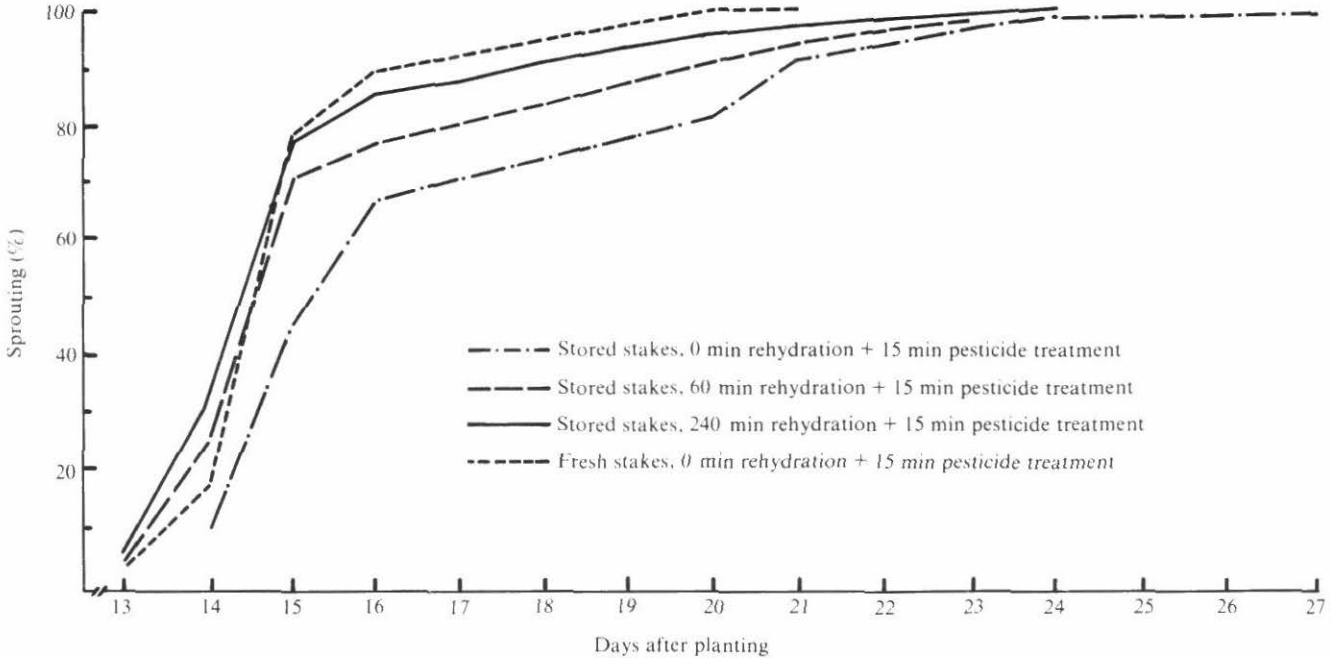

Figure 2. *Sprouting process of stakes (cv. CMC-40) stored 201 days as influenced by rehydration treatments compared to sprouting of fresh stakes.*

compared with stakes given the water soaking treatment. When yield components were analyzed at harvest, the stakes soaked in the nutrient solution showed an improvement in sprouting vigor as well as an increase in thickened root number per plant (Table 2). This yield increase went even beyond the level obtained with fresh stakes (CIAT, 1982).

Conclusions

The information provided in this paper leads to the following conclusions:

1) Both dehydration and pathogenic infestation are important causes of stake deterioration and loss of viability during storage.

2) With these two processes controlled by appropriate storage conditions in a shady environment that is not too dry and chemical protection prior to storage, planting material can maintain full viability for several months.

3) Small losses of moisture and carbohydrate reserves during storage may cause a reduction in sprouting vigor of the planting material even if viability is maintained.

4) Restoration of sprouting vigor and stimulation of thickened root formation is feasible with soaking treatments in a bioactivator solution.

5) Stakes treated with a bioactivator can produce a crop that yields as high or higher than fresh planting material, even after more than 6 months of storage.

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CHAPTER 7. CASE STUDIES: PRODUCTION PROGRAMS FOR SEED POTATO

Seed Potato Production in Brazil

Elcio Hirano, EMBRAPA-SPSB, Planaltina, Brazil

Introduction

Annual potato production in Brazil is 1.8 million tons, but the per capita consumption of 11 kg per year is among the lowest in Latin America. This low consumption shows that potatoes are not of great economic importance in Brazil. The area sown in 1978 was 181,268 ha, which is insignificant in comparison with other agricultural products such as maize with 11.3 million hectares, and beans with 4.2 million hectares. Another important factor is that there are alternative sources of energy that are cheaper and more traditional than potatoes, such as cassava, yams, and sweet potatoes.

Seed potato production began in Brazil in the 1960s with a certified cross resulting from the multiplication of basic seed potato imported from Europe. The states that produce seed potatoes are Rio Grande do Sul, Santa Catarina, Parana, Sao Paulo, Minas Gerais, and Espirito Santo. The production is concentrated in the central southern states of the country in areas with a cold winter, or in higher altitude regions, ie., more than 800 m.

Government action

Through the Ministry of Agriculture and the government's various agricultural secretaries, three major forms of action were taken to produce basic seed potatoes: creation of potato classes, assistance in promoting the sale of nationally-produced basic seed, and initiation of cultivar trials. These are described below.

Seed Potato classes

Up until 1980, ministerial laws only existed for certified seed production. At this time, the Ministry of Agriculture created the Permanent Technical Commission for Potato Seed, and its first action was to revise the production legislation. This was completed in 1981 through a ministerial decree, which created three classes of potato seed: basic, registered, and certified. The certified class is now operating in the states of Rio Grande do Sul, Santa Catarina, Parana, Sao Paulo, Minas Gerais, and Espirito Santo, and accounts for approximately 20% of Brazil's seed requirements. The basic class is operating in the states of Santa Catarina, Parana, and Minas Gerais; as yet, none of the Brazilian states have used the registered class. The permissible disease levels in each of the classes are shown in Tables 1 and 2.

Commercialization

Brazilian basic seeds potato suffered commercialization problems from the start for two reasons:

1) According to the legislation, Brazilian basic seed is allowed to have a higher level of virus diseases than is the case in Europe in order to fit the country's climatic and technological conditions; in addition, the potato production costs are greater in Brazil than in Europe. Therefore, both the inferior quality and higher price of the basic seed tubers have made them very difficult to commercialize.

2) The 25-year-old commercial tradition of potato seed importation has had a great influence on the market in Brazil. Thus, it has been necessary for the Ministry of Agriculture to intervene and create a guaranteed demand for national basic seed through a production policy. This policy has been implemented in the following manner: the producer receives authorization for basic seed importation only if he presents a receipt for a pre-established purchase of a quantity of nationally-produced basic seed. Table 3 shows the volume of domestic sales in relation to imports.

Cultivar trials

At the beginning of 1979, national trials for potato cultivars were initiated, which were coordinated and executed by EMBRAPA and related institutes, in order to select particular cultivars for importation throughout the year. The aim of the national trials was to help the producer choose the most suitable cultivars for his region, and to give exporters advice on the cultivars that could be sold to Brazil.

Table 1. **Permissible disease and abnormality levels for plants during field inspections (%).**

Abnormality or pathogen	First inspection					Second inspection				
			Certified					Certified		
	Basic	Registered	A	B	C	Basic	Registered	A	B	C
Light mosaic	2.5	5.0	7.0	10.0	12.0	1.5	4.0	5.0	8.0	10.0
Severe mosaic	0.5	1.0	3.0	5.0	6.0	0.3	0.5	1.0	2.0	3.0
Potato leaf roll virus	2.0	3.0	5.0	10.0	13.0	1.0	2.0	2.5	8.0	10.0
Other virus	1.0	2.0	3.0	4.0	6.0	0.5	1.0	1.5	2.0	4.0
Virus limit	3.0	5.0	7.0	10.0	14.0	2.0	3.0	4.0	8.0	11.0
Bacterial wilt (*Pseudomonas solanacearum*)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Soft rot, black leg (*Erwinia* spp.)	2.0	2.0	6.0	8.0	10.0	2.0	3.0	4.0	6.0	8.0
Varietal mixture	0.5	1.0	2.0	5.0	5.0	0.5	1.0	1.0	1.0	2.0
Others[a]										

a. The number of plants which cannot be tested for virus symptoms due to the occurrence of late blight *(Phytophthora infestans)*, black leaf spot *(Alternaria solani)*, weak plants, or other abnormalities should not exceed 20% of the total number of plants in the field. This evaluation is at the discretion of the inspector, who can either certify or reject the field.

Table 2. **Permissible disease and abnormality levels during tuber examinations (%).**

Abnormality or pathogen	Basic	Registered	Certified		
			A	B	C
Transmissible					
Bacterial wilt (*Pseudomonas solanacearum*)	0.0	0.0	0.0	0.0	0.0
Soft rot (*Erwinia* spp.)	1.0	1.5	2.0	2.0	3.0
Common scab (*Streptomyces* spp. and *Helminthosporium solani*)	10.0	10.0	10.0	20.0	25.0
Fusarium dry root (*Fusarium* spp.)	2.0	3.0	4.0	5.0	5.0
Canker (*Rhizoctonia solani*)	10.0	10.0	10.0	20.0	20.0
Late blight (*Phytophthora infestans*)	0.5	0.5	1.0	2.0	3.0
Brown leaf (*Cylindrocladium* spp.)	2.0	3.0	3.0	5.0	5.0
Root-knot nematode (*Meloidogyne* spp.)	0.5	0.5	1.0	1.5	2.0
Limit	10.0	10.0	15.0	30.0	40.0
Nontransmissible					
Cracks	5.0	5.0	10.0	10.0	10.0
Cuts or mechanical lesions	2.0	2.0	5.0	5.0	5.0
Insect injury	5.0	5.0	10.0	10.0	10.0
Hollow center or blackening	5.0	5.0	10.0	10.0	10.0
Internal spots	5.0	5.0	10.0	10.0	10.0
Burns	2.0	2.0	5.0	5.0	5.0
Varietal mixture	0.5	1.0	1.5	2.0	2.0
Limit	5.0	5.0	10.0	25.0	35.0

Table 3. **Domestic sales of basic seed potatoes in relation to imports.**

	Quantity (tons)				
	1979-80	1980-81	1981-82	1982-83[a]	1983-84[b]
Imports	12,480	14,340	12,515	9,246	7,500
EMBRAPA basic seed sales	639	848	1,074	1,910	2,340
% of imports	12	5.910	8.580	20.65	31.20

a. Actual quantities until September 30, 1982 plus estimates from October-December, 1982.
b. Quantities estimated.

Production system for basic seed

Basic seed production began in Brazil in the 1960s through the efforts of the Agronomic Institute of Campinhas in São Paulo. However, it was EMBRAPA, through the Basic Seed Production Service in Canoinhas, Santa Catarina, that developed and set up the technology on the basis of previous experiences in both Brazil and Europe, notably the experience of the system adopted in the Federal Republic of Germany.

The production system is shown in Figure 1 and is based on three vital points:

- Meristem culture to provide virus-free material.
- Clonal multiplication in four stages, denominating prebasic generations according to the descriptions in Figure 1.
- Post-harvest quality control carried out on all basic seed lots using samples of 100 tubers from each hectare that has been approved by field inspectors.

The supply of basic seed produced by EMBRAPA has steadily increased. The initial production in 1975 was 94.9 tons; in 1982 sales reached 1910 tons, which corresponds to 20% of the volume of potato seed imported. This increase shows the growing significance of nationally-produced seed, which is an important advance since it diminishes Brazil's dependence on imported material for planting in the production fields.

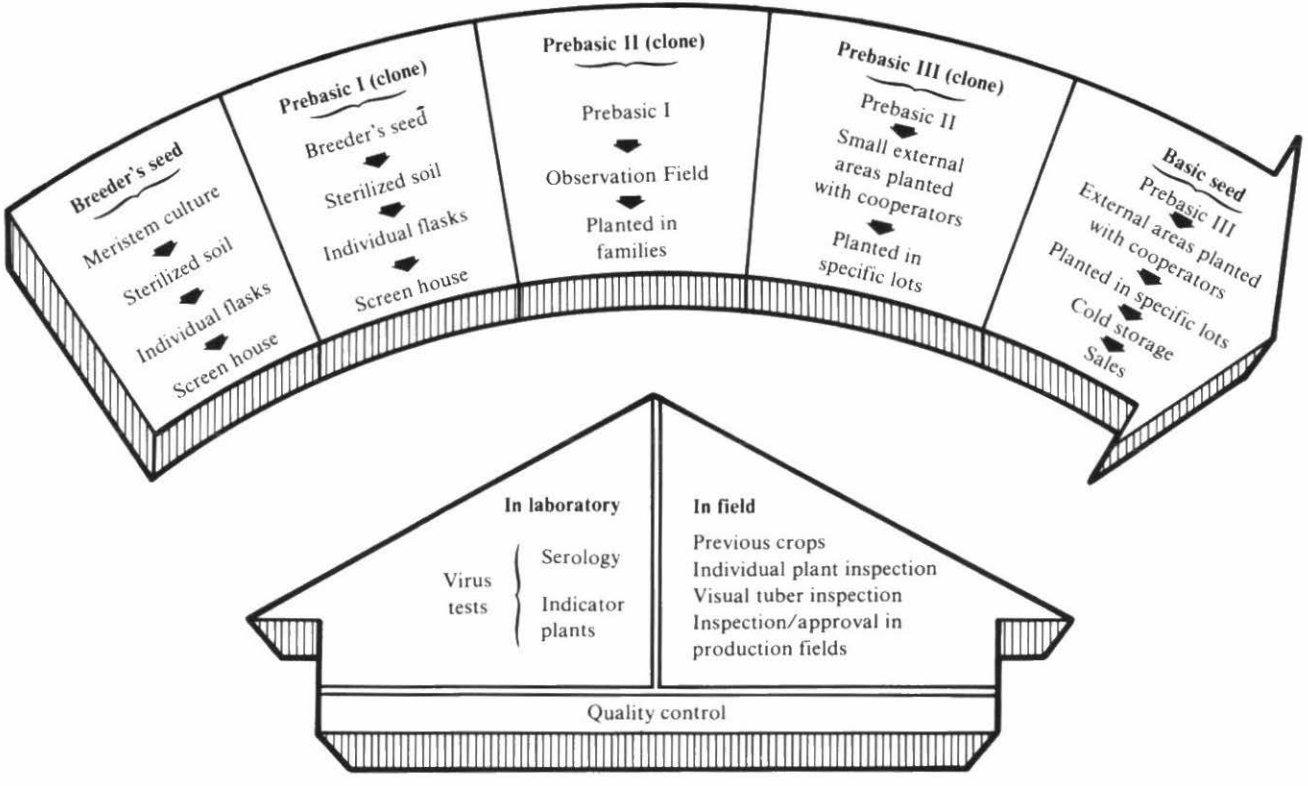

Figure 1. *Production system of EMBRAPA for basic seed potato.*

Seed Potato Production in Chile

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Introduction

The lack of good quality seed is one of the most important factors limiting increased potato yields in the developing world. However, there are very few certified seed programs to supply good seed operating satisfactorily in the developing countries.

The Chilean Certified Potato Seed Production Program is one of the few that has operated successfully in Latin America over the past two decades. From an institutional point of view, the distinctive characteristics of the Chilean program are:

- The excellent coordination and collaboration that exist between the diverse private and public institutes that participate in the production process, certification, and distribution of seed to users.
- The participation and organization of both the private producer and the merchandiser of the certified seed.
- The vital role played by INIA (National Institute of Agriculture and Animal Research) in the development of appropriate technology for seed production and storage, generation of good quality basic seed stocks, and distribution of these inputs to commercial producers of certified seed potatoes

Due to this collective effort, the Chilean program has produced approximately 5500 tons of certified seed annually over the last 5 years and, in addition, another 6500 tons of good quality seed is produced by other entities which do not form part of the Chilean national program.

This total of about 12,000 tons of good quality seed potato produced annually represents approximately 50% of the commercial potato producers' requirements in the country.

Background

Numerous research results and experience clearly show that the use of poor quality seed potatoes in the most important technical parameter limiting yield increases in Chile. Therefore, any effort the country makes to increase potato productivity must be based on a substantial increase in the use of certified seed or good quality seed. Major efforts leading up to the current seed production program are described below.

The government established seed certification for potatoes in 1936, and in the following year the Ministry of Agriculture imported certified seed potatoes from Nova Scotia, Canada. Among the introduced varieties were President, Green Mountain, Katahdin, Irish Cobbler, Bliss Triumph, and Golden. These were first grown in Los Angeles in the Bío-Bío region, but due to the high aphid population and other insect vectors of viruses there it became necessary to change to a site with a cooler climate. Thus, in 1939 work began on multiplication of these imported varieties on the Centinela farm close to Lake Llarquihue.

In the 1940s, the Ministry of Agriculture's Department of Genetics and Plant Health began to develop a seed potato certification program that lasted until 1964. The first generation seed was clonally multiplied to produce basic seed, and the seed from this second generation multiplication was given to private producers for certified seed production.

This first effort to produce certified seed potatoes did not have the success that was expected. The program placed a great deal of emphasis on the reproduction of varieties with both white flesh and skin, without regard to the Chilean consumer's preference for potatoes with colored skin and yellow flesh. In addition, problems with management, isolation, and rotation of the fields destined for basic seed production led to an increase in phytosanitary problems at the Centinela farm, especially common scab (*Streptomyces scabies*) and the root-knot nematode (*Meloidogyne* spp.).

In 1959, the company Segenta Ltda. began a seed potato certification program using varieties from the Netherlands and Germany. Near the city of Puerto Vargas (in the province of Llarquihue), Segenta produced basic seed through multiplication of both tuber units and basic clones. The production of the registered and certified stages was brought about through contracts with private producers.

The Segenta program was relatively successful, particularly considering that it resulted in the spread of varieties such as Pimpernel, Grata, Urgenta, and Sevara. At peak times, about 2500 tons per year of certified seed was produced, part of which was exported to Peru. Segenta's production program finished in 1971 partly due to political and economic problems and partly due to other difficulties, such as basic seed production at the company's farm. The small area of the farm resulted in the unwanted establishment of mixtures from volunteer plants.

During 1968-69, INIA began to develop a potato production program for prebasic and basic seed at the Remehue experimental station in Osorno. However, this was not continued due to the accelerated development of the certified seed program, which motivated INIA to create a specialized center for the multiplication of these earlier stages. This center at the La Pampa experimental substation had been until 1980 virtually the only source of prebasic and basic seed potatoes in the national certification program. Commencing in the 1977-78 season, other companies and institutions began the multiplication of prebasic and basic seed.

Structure of certification program

The basic structure and complementary elements of the Chilean seed potato certification program are described below.

Source of information and technology

The function of the information and technology source is to answer the questions of what, where, how, and when to produce certified seed. In Chile, this is the responsibility of INIA and also of the universities.

Varieties

In a certified seed potato production program, it is of vital importance to define the varieties or cultivars that are most important, their priority, and the volume that has to be multiplied.

Varietal differences in yield, time of maturity, resistance to pests and diseases, appearance of the tubers, cooking quality, and market acceptance should be considered. Location is also a consideration, since a variety that performs well in one area can give poor results in another. Thus, there is a need to collect adequate information about the best varieties to be recommended, either through trials carried out on a small scale or in experimental plots in the potato-producing areas.

In this manner, INIA has introduced, maintained, and multiplied the most important commercial varieties that exist in Chile at the moment (Desiree, Ultimus, Mirka, Bineje, Cardinal, Kennebec, Sebago, Spartaan, Arka). At present the breeding project is also releasing two new varieties: Yagana-INIA and Fueguina-INIA. It has been considered of great importance to develop national varieties that are adapted to the environment and are resistant or tolerant to the country's principal diseases and pests.

Localities

A certified seed program must be established in a zone or region in which serious diseases or pests are not limiting to the production of clean seed tubers. The area must also be one in which a high yield can be obtained. Usually these areas have a cold, moderately humid climate, with light soils that are also permeable and slightly acid. Such conditions are good for potato growth, but are not conducive to the survival and reproduction of aphids, which are the principal vectors of the most serious potato virus diseases (potato leaf roll virus, PLRV; potato virus Y, PVY; potato virus A, PVA).

The dispersion of these important potato viruses is positively correlated with the flight activity of the aphid vector. This activity, defined as the number of insects flying over a potato crop, can be estimated by means of a water tank, the bottom of which is painted yellow (known as the Moericke trap). This is a selective trap, attracting almost exclusively insects which prefer the yellow color and/or water. Among these almost all of the potato virus vectors are found.

For more than two decades, INIA, in collaboration with other institutes, has studied aphid activity in the potato crop throughout the country and its relation to the dispersion of PLRV and PVY. This research has made it possible to determine the most appropriate zones for seed potato production, and also the most appropriate dates for planting and harvesting seed lots (Figure 1). In addition, it has shown the best time for roguing and the application of insecticides, as well as the optimum time to burn off the leaves.

Recent research indicates that aphid activity is greatest in the northern provinces and decreases towards the south, and the dispersion of PLRV and PVY occurs in a similar manner (Table 1 and Figure 2).

Production technology

Important production techniques include the following: rotation, selection of a suitable variety, soil preparation, fertilization, planting date,

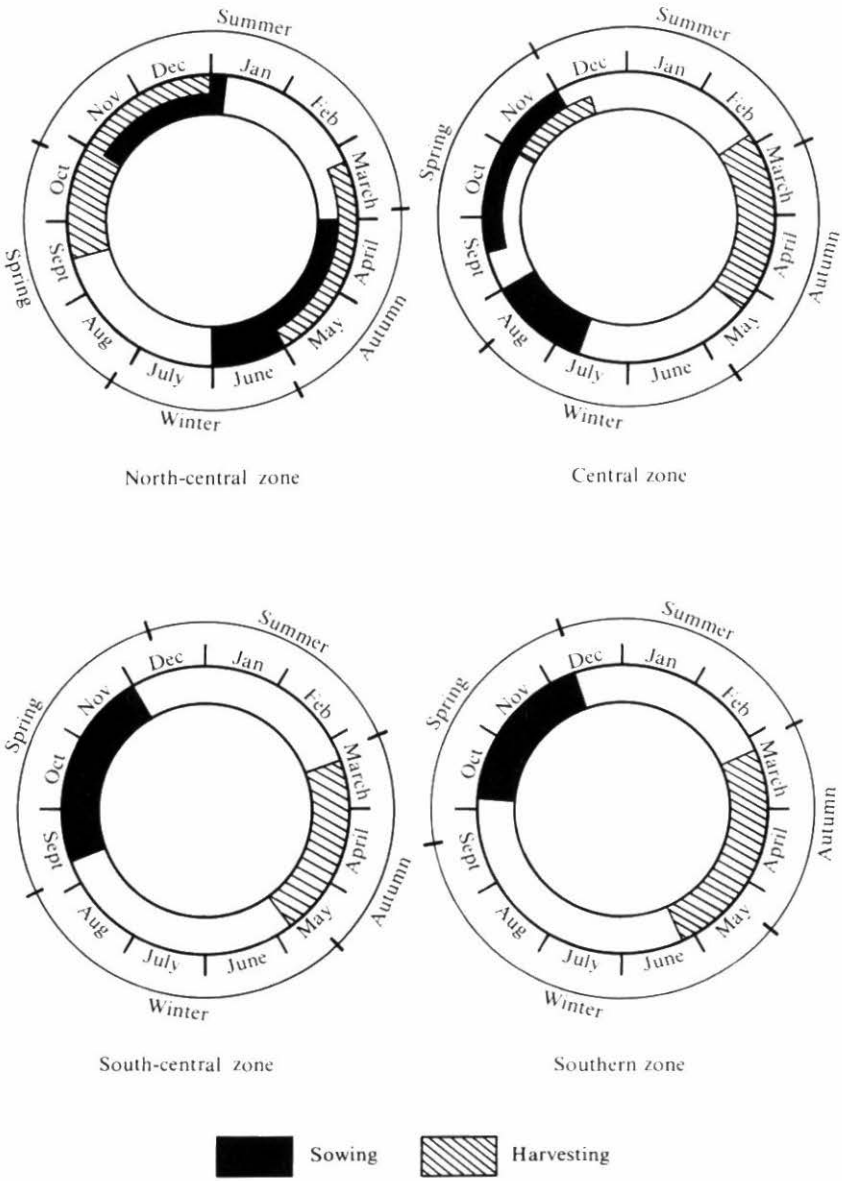

Figure 1. *Sowing and harvesting times in the principal potato-producing zones of Chile.*

Source: CENDERCO-INIA-CIP, modified, 1979.

Table 1. **Annual increase in PLRV and PVY infections in various regions of Chile.**

Region	S. latitude	Annual increase in infection (%)	
		PLRV	PVY
Santiago	33°37'	11.7	11.4
Cautin	38°45'	2.8	8.7
Valdivia	39°40'	6.2	6.5
Osorno	40°35'	2.2	2.2
Llanquihue	41°20'	0	0
Magallanes	53°20'	0	0

method and density of planting, weed control, ridging, irrigation, control of pests and diseases, time and method of harvesting, selection, and storage. In Chile, a great part of the responsibility for generating technology to produce good quality seed potatoes falls on INIA's potato program. The yield level obtained by the commercial producers of potato seed and the health status of the tubers produced with the recommended methods shows that production technology is moderately well developed.

Production of prebasic and basic seed

The generation of plots or stocks of commercial varieties of healthy tubers (prebasic seed) by multiplication constitutes another vital element of a certified seed potato production scheme.

Although the systems for producing prebasic and basic seed are varied, reproduction and clonal selection continues to be the method most extensively used. This method, suitably implemented and applied, allows the varieties to maintain both their purity and genealogical identification, as well as allowing conservation of seed tubers in a good sanitary state.

Multiplication and clonal selection is a long process (lasting at least four seasons) as well as a complex and costly one (requiring infrastructure, machinery, equipment, and highly-qualified personnel). For these reasons it is not normally profitable for producers in individual organizations. Therefore, this work is usually carried out by an institution (generally, part of the government or a university) that can be included within the subsidy programs of the government.

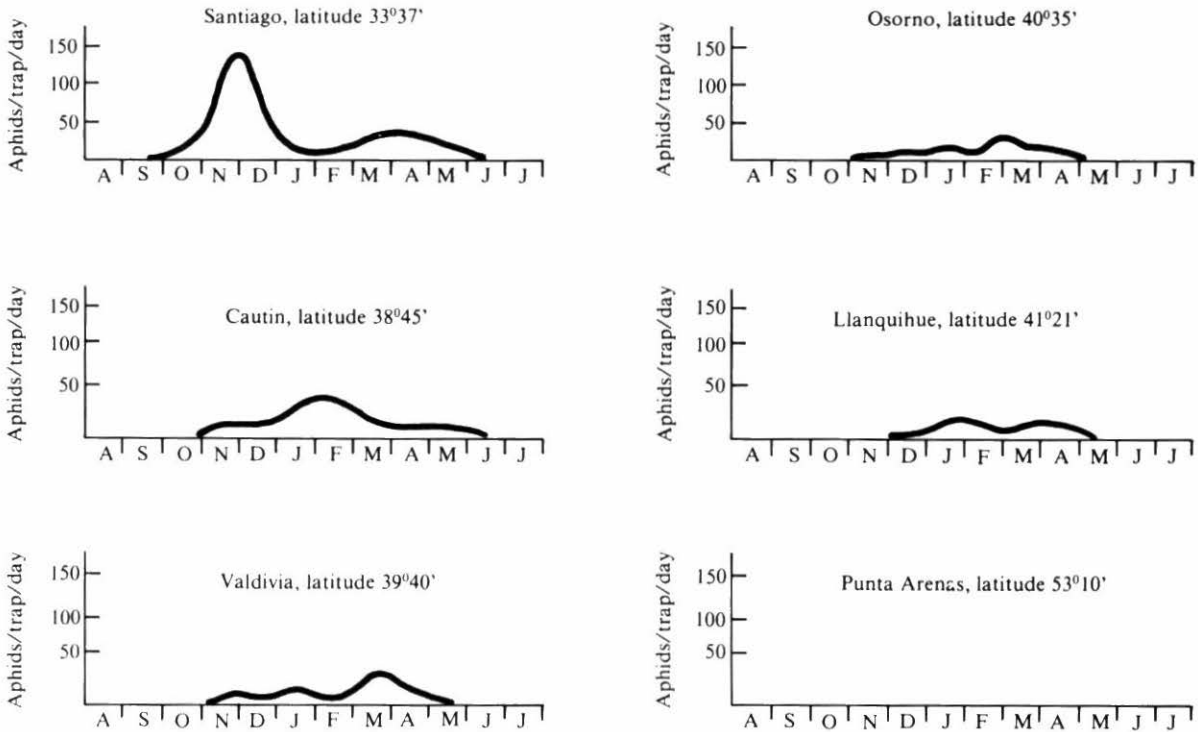

Figure 2. *Aphid activity in various regions of Chile, 3-year average.*

In Chile, prebasic and basic seed production is carried out by INIA at the La Pampa substation in Purranque, Osorno. Figure 3 shows the method of reproduction and clonal selection that is followed. Area, production, and yield of prebasic and basic seed produced by INIA over the last 15 years is shown in Tables 2 and 3. Of the numerous problems that limit the production of good quality seed potato, health is the most important, particularly the avoidance of virus diseases. Their determination and control is both difficult and complicated, requiring the application of sophisticated techniques.

Determination of virus diseases in prebasic seed (tuber units, clones, clonal groups, and clonal families) and basic seed is carried out by INIA using the following virological techniques:

- Tuber indexing
- Plant indicators (*Gomphrena globosa*, PVX; *Solanum demissum*, A-6, PVY, and PVA; *Chenopodium quinoa*, PVS; *Datura metal* PVM)
- Serology (PVX, PVY, PVM, and PVS)
- Callus dyeing with the Igel-Lange test (PLRV)
- Symptomatology
- Winter plots (post-harvest tests)

The success of control efforts by INIA for PLRV, PVX, and PVY is shown in Figures 4 and 5.

Production of registered and certified seed

The certified seed potato multiplication process is often carried out by the private sector. The success of this process depends, to a great extent, on how well trained these producers are, not only in production techniques but also in storage and commercialization. Farmers are also necessary to the success of the certification program, although they are traditionally slower to adopt new procedures.

Some examples in Chile of companies and organizations that are devoting themselves to the commercial production of certified seed potatoes are the National Agriculturalist S.A. (ANASAC), the National Agricultural Society and the Dutch firm ZPC (SEEDS S/Z), Segenta Ltda., PROSECOR Ltda. from Corte Alto, PROSEMONTT Ltda. from Puerto Montt, and the Potato Producers Association from Osorno (AMPAX Ltda.). The recent production history of certified seed potatoes is shown by the numbers given in Table 4.

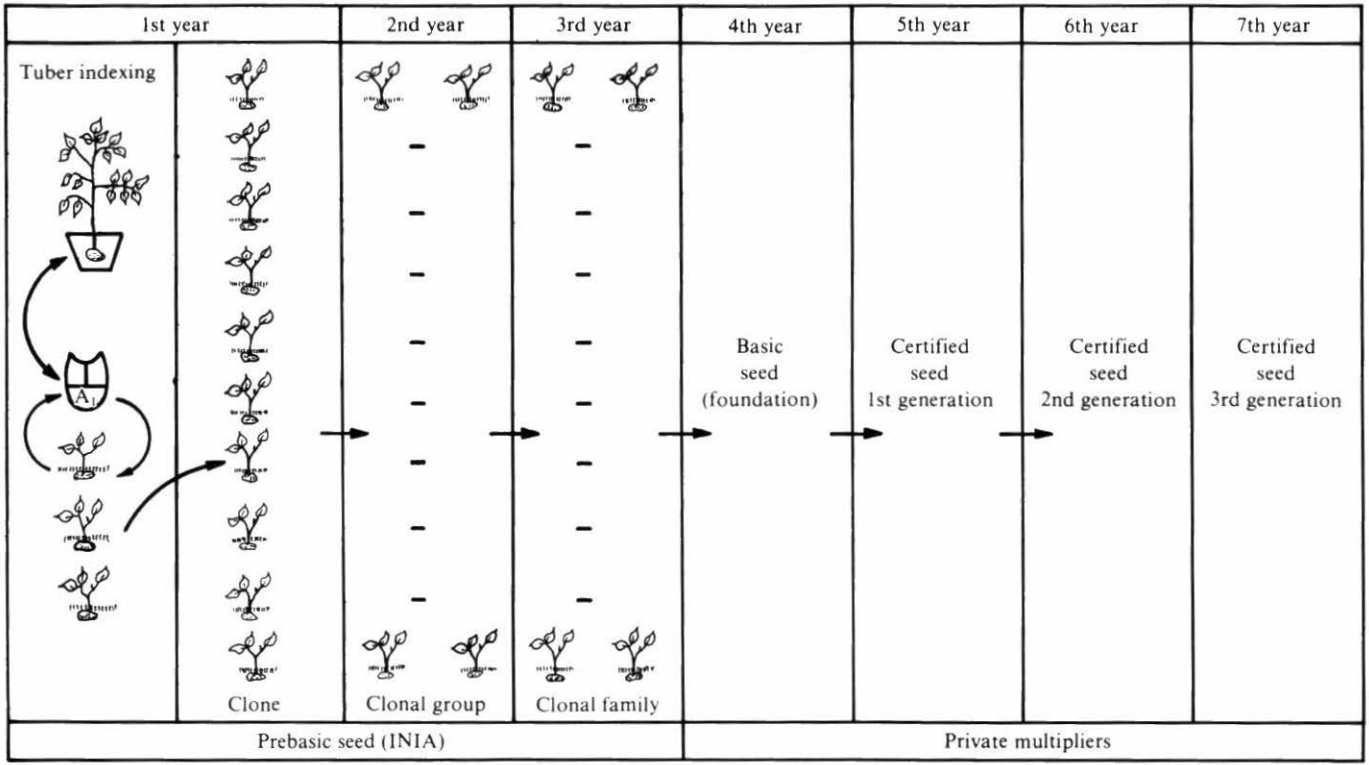

Figure 3. *System of INIA for clonal selection and reproduction of prebasic and basic seed potatoes.*

Table 2. **Area, production, and yield of prebasic seed produced by INIA.**

Season	Area (ha)	Production (t)	Yield (t/ha)
1968-69	1.0	15.0	15.0
1969-70	1.5	22.5	15.0
1970-71	2.0	41.0	20.5
1971-72	2.0	67.0	22.3
1972-73	3.6	79.0	21.9
1973-74	4.1	69.0	16.8
1974-75	2.3	50.0	21.7
1975-76	2.4	57.0	23.8
1976-77	2.3	59.0	25.7
1977-78	1.6	46.0	28.8
1978-79	1.8	34.0	18.9
1979-80	1.7	51.0	30.0
1980-81	2.3	74.0	32.2
1981-82	2.0	65.0	32.2
1982-83	2.0	69.0	34.5
Mean	2.2	53.2	24.0

Table 3. **Area, production, and yield of basic seed produced by INIA.**

Season	Area (ha)	Production (t)	Yield (t/ha)
1968-69	7.5	129	17.2
1969-70	17.3	195	11.3
1970-71	15.1	249	16.5
1971-72	26.2	260	9.9
1972-73	30.1	406	13.5
1973-74	38.3	599	15.6
1974-75	35.5	343	9.7
1975-76	23.5	265	11.3
1976-77	24.2	241	10.0
1977-78	32.4	343	10.6
1978-79	34.5	334	9.7
1979-80	33.6	410	12.2
1980-81	18.2	366	20.1
1981-82	22.0	560	25.5
1982-83	22.5	520	23.1
Mean	25.4	348	14.4

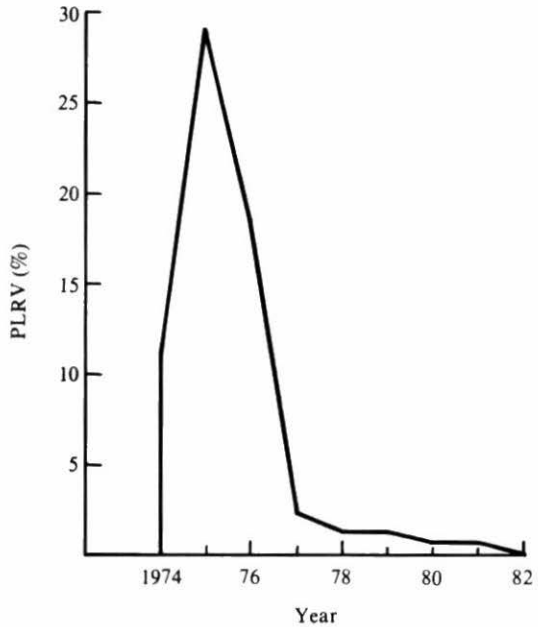

Figure 4. *Occurrence of PLRV in prebasic and basic seed potatoes produced by INIA.*

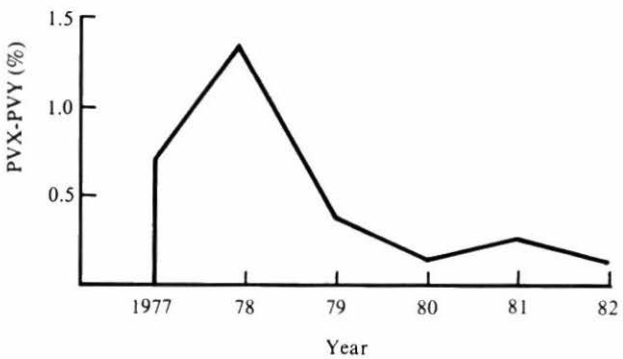

Figure 5. *Occurrence of PVX and PVY in prebasic and basic seed potatoes produced by INIA.*

Table 4. **Area, production, and yield of certified seed in Chile.**

Season	Area (ha)	Production (t)	Yield (t/ha)
1968-69	322.5	1843.0	5.7
1969-70	347.1	3444.4	9.9
1970-71	558.3	6161.9	11.0
1971-72	887.2	7382.4	8.3
1972-73	572.1	6477.0	11.3
1973-74	899.0	8034.3	8.9
1974-75	534.4	4155.3	7.8
1975-76	253.1	3094.9	12.2
1976-77	430.6	4392.4	10.2
1977-78	528.0	2406.7	4.6
1978-79	494.9	3655.0	7.4
1979-80	710.5	6898.4	9.7
1980-81	883.6	6815.7	7.7
1981-82	558.3	4697.7	8.4
Mean	570.0	4961.4	8.7

Source: SAG, Agricultural Protection Department.

One of the principal problems of seed potato certification in the Chilean program has been the 'escape'* of certified material from the nurseries, which is then sold as 'normal potato seed' (Table 5). At present, a study entitled "Agroeconomic Study of the Production and Use of the Certified Potato Seed in Chile" is being developed with the aim of determining those marketing and commercialization problems that are impeding the expansion of certified seed used in the country.

The documentation of the technical and institutional characteristics of the Chilean experience, as well as the identification of the reasons that explain its success in the last few years, will allow conclusions to be drawn, that can contribute to improving potato certification systems in other developing countries. It has been found that these programs, after a rapid initial expansion of 3 or 4 years, face technical and socioeconomic problems that limit their growth and affect their viability. The nature and importance of these problems, especially those of a socioeconomic character, have not been adequately investigated yet.

* Unauthorized use of certified material.

Table 5. **Total, selected, certified, and 'escaped' seed potato production in Chile.**

Season	Total	Production (t)			
		Selected[a]	Certified	Escaped[a]	% Escaped
1978-79	6,596	5,063	3,655	1,381	27.3
1979-80	11,902	8,225	6,893	1,332	16.2
1980-81	19,740	15,545	6,815	8,730	56.2
1981-82	18,962	11,947	4,698	7,249	60.7
Mean	14,300	10,195	5,515	4,673	45.8

a. Estimated values.

Source: SAG, Agricultural Protection Department.

Official certification agency

An official certification agency is necessary to standardize and check the production, storage, selection, and commercialization processes of the certified seed potatoes. In most countries, this is the responsibility of the Ministry of Agriculture or a similar agency. The function of such an agency is to ensure that the rules and standards guaranteeing the quality of the certified tubers are fulfilled. Normally it is independent of the other parts of the certification program, in spite of its close interaction with each one of the program's components. This independence facilitates the actions of the agency and contributes to its efficiency.

Certification specialists should have access to sufficient material support (vehicles, laboratories, equipment, implements, greenhouses, and field plots for post-control testing) and personnel (professionals and technicians, especially) to allow an accurate diagnosis of the quality of the seed potatoes in any of the production stages. The certification agency should keep its specialists informed of the latest advances being made in diagnostic and health control measures that apply to specific production problems or regions.

In Chile, the Technical Seed Unit belonging to the Ministry of Agriculture's Agricultural and Stock Farmer Service (SAG) is the official agency in charge of seed potato standardization, control, and certification.

Complementary elements of certification program

Commercial potato producers

Although the certification program is not directly integrated with commercial potato producers or certified seed users, these both play a vital

part in such programs. In Chile, for example, the producers of early potatoes in the 4th region (Coquimbo and Valparaiso) have been the principal users of certified seed and have introduced a dynamic element to the whole system.

Market consumers

Market consumers are the other fundamental complementary component in a seed certification program. Market consumption includes fresh potatoes for human consumption; potatoes for the agro-industry (puree, chips, French fries, starch, and derivatives), and potatoes for animal consumption (chopped, cooked, ensiled, and processed into wholemeal flour).

Conclusions

The certified production program for seed potatoes in Chile has developed considerably over the last few years. The strong support given to the certification process through the multiplication and production of good quality prebasic and basic seed, and the generation and transfer of technology in commercial production and in registered and certified seed storage have begun to yield results. After two decades of seed potato certification, a rise in productivity at the national level has been achieved, particularly in the certified region (Figure 6). The value of the seed tubers generated in the certification process corresponds to an annual income, for the certified region, exceeding US $2 million.

The existing relations and interactions between the various elements of a certified seed production program are different in each country. Nevertheless, the structure and basic elements are independent of a country's economic system and appear to respond well to an appropriate distribution of resources that considers specific concerns and conditions.

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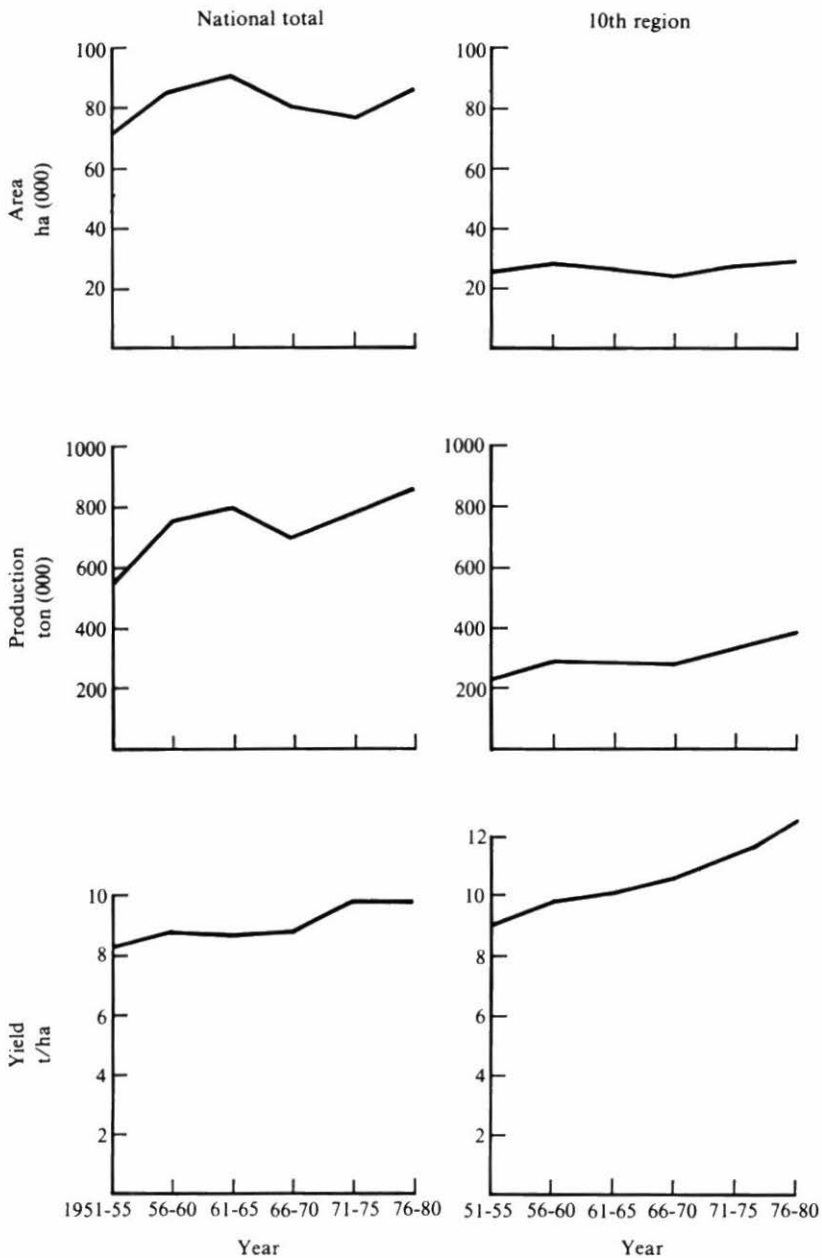

Figure 6. *Quinquennial area, production, and yield of potato for the whole country and for the 10th region.*

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Seed Potato Production in Ecuador

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Introduction

Ecuador has an area of 270,670 km^2 and a population of about 8.5 million. The country extends from $1^0$24' latitude north to 5' latitude south and from $75^0$9' to $80^0$50' longitude east. Although the country is situated in the torrid zone, it has many different climatic conditions due to the mountains and valleys that run along its length.

In Ecuador potato is the fourth most important crop in terms of production value, and the fifth most important crop in terms of the volume produced. It is cultivated on approximately 40,000 ha, which indicates its importance in the basic diet of the Ecuadorians.

In its potato program at the Santa Catalina experimental station (altitude 3050 m), INIAP (National Institute of Agriculture and Animal Research) has developed the necessary technology to increase both the production and the productivity of the potato crop at a national level. This increase comes through the development of improved varieties, production of seed, improved agronomic practices, and control of pests and diseases. However, the success of potato production depends, to a large extent, on the use of good quality seed that is free of contamination, especially virus contamination, which is the major cause of the crop's gradual decrease in production. This production decrease is an aspect of Ecuador's certified seed scheme that has been strongly criticized because it shows that the conventional technology used for basic seed production has been unable to guarantee the required seed quality.

Certified seed production by conventional techniques

For several years the basis of certified seed production (Figure 1) has been the tuber or row unit. Under this system, INIAP conserves good quality, 'elite' tubers from new varieties released to farmers. These elite tubers are cut into two or three parts to produce tuber units that are each sown individually. Roguing is carried out to eliminate all of the units that show virus symptoms or other diseases, or produce atypical plants. In this way both material for the following stage of production and more elite material for the re-initiation of the overall process are obtained at harvest.

The tubers produced from each tuber unit are planted in the next multiplication cycle in row units, which in turn are subjected to rigorous roguing, and are then used for the production of breeder's seed. These seeds are put through successive multiplications and pass from the category of breeder's seed to basic seed and on to registered seed, which is given to qualified seed producers for their certification. This certification is controlled by the National Seed Program, which has its own rules on seed production.

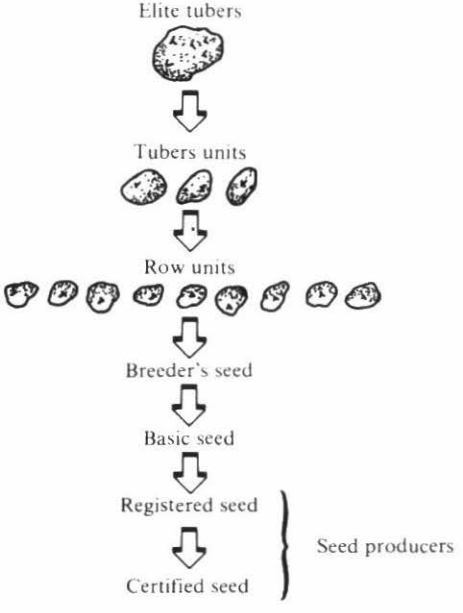

Figure 1. *Certified seed production scheme.*

This seed production system has presented the following problems:

- The evaluation of phytosanitary plant status in the different stages using visual symptoms alone is no guarantee that all the contaminated plants will be eliminated.
- The roguing requires knowledgeable technicians familiar with the symptoms of the various virus diseases. The process is both long and tedious, especially with those varieties that present a high percentage of infected plants, or when the area to be rogued is large.
- There is no guarantee that the scheme is initiated with tubers of optimal quality.
- There are an excessive number of multiplication cycles, and certified seed is not produced in either sufficient quantity or with sufficient quality to significantly change potato production in the country.

Tissue culture and rapid propagation techniques

The problems described above have led INIAP to apply a new seed production technology based on tissue culture and rapid propagation to produce seed free of viruses and other pathogens.

The International Potato Centre (CIP) cleaned three of the five potato varieties produced in the certified seed scheme using thermotherapy and meristem culture, thus providing *in vitro* material that was free of the principal viruses and viroids that infect potato. *In vitro* micropropagation and *in vitro* rapid propagation techniques were then used on this material to produce the first generation of the seed production scheme. These two techniques have allowed the restructuring of the whole seed certification process.

The phytosanitary status of *in vitro* material, the material used in rapid propagation in the greenhouse, and the material being reproduced in the field is determined through serological tests. In addition, roguing is used to eliminate plants with virus symptoms. This process is continued in the following generations with the principal objective of conserving the seed quality.

When the plants *in vitro* are taken to the greenhouse and subjected to rapid propagation through successive shoot harvests, each mother plant produces 200-300 shoots. These shoots are taken to the field where they produce 2000-3000 tubers; that is, each *in vitro* mother plant produces

2000-3000 high-quality seed tubers at the end of one season. This material is then multiplied twice so that it can later be given to the seed growers who produce the certified seed.

Conclusions

After two years of experience with this methodology, the following conclusions have been drawn:

1) The material handled *in vitro* maintains optimal phytosanitary status, and when conserved in the laboratory, it can be used to generate a large number of plants.

2) The rapid propagation techniques allow a very large number of seeds to be produced in a very short time in comparison with conventional methods.

3) The value of the seed justifies serological testing complemented by roguing.

4) The superior phytosanitary status of the material produced with the new system has been confirmed.

5) In a very short time it has been possible to significantly increase the production of certified seed both in volume and quality. This should soon be reflected in increases in production per unit area.

6) It is necessary to clean both the remaining improved varieties and the promising clones.

Seed Potato Production in Mexico

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Introduction

Potato cultivation in Mexico dates back several decades. Its commercial exploitation is thought to have started in the mountain ranges, but later due to research work carried out on the crop, it was introduced to low altitude irrigated zones, where the greatest yields have been obtained. These changes have principally been brought about by the use of new technology, the topography of the land, and the size of the farms, all of which have allowed mechanization to take place.

Potato production in Mexico has increased rapidly over the last 50 years, and has been extended to almost all the country's states. In accordance with the increasing urbanization and the rise in the demand for food, the potato has changed from being a subsistence food to a commercial one. Although it is not a staple in the diet of the population, it constitutes the principal source of income from agricultural products in the mountain ranges, where irrigation is not practiced and production depends on weather conditions.

The different sowing and harvesting times in Mexico's diverse regions have made it possible for potato cultivation to spread throughout the country, and for a supply of potatoes to be available during a large part of the year, both for seed and for consumption. This requires an efficient distribution of the seed produced, and gives a constant supply of fresh potatoes to the markets.

The national area devoted to potato production is estimated at 70,000 ha with a total production of more than 900,000 tons. Mexico has achieved

self-sufficiency in potato production both for consumption and for seed, and only because of market preferences is a small amount introduced from the United States to the state of Baja California Norte.

The most important factors that limit potato production are the shortage of good quality seed for the high valleys and the mountain ranges, the limited diversity of suitable varieties both in irrigated zones and mountain ranges, and pests and diseases in certain parts of the country. With regard to economic factors, strong price oscillations frequently put the producer at a disadvantage. There are also problems with labor shortages and lack of official credit.

Certification program

In 1948, new techniques were initiated in Mexican potato production, which in some cases generated technology and in others involved adapting that which already existed. One of the aims of the National Potato Program was to produce healthy seed potatoes. In order to do this, different aspects of production were studied, such as fertilization, sowing and harvesting time, variety testing, and pest and disease control. These studies were carried out in different regions of the country, thereby identifying zones for seed production, zones for reproduction or multiplication, and zones for commercial production.

The Potato Seed Certification Program was initiated in 1957, and sowing was carried out with selected farmers in those zones that were considered the most appropriate for seed production. The aims of this program were:

- To produce acceptably healthy certified seed, as free as possible from diseases caused by viruses, bacteria, and fungi, and with physical and genetic purity preserved.
- To produce seed of varieties that were most accepted in the markets, with good yielding ability and excellent cooking characteristics.
- To supply the country's need for certified seed potatoes.
- To prevent the importation of seed potatoes.

In order to establish the Potato Seed Inspection and Certification Program, standards and recommendations had to be formulated to define requirements and tolerance levels for different seed categories. After studying the programs of other countries, particularly those used in Holland and the United States, it was found that exact duplication of such

standards would make production of certified seed very difficult in Mexico. Therefore, a program was adopted that reflects the particular necessities and agricultural levels present in Mexico, including realistic levels of permissible diseases.

Seed certification is run by the National Service of Inspection and Certification of Seeds. This body is under the control of the Secretary of Agriculture and Hydraulic Resources (SARH). The personnel in charge of potato certification received preliminary training in different sections of SARH, principally in the National Agricultural Research Institute (INIA), where criteria for diagnosing crop pests and diseases are studied and unified.

The inspections for categorizing the seed are mainly made visually, and only small samples are checked by serological tests (enzyme-linked immunosorbent assay,ELISA) in order to find out the degree of confidence of the visual inspection, and to confirm the presence or absence of the principal potato phytopathogenic viruses. The categories used for certification are: basic, registered, and certified.

Initially, the method used for seed production was the tuber unit, but this was later rejected due to the risk of introducing contamination during management and cultivation. It was replaced by the clonal method, which consists of multiplying three generations in order to obtain basic seed.

Potatoes are produced in two general areas of the country. About half are produced in the irrigated valleys, and the other half are produced in non-irrigated ranges. Of the area under irrigation (35,000 ha), about 23,000 ha (or 33% of the total area planted in the year) is sown with certified seed. The rest is sown with potatoes selected by the producers themselves. This situation makes the average national production low (13.3 t/ha). Additionally, the crop is affected by adverse climatic conditions in the mountainous regions, and by low sowing density due to the topography of these regions.

Under non-irrigated conditions where the varieties cultivated are mostly indigenous or improved Mexican varieties, a negative selection system is used that consists of selecting those tubers for seed that are deformed or so small that they are not commercially acceptable. In 1978, a seed potato selection system was started in the mountain ranges by selecting plants during the growth period of the crop, and it is already possible to observe the excellent results being obtained in the field. In other areas of the country, the National Potato Program, which is a part of INIA, has initiated a seed production program in coordination with the Regional Potato Cooperative Program (PRECODEPA). This seed production

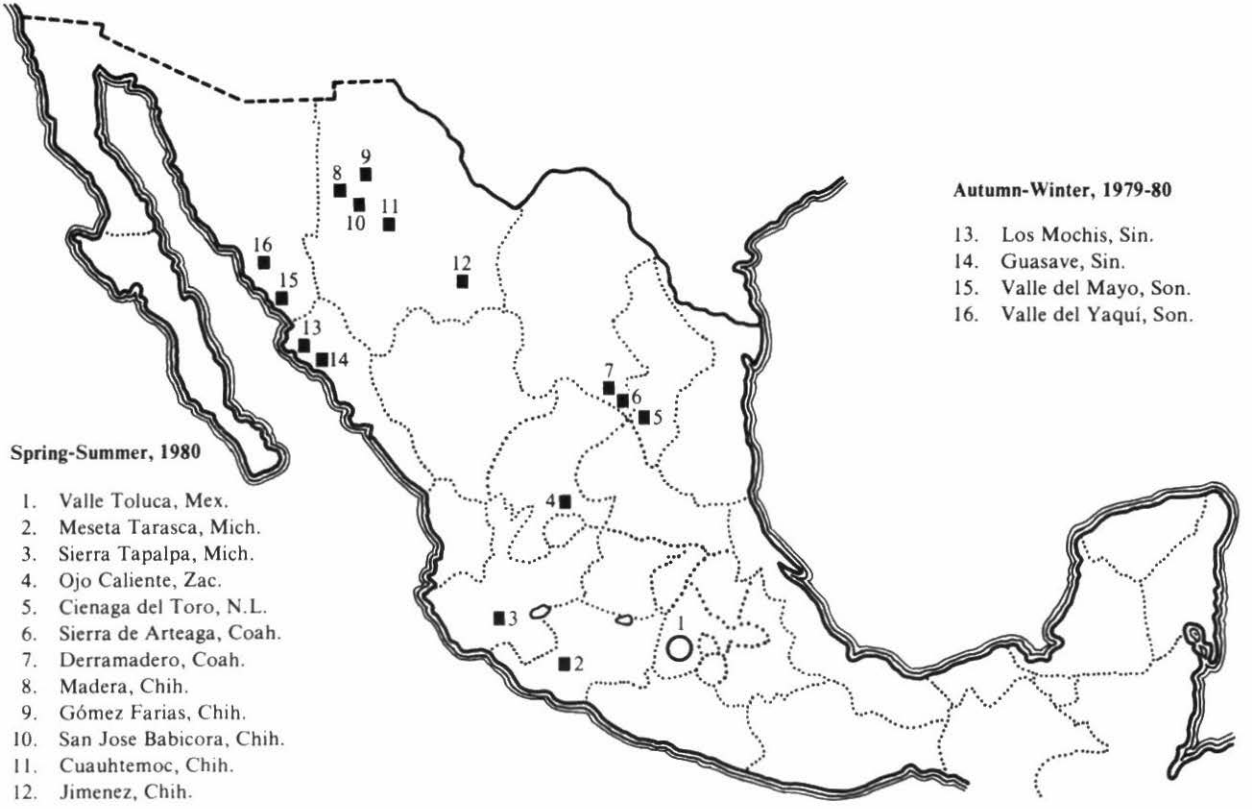

Figure 1. *Production zones for certified seed potatoes.*

Table 1. **National production of certified seed potatoes.**

	Production (t)												
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Sonora	0	0	0	0	0	387	1,156	276	5,462	8,840			
Sinaloa	0	0	0	500	5,108	8,826	7,712	9,786	18,321	25,508			
Chihuahua	0	0	0	825	3,081	5,227	7,995	6,347	10,564	8,474			
Coahuila	0	1,800	1,760	1,100	2,000	643	442	1,524	2,815	3,097			
Jalisco	0	0	0	0	0	0	0	647	1,290	2,535			
Michoacán	1,455	1,385	2,797	2,145	3,121	377	1,193	460	879	1,492			
Estado de México	6,395	6,090	6,375	7,748	9,523	7,540	7,299	8,820	9,795	8,668			
Guanajuato	5,747	5,312	3,439	0	0	0	0	0	0	0			
Others	0	0	0	0	0	440	992	386	650	229			
Total	13,597	14,587	14,371	12,318	22,833	23,440	26,789	28,246	49,686	58,843	41,200	39,671	42,528

program is for those varieties that are beginning to be supported by the agricultural potato producers in non-irrigated zones, and it uses seed produced in INIA's experimental fields in the Toluca Valley. These producers have also begun to grow seed for both the native and improved Mexican varieties.

The distribution of the production zones for certified seed potatoes is shown in Figure 1, and the volume of production is shown in Table 1.

Seed Potato Production in Vietnam

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Introduction

The improvement of seed potato production in Vietnam is based on two techniques: a) the establishment of healthy, high-yielding clones, notably by the methods of meristem culture and/or thermotherapy, and b) the multiplication of these selected clones in controlled conditions. The virus-free or low-level virus materials must attain a certain size before release to agricultural cooperatives for the production of potatoes for consumption.

The introduction of new rice varieties to Vietnam enables the substitution of the rice monocultural system by a rice-dry farming-rice rotation system. As the Vietnam weather favors the growth and tuberization of potato, and as rice alone cannot meet the staple food demand of the growing population, potato has been chosen as an ideal crop for this new system of rotation. The potential area for potato production in the Red River Delta has been estimated to be at least 200,000 ha.

Nevertheless, despite considerable effort by the Ministry of Agriculture, potato area in the last 10 years has been limited to below 100,000 ha. The major limiting factor is production and conservation of seed potatoes. In the northern provinces of Vietnam, potato is grown in the winter season from November to January. Seed potatoes are then stored over 9 hot, humid summer months. Losses due to bacterial deterioration and evaporation are considerable during this storage period, normally exceeding 40%.

Another major problem has been the permanent presence of disease vectors. These cause a very rapid virus reinfection of imported healthy

clones, which leads to yield decreases. In order to overcome this problem, a national program for improved seed potato production was established in 1977. One of its main goals was to make use of modern tissue culture techniques in the mass propagation of selected potato clones, and to maintain these clones in a healthy state over long periods of time.

Tissue culture and mass propagation

It has been demonstrated by Nozeran and coworkers at the Orsay University in France (personal communication) that by successive *in vitro* subculture of cuttings of very young potato plantlets, an enormous number of individuals can be produced in a very short time. Roca et al. (1978) have also used node cuttings in combination with a multiple-meristem technique in order to rapidly micropropagate potato *in vitro*. Our research data over the last two years using the subculture of cuttings shows that on appropriate media, subcultures can be carried out successively every 20 days, with each plantlet giving at least three cuttings each time. This means that a total number of 318 (387 million) individuals can be obtained, theoretically, in one year from a single cutting. Such a quantity of culture tubes is economically impossible to handle, so a rapid propagation technique has been developed using the six steps described below. Only the first of the six steps requires sterile conditions. The rest of the steps can be carried out in semi-sterile or field conditions.

Step 1. Multiplication *in vitro*

The following medium is used:
Macroelements: Knop, half strength
Microelements: Berthelot
Vitamins: Morel
Sucrose: 20 g/liter
Agar: 7 g/liter
pH: 6.5

No growth substances are added. Each cutting is transplanted to a test tube (25 x 200 mm) with 5 ml of medium. The tubes are illuminated by natural light under a plastic cover at ambient temperature, and subcultured every 20 days. Healthy clones maintained in the *in vitro* gene bank supply the desired number of initial plantlets for this step.

Step 2. Multiplication on sand

In this step, a 5-cm layer of steam-sterilized fine sand, bordered by a wooden frame (1 x 10 m) is used as a multiplication bed. Cuttings from the

test tubes are inserted 0.5 cm deep into the sand at a density of 1250 cuttings/m^2. High humidity is ensured by spraying twice a day with a very diluted solution of mineral fertilizer and by covering the surface of the bed with a plastic sheet. Rooting can be observed after 4 days and the new plants are ready to be subcultured once again on sand after 4 weeks.

Step 3. Multiplication on enriched soil

The same manipulation is repeated, but this time the multiplication bed consists of a steam-sterilized mixture of soil and manure (2:1 w/w).

Due to the abundance of nutrients, the growth of cuttings is very fast; the leaves become larger, and the juvenile appearance of the plants gradually disappears. After 20 days, the first harvest of apical buds can be obtained. The regrowth of lateral buds permits a second, third, and fourth harvest of actively growing buds. These buds are used for potting in the next step.

Step 4. Potting

Potting of buds is carried out by inserting the cut end of the buds in a mixture of soil and manure (2:1 w/w) contained in a cylindrical plastic pot made by rolling a PVC (polyvinyl chloride) sheet (5 x 12 cm). Banana leaves can also be used successfully for pots. High humidity is necessary in the first week. Rooting begins after 3 to 4 days, and then the buds grow and give rise to potato plants with compound leaves and a highly developed root system. The plants are ready for planting in the field after 15 to 20 days.

Step 5. High-density planting

Field planting of the potted plants is a simple procedure, and their yield is comparable to that of traditional tuber-derived plants. However, as farmers are only familiar with traditional tuber planting, this step aims at producing large quantities of small seed tubers. These are obtained by dense planting (150,000 plants/ha) at a low fertility level. The growth of potato plants can also be controlled by limiting the water supply. Fungicide and insecticide application is necessary to prevent insect vectors and late blight. This step is often carried out in state farms or in advanced cooperatives.

Step 6. Seed potato production

One or two cooperatives are chosen in each district to produce seed potato from the small tubers harvested in Step 5. Potatoes are grown by the traditional methods and then harvested for use as seed potatoes for other cooperatives.

Gene bank

An *in vitro* gene bank with 70 potato varieties, most obtained from the International Potato Centre (CIP), is maintained at Dalat. Subculture is carried out every two months by one technician. Each variety is maintained in 50 tubes. The maintenance cost is much lower than with traditional methods, and the danger of virus reinfection and weather hazards is completely eliminated.

Conclusions

Based on our experience, a station for seed potato multiplication handling 10,000 tubes could produce 1500 tons of seed potato with low virus levels every year. Two technicians can subculture 1000 tubes per day, and no artificial light or climatization is needed. (The tubes are placed under a plastic cover at 50% natural light.) The procedure is believed to be applicable on a large scale in Vietnam as well as in many other developing countries. A pilot station with 10,000 culture tubes is now operating at Dalat City in the Central Highlands of Vietnam.

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CHAPTER 8. CASE STUDIES: PRODUCTION PROGRAMS FOR CASSAVA PLANTING MATERIAL

Production of Cassava Planting Material in Cuba

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Introduction

The objectives of the production program for cassava planting material in Cuba are to:

1) Promote the rapid adoption of superior clones, which are fundamental for obtaining increased yields. These clones are used for human consumption, and are resistant or tolerant to both *Xanthomonas manihotis* and *Sphaceloma manihoticola*.

2) Propagate material that is acceptably free from stake-transmitted diseases and pests.

3) Obtain vigorous stakes that guarantee high germination levels, so that the amount of replanting is kept to a minimum.

4) Establish a base for subsequent yield increase through the use of clones with superior quality and high-yield potential.

The production of original and basic seed is carried out in the experimental stations by the Ministry of Agriculture's Centre for Improvement of Agamic Seeds (CEMSA). Registered seed is produced on farms belonging to the Ministry of Agriculture's Seed Producing Agency (EPSV). Certified seed production is done on the state farms and in the production cooperatives.

Although cassava seed certification was initiated in Cuba in 1969, it was not until 1980 that the whole scheme was completed. Certification at all levels is carried out by the Ministry of Agriculture's National Service for

Inspection and Certification of Seed (SNICS), which authorizes or rejects the utilization of propagating material as well as determines its category.

This certification scheme has allowed the rapid diffusion of recommended clones. Its most direct impact can be appreciated by the yield increases that have been obtained at a national level over the last few years, and by the increased amount of land that has been cultivated on the state farms and cooperatives.

Seed certification system

The seed certification system consists of four phases or categories through which a variety must pass before stakes can be considered suitable for releasing as certified seed.

Breeder's seed

The stakes and plants belonging to this category come from mother plants, and are selected according to the methodology approved for each variety. For example, in the variety Señorita, the plants must be free from symptoms of blight, superelongation, and anthracnosis. They must also develop at least 10 commercial roots, and have a yield of not less than 11 kg per plant after a year. Finally, the mother plants must satisfy both the morphological and botanical descriptions of their particular variety. These have been established on the basis of 25 descriptors.

Basic seed

The mother plants from breeder's seed are used to provide planting material for the rapid propagation method using two-node cuttings as described in the paper by J. Cock in Chapter 5. After the rapidly propagated plants are at least 10 months old, stakes from the primary branches are taken to form the basic seed category. These plants have the following requirements:

- Varietal purity, 100%
- Infestation with bacterial blight, 0%
- Infestation with superelongation disease, 0%
- Plants with more than 10 commercial-sized roots, over 90% of the population

Registered seed

In this category, two generations are allowed, which are known as Registered I and Registered II. The requirements are:

- Varietal purity, 99.5%
- Infestation with bacterial blight, maximum 0.5%
- Infestation with superelongation disease, maximum 0.5%
- Plants with more than 10 commercial-sized roots, at least 85% of the population

Certified seed

Two successive generations are allowed in this category, which are known as Certified I and Certified II. The minimum requirements are:

- Varietal purity, 97%
- Infestation with bacterial blight, maximum 1.5%
- Infestation with superelongation disease, maximum 1.5%
- Plants with more than 10 commercial-sized roots, at least 70% of the population

Three inspections are made during the year. The first of these is at the time of planting in order to evaluate the quality of the stakes. The second, carried out between 5 and 6 months after planting, is to evaluate the vigor of the crop, the presence of pests and diseases, and the crop's varietal purity. The third, which is made 10 to 15 days before the onset of harvest, is to determine the crop's varietal purity, phytosanitary status, and yield components. In the inspections, at least 100 plants per hectare are evaluated at random by taking samples at regular intervals around the field.

Commercial or pre-commercial clones

Up until 1980, only two clones were certified: Señorita and Pinera. These were the first two clones with high-yield potential that were recommended by CEMSA's cassava program.

At present, Señorita occupies approximately 70% of the total area cultivated in the country. This is a local Cuban clone, which has white-fleshed roots and rose-colored skin. It is an erect plant type, with symmetrical root formation, but it is susceptible to *Xanthomonas manihotis*. However, this disease can be avoided to an acceptable extent, at least from the production point of view, if planting is carried out in the dry season (November to January) using lignified stakes obtained from the primary branches of the plant.

The clone Pinera occupies about 5% of the total area. Other varieties are replacing it in areas which produce cassava for human consumption, but it is being multiplied in areas where production is for animal feed. This clone

is very vigorous, highly productive, tolerant to *Xanthomonas*, and erect, but has very poor post-harvest shelf life.

In 1983, the clone CMC-40 was released. This clone, introduced from CIAT in Colombia but of Brazilian origin, has shown good adaptation to Cuban conditions. It is an early clone with a growth cycle of 6 to 8 months, which allows planting in the optimum months (November to January) and harvesting in the months of June to August, a time of year when traditionally it has been difficult to obtain cassava.

In 1984, two other clones will be released: CEMSA 5-28, a hybrid obtained from polycrosses in which Señorita was the female parent, and CEMSA 74-725, which is a hybrid between Señorita and Pinera. Both these clones have high-yield potential and are tolerant to *Xanthomonas*. They are good quality, erect types, and are easily harvested mechanically.

The clone CEMSA 80-99 will be passed to the agricultural extension agency for testing in 1984. This clone is highly resistant to *Xanthomonas* and keeps well after it is harvested.

Basic seed production

CEMSA propagates the original material through the rapid propagation techniques described in this workshop, but adapted to Cuban conditions. These techniques have helped to clean the propagation material of *Xanthomonas manihotis*. Table 1 shows the quantities of basic seed produced and projections for 1984.

Impact of research program

With the use of high-yielding clones, good quality planting material, and the adoption of the so-called 'Colombian system', many state farms and cooperatives have increased their yields from between 5-10 t/ha to between 20-25 t/ha.

Table 1. **Quantities of basic cassava seed produced or projected in the period 1982-1984.**

Clone	Production (thousands of 25-cm stakes)		
	1982	1983	1984
Señorita	16.7	165.0	488.0
CEMSA 5-28	15.0	36.0	36.0
Pinera	—	10.0	—
CMC-40	—	60.0	70.0
CEMSA 80-99	50.0	—	—

Although the national average yield is still low, it has entered into a phase of gradual increase, and cassava production has risen from 73,253 tons in 1979 to 131,889 tons in 1981. The national research program has played a fundamental role in this success.

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Production of Cassava Planting Material in India

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Introduction

Cassava is propagated in India with cuttings from mature stems, 8-12 months old. About 10-15 cm of the basal portion and about 25-30 cm of the tender tops are discarded. In the southern states where cassava is cultivated commercially, like Kerala and Tamil Nadu, stakes are obtained from the stems of the previous crop. During the interval between harvesting and planting the next crop, the bundles of loosely tied stems usually are kept in semi-shady to shady places. In the tribal belts of the northeastern hills where cassava is grown as one of the many crops in shifting cultivation plots, numerous cases are seen where the entire plant is allowed to remain in the field after the removal of the tubers.

In states like Kerala, which enjoys both southwest and northeast monsoons, planting is done twice a year, i.e., April-May (main crop) and August-September. The main season crop is harvested in February-March and the stems thus obtained must be stored for about two months. The crop planted in August-September is usually harvested after about 11-12 months, and so the stems are used for planting without any interval. In the northeastern hills of India, however, cassava is planted only in one season (April-May), depending on the onset of the rains. This region experiences heavy rainfall but enjoys a subtropical climate, having cooler winters, which cause cassava defoliation by December-January. The harvested stems are either allowed to stand in the field or are stored and utilized for planting after a period of 3-4 months.

Factors affecting stake quality

The quality of the cassava planting material is dependent on various factors such as age of the stem, thickness of the cutting, length and viability of the stake, and the extent of mechanical injury caused during collection, storage, transport, and planting.

Stake age

This depends on the availability of stems at the time of planting, and often planting material of any age is used. However, it has been observed that stems 8-12 months old are the most suitable for preparation of stakes.

Stake thickness

The stakes contain a fairly high amount of carbohydrate which serve as food reserves for the initial establishment of the plants. The vigor of the emerging plants depends on the availability of the food reserves, which are generally higher in the case of thicker stakes. Experience shows that stems with a diameter of 2-3 cm are ideal for planting. The hard basal portion of the stems are not suitable for planting as they have more lignified tissues which may not support the emerging buds. The top tender portion of the stems desiccate quickly under dry conditions, and so they are equally undesirable for planting.

Stake length

Stake length is very important as it is related to the depth of planting. Since planting deeper than 5 cm results in a swelling of the stake with a consequent reduction in tuber yield, a stake length of 20 cm is advantageous. However, trials showed no appreciable difference in tuber yield between stake lengths of 20 cm and 30 cm.

Stake viability

Although varietal differences are observed in the sprouting of stakes, stake viability is also dependent on other factors like extent of storage, mechanical damage, and infection by pests and pathogens.

In a study conducted to examine the sprouting and establishment of stakes, the stems were subjected to different pre-harvest/pre-storage treatments. Measurements of leaf area index were made at intervals of 20 days starting from the first month after planting until the date of termination (3 months after planting). Stakes from plants that had been

topped at harvest and stored with the mother stake had the highest leaf area index (mean 3.15), followed by those from plants whose tops had been dipped in wax and stored with the mother stake (mean 2.85). Leaf area index was lowest in the case of topping, allowing to develop axillary sprouts, and storing with the mother stake. The dry matter distribution observed at 90 days after planting showed that dipping the tops in wax and storing with the mother stake gave the highest amount of dry matter (100 g/plant).

One cause of desiccation in stored stakes is severe infestation by scale insects. The scale insects can be effectively controlled by spraying parathion at fortnightly intervals (Rao and Pillai, 1972). It was also observed that there was no adverse effect on the sprouting of stakes obtained from the treated stems after a period of two months of storage.

Mechanical damage

The stems are prone to mechanical damage at any time, from sprouting until they are used as planting material in the ensuing season. Hence, maximum care should be exercised in handling the material during intercultural operations, harvesting, storing, and transporting.

Rapid propagation techniques

Cassava is one of the vegetatively propagated crops with a low multiplication rate. One cassava plant with two stems would normally give 10-12 planting stakes of 20-cm lengths after a year. In order to try to improve this slow rate of multiplication, a field trial was conducted with close spacing and planting single or double stakes to each hill. It was observed that spacings of 60 x 60 cm and 90 x 45 cm were significantly superior in single-stake planting as compared to other spacings, while double-stake planting considerably reduced the number of good stems under different spacings (Mohankumar et al., 1980). It was therefore suggested that for the maximum production of good quality planting material without sacrificing root yield, a spacing of 90 x 45 cm should be adopted for the non-branched type of cassava. Under this spacing it was possible to double the production of planting material.

An attempt was made to use split stakes (Sasidhar et al.,1977) to increase planting material in the variety M-4. The yield performance of split stakes (splitting the 20-cm long stakes into two equal halves longitudinally) was compared with that of whole stakes planted vertically, slanting, and horizontally. The results showed that the vertical planting of whole stakes yielded 32 t/ha as against 20 t/ha when split stakes were used.

Another approach towards more rapid propagation of cassava was made by inducing sprouting in split, single-node cuttings. With the help of a mist chamber, 647 plants and 3235 planting stakes of 20-cm lengths can be produced from a single cassava plant in one year, as against 10 plants and 100 planting stakes in the conventional method (Kamalam, 1978). Thus, the cassava propagation rate can be increased 323 times the normal rate.

Disease elimination through tissue culture

A program to produce disease-free plants using cassava meristem culture and clonal multiplication of elite varieties is under way at the Central Tuber Crops Research Institute (CTCRI) in Trivandrum. The technique for virus elimination developed by Kartha and Gamborg (1975) and later modified by Nair et al. (1979) is being utilized for this purpose. The essential feature of the technique is the aseptical transfer of about 0.5 mm of meristematic dome tissue into Murashige & Skoog solid medium supplemented with 1.0 M naphthaleneacetic acid, 1.0 M benzyl adenine, and 0.1 M gibberellic acid (GA_3). Explants are incubated at about 25°C in a 16-hour light (4000 lux) and 8-hour dark cycle. After 3-4 weeks, the developing explants are transferred to a rooting medium (the same as above but without gibberellic acid). In another 3-4 weeks the explants regenerate into whole plants. They are then washed free of medium and planted into a sterile potting mixture (soil, sand, and powdered dry cattle manure in a 1:1:1 proportion).

More than 90% of the plants produced by this method are symptom-free. These plants are presumed disease-free on the assumption that all diseased plants will show symptoms under the growth conditions mentioned above. During 1982, 28 disease-free germplasm accessions were obtained. Meristem culture has also been used to raise and multiply five CTCRI hybrids and two prominent local cultivars. The resultant plants are now growing in the field.

Critical problems

Since the main planting season in the state of Kerala is April-May, the crop faces severe drought in the summer months of December-April. As this period is ideal for making cassava chips, and the soil conditions also become unfavorable to support the growth of plants, the farmers are forced to harvest the crop during this time. However, the stems then have to be stored until the following planting season, often resulting in the rapid deterioration of the planting material due to dehydration of the stems and attack by pests and pathogens.

The absence of an organized institution for the multiplication and distribution of planting material at the appropriate time is one of the limiting factors in almost all the cassava growing areas of the country This situation is so grave in the state of Tamil Nadu, where cassava mosaic disease is rife, that the root yield is reduced by an average of 30%.

Other problems include lack of interest among growers to produce and maintain disease-free stocks on farms, since disease and pest problems are not as severely felt as with grain crops.

Strategies for increasing planting material production

Cassava is grown on 0.35 million ha (1980-81) in India, and the National Commission on Agriculture has projected a target of one million ha of cassava production by 2000 AD. The additional land to be brought under cultivation will mainly be in the nontraditional areas, where presently cassava is grown on a limited scale. The additional area of about 0.2 million ha targeted for the traditional cassava growing states like Kerala and Tamil Nadu can be planted by collecting planting materials from the existing plantations. For the remaining area of about 0.45 million hectares in other central and northern states, practically no local source exists from which planting materials can be obtained on a large scale. Immediate steps are required to establish model nurseries for the production of superior quality, disease-free planting materials, particularly in these nontraditional areas. One such regional nursery for tuber and rhizome crops has already been established in the hilly state of Meghalaya, which will supply seven northeastern states. Such nurseries can also be used to demonstrate improved packages of practices to the growers and to train them in methods of improved cultivation. Similar progeny farms are required in different parts of the country to meet the need for healthy planting materials.

For rapid multiplication of cassava planting material, some of the tested techniques like single-node or two-node cuttings can be employed. Shoot tips obtained through pruning can also be used in multiplication programs. Regular marking and roguing of plants with transmissible diseases will help in keeping the propagating materials free from such diseases. Before storage or transportation of stems, protectant fungicidal/insecticidal treatments are essential. Since longer stems store better under shady and humid (about 80% RH) conditions and moderate temperatures (20-23°C), it is desirable to adopt such practices in the multiplication nurseries when the stems cannot be used for planting immediately after harvest.

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Production of Cassava Planting Material in Mexico

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Introduction

In 1982 there was insufficient production of basic grains in Mexico, and for the first time in the country's history the overall agricultural balance was in deficit. Mexico is now importing grains at a cost of US $770 million per year.

With the aim of solving this problem, the federal government has established various agricultural programs with the following objectives:

- Increasing the area cultivated
- Increasing the production per unit area
- Avoiding erosion and reducing post-harvest losses

One of the ways of achieving these goals is to cultivate cassava, since it can be grown in marginal areas where there are acid soils of low fertility, which, at present, are not agriculturally productive. In addition to this, cassava has high production indices per unit area and lends itself to intercropping. Cassava could efficiently substitute for part of the imported, subsidized grains used in animal feed diets. In addition to saving foreign exchange, this would create employment in different areas and assist in social and economic development.

Background

Cassava has been cultivated in Mexico since pre-Hispanic times. This is confirmed by Bronson (1966), who observed that the distribution of cassava was associated with the area in southeastern Mexico and Central America which had been inhabited by the Mayan civilization.

At present, cassava occupies an important place in family gardens, where it is grown in cropping systems with a great many different species. Purchased inputs are generally nonexistent, and the production is mainly for home consumption. The total area planted in 1977 was 4000 ha, with an average yield of 10.5 t/ha.

The area planted with cassava is slowly increasing with the objective of supplying the demand in urban centers and by some pork producers. However, the time when cassava occupies the potential area of half a million hectares of marginal soils, which exist in southeastern Mexico, is still far off.

An important part of the strategy for the development and expansion of this crop has been the Cassava Research Program. This forms part of the National Institute of Agricultural Research (INIA), which itself is part of the Secretariat of Agriculture and Hydraulic Resources (SARH).

Research program

Since 1967 cassava research in Mexico has been carried out in a rather isolated manner, treating the crop as a vegetable. It was only in 1977, with the support of various different institutes in the agricultural sector, that the Cassava Research Program was initiated. The program brought together an interdisciplinary group of professionals, most of whom had been trained at CIAT.

This interdisciplinary group is stationed in Huimanguillo, Tabasco, in southeastern Mexico. Its objective is to generate technology for cassava production, processing, and utilization, in order that the crop becomes economically viable and well-adapted to the agricultural conditions of the Mexican tropics. After 6 years, there is now a technological package with which yields of 20-25 t/ha can be obtained at a commercial level in acid soils of medium to low fertility.

An important aspect of the production technology is the use of selected varieties, which are propagated by means of the two-node cutting method. The multiplication phase was brought about with the support of a rapid propagation project.

Propagation project

In the mid-1970s, rapid propagation projects were implemented to support the production programs in the municipalities of Loma Bonita, Oaxaca, and Centla in Tabasco. The purpose of the projects was to provide

the producers with plantlets from disease-free varieties. However, due to economic problems, these programs disappeared soon after they were started.

In 1977, with the initiation of the Cassava Program in Tabasco, a rapid propagation project was established using the two-node cutting system. The objective was to produce sufficient vegetative material to use in the different research projects that were being established. The material produced was used to establish regional trials, which were located from the state of Baja California Norte, in Mexicali, to the state of Chiapas. The major concentrations were in the states of Veracruz and Tabasco.

In 1980, the research program selected two clones, M Mex 59 and M Pan 51, both tolerant to pests and diseases and yielding over 25 t/ha in acid soils. These varieties were released under the names of Costeña and Sabanera, respectively.

Emphasis was placed on rapidly propagating these varieties in order to support commercial-level production programs of 1000 ha in southeastern Mexico. Two hundred rapid propagation chambers were established in 1982 in the experimental stations of Cotaxtla, Papalaopan, and Huimanguillo. The two-node cutting techinque was used, similar to the one developed by CIAT. The varieties propagated were mainly Costeña and Sabanera, but also included smaller numbers of other varieties adapted to different environments such as ITU, CMC 40, and the hybrid CM 309-165.

The plantlets, due to the special management they require, were planted under the supervision of INIA. The farmers were given vegetative material in the form of stakes. It is important to note that in Mexico, at present, no standards exist for the certification of cassava planting material, and as a result, phytosanitary control is only exercised when the stakes are handed over to the farmers.

Results

In the agricultural year 1982-83, the goal of producing enough material to plant 1000 ha of the recommended varieties was achieved; however, due to the administrative problems at that time, the production program in Tabasco was unable to plant this area. As a result, the planting material was sent to other states such as Quintana-Roo, Campeche, Yucatan, Veracruz, and Chiapas, where 300 ha were established with the selected varieties.

The leaf propagation method was tested, but was not implemented on a large scale because it required new infrastructure and personnel. This was

also the case with the genetic material obtained from meristems, which was introduced to the INIA laboratories in Zacatepec, in the state of Morelos.

Conclusions

The selection of new varieties for different agricultural systems is an important part of the Cassava Research Program, and propagation techniques will continue to occupy an important place in the program in order to supply sufficient material for the release of these new varieties. For a successful program, rapid propagation techniques should be used in conjunction with varietal selection, using the existing methods in an integrated manner.

Meristem propagation will serve as a method of introducing new materials and propagating them in the initial phase for testing. Propagation by means of leaves and two-node cuttings will be implemented to increase the number of promising varieties so that maximum use can be made of the small amount of material available in the first phase of evaluation. With the simultaneous evaluation and multiplication of planting material, the problems of massive propagation in the final stages of selection will be avoided, since the material already will have been propagated and used in demonstration plots.

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Production of Cassava Planting Material in Nigeria

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Introduction

Demand for cassava planting material has been rapidly increasing in Nigeria since the late 1970s. The major reason, apart from a national emphasis on increased cassava production, is the enormous yearly loss of planting material from cassava mealybug (*Phenacoccus manihoti*) and green spider mite (*Mononychellus tanajoa*). Production of cassava roots and stems has declined by 60% and 43%, respectively, in recent years. A nationwide program to produce cassava planting material was initiated against this background of declining supply and the inherently low propagation rate of the crop.

Cassava has become the main carbohydrate staple for over 50% of the population of Nigeria. Production can increase by over 300% if the various constraints, notably, pests and scarcity of planting materials, are resolved. The national research agencies, the International Institute of Tropical Agriculture (IITA), and the National Seed Service (NSS) are improving the availability of cassava planting materials through research for better technologies and active multiplication and distribution of improved planting materials.

Methods of increased stake production

Pruning and spacing

Studies were carried out at Umudike (05°29'N, 07°35'E, alt. 122 m) in 1979 and 1980 on the effect of pruning and spacing on the production of

stakes. Results showed that the multiplication ratio of 1 ha of mature cassava to 14 ha of new crop can be increased to 1:30 by pruning stems three times at 4-month intervals within the year (Table 1). Pruning four times in 12 months at 3-month intervals also increased the quantity of stakes significantly. The efficiency of the practice, however, depended on variety. Pruning twice at 6-month intervals did not produce a significantly greater number of stakes than the control (no pruning or cutting at harvest). Closer spacing within the row on 1-meter ridges increased the number of stakes significantly. The best arrangement from the study was planting at 75 x 100 cm and pruning once every 4 months for 12 months. The last pruning is, of course, the harvest of the crop.

Node number and planting position

Studies on the influence of node number and planting position on the production of stakes were conducted with three Nigerian cassava varieties (60506, TMS 30395, and TMS 30211). It was found that planting position -vertical, horizontal, or angular (40-45^0)—had no effect on the number of

Table 1. **Mean number of 20-cm stakes produced by cassava varieties 60506 and Nwugo as affected by pruning frequency and spacing.**

Spacing (cm)	Pruning frequency	Stakes/ha (000)[a]	
		60506	Nwugo
100 x 100	No pruning	135	140
100 x 100	2 times at 6-month intervals	195	175
100 x 100	3 times at 4-month intervals	210	213
100 x 100	4 times at 3-month intervals	202	198
75 x 100	No pruning	170	200
75 x 100	2 times at 6-month intervals	216	232
75 x 100	3 times at 4-month intervals	315	294
75 x 100	4 times at 3-month intervals	240	216
50 x 100	No pruning	225	202
50 x 100	2 times at 6-month intervals	220	210
50 x 100	3 times at 4-month intervals	284	270
50 x 100	4 times at 3-month intervals	238	240
25 x 100	No pruning	190	180
25 x 100	2 times at 6-month intervals	193	200
25 x 100	3 times at 4-month intervals	238	241
25 x 100	4 times at 3-month intervals	205	198

a. SE ± 5.8

Source: NRCRI, Annual report, 1980.

20-cm stakes produced (Table 2). However, stake number was significantly affected by node number and variety. Ten-node stakes produced significantly higher numbers of stakes than 2- or 4-node stakes, but no significant differences were found among stakes of 10, 8, and 6 nodes. Generally, the amount of planting material increased with higher numbers of nodes on the stakes. Significant varietal differences were observed: TMS 30211 and TMS 30395 produced more stakes than 60506 at all treatment regimes.

Table 2. **Effect of node number and planting position on production of 20-cm stakes from three cassava varieties in a rainforest zone (Umudike).**

Variety[a]	Planting position[b]	Stakes/ha (000) Node no.[c]				
		2	4	6	8	10
TMS 30395	Horizontal	140	240	241	326	315
	Vertical	220	260	410	404	467
	Angular	287	301	394	394	414
TMS 30211	Horizontal	197	212	298	229	278
	Vertical	200	273	290	315	393
	Angular	157	229	253	327	377
60506	Horizontal	123	138	179	136	226
	Vertical	0	158	147	180	192
	Angular	0	207	165	292	342

a. SE ± 2.9
b. SE ± 1.3
c. SE ± 2.9
Source: NRCRI, Annual report, 1981.

Rapid multiplication techniques

The rapid propagation technique of Wholey and Cock (1973) and Cock et al. (1976) was studied and adapted for Nigerian conditions. Ene (1978a) studied some factors affecting production of propagules and recommended the period between November and April as the best season for propagule production. A method for massive production of propagules was described in another study (Ene, 1978b). It was shown that one mature plant could, within 14 months, produce about 30,000-60,000 propagules which could perform as well as normal 20-cm stakes in terms of root yield, dry matter, and starch production. Sterile conditions and humidity chambers were maintained in these studies, as they are essential for obtaining disease-free propagules. Okeke (1981) studied a rapid multiplication technique using

healthy cassava plants in which type of rooting medium and sterilization of media were investigated. It was found that unsterilized soil was as good as other media for rooting stakes. Propagules grew best and accumulated the greatest amount of dry matter within 47 days in unsterilized soil (Tables 3 and 4). It was concluded that for rapid multiplication of improved, disease-free materials, a farmer would require a nursery bed of well-drained soil near a water source, shade, and polyethylene bags. This method has proved successful in the rapid multiplication of breeder's material.

Table 3. **Effect of growth media on stake sprouting and linear growth rate of propagules.**

	Mean no. propagules per stake[a] after 34 days		Mean linear growth rate[b] (cm/day) after 47 days	
Treatment	Sterilized	Unsterilized	Sterilized	Unsterilized
Soil/compost (1:1)	8.6	8.6	0.33	1.05
Soil/compost (2:1)	8.1	8.3	0.40	0.66
Soil/compost (1:2)	9.1	9.4	1.03	1.32
Soil + N-P-K-Mg	9.5	9.8	0.49	0.94
Soil	9.3	9.7	0.48	1.06

a. SE ± 0.34
b. SE ± 0.06

Table 4. **Effect of growth media on top growth of propagules.**

Treatment	Mean dry weight after 47 days (g/plant)
Distilled water	4.30
Sterilized soil	3.95
Unsterilized soil	5.80
Sterilized soil + N-P-K-Mg	2.59
Unsterilized soil + N-P-K-Mg	5.06
Soil/compost (1:1) sterilized	3.16
Soil/compost (1:1) unsterilized	3.72

Multiplication and distribution of planting material

The National Seed Service (NSS) of the Federal Department of Agriculture has responsibility country-wide for producing foundation seeds of rice, maize, cowpeas, sorghum, wheat, millet, and cassava

cuttings. Foundation seeds are supplied to State Seed Multiplication Units for production of certified seed, which is then distributed to farmers. The NSS has three regional offices: at Jos for the northeast zone, at Zaria for the northwest zone, and at Umudike for the southeast zone.

The cassava/maize program of the National Accelerated Food Production Project took off successfully, but then suffered from a scarcity of cassava cuttings. Special problems associated with the production of cassava planting materials include a low multiplication ratio (1:10); poor storability of cuttings (usually no more than 14 days); bulky planting materials (a 7-ton lorry can only carry 400 bundles, enough to plant 10 ha); and poor sprouting of stems infested with cassava mealybug (*Phenacoccus manihoti*). In order to achieve a 6% increase in cassava production, the supply of cassava cuttings to growers had to be undertaken by an institutional arrangement.

National research centers (the National Root Crops Research Institute and the Institute of Agricultural Research and Training of the University of Ife) and the International Institute of Tropical Agriculture produce breeder's seed and stage I foundation seed. The National Seed Service produces the stage II foundation seed for distribution to state ministries of agriculture in the cassava growing areas; these later produce certified seed which they distribute to their farmers. Although support for direct food production is largely a function of the states, the federal government assists in the provision of essential inputs, such as seeds and fertilizers, at subsidized rates. The federal government-assisted Cassava Multiplication Programme consists of the following elements:

- A grid of elite cassava multiplication plots in locations close to the states that will receive the stakes. Table 5 shows the areas established by the NSS in the different locations.
- A grant to each state in the cassava belt to establish a 15-ha cassava multiplication plot. Payment is made after inspection of the plots by the NSS. Table 6 shows the states involved and the location of the plots for 1983.
- The use of rapid propagation techniques to build up desirable cassava clones and to produce planting materials free from bacterial blight. The NSS, national research centers, and IITA use these techniques in four rapid multiplication centers operating in the country (two in Ibadan, one in Umudike, and one in Samara). Their combined potential production is 52,000 seedlings per month.

Participating states provide necessary logistic support by making trucks available to carry cassava cuttings, providing vehicles for monitoring

Table 5. **National Seed Service cassava multiplication plots.**

Location	Area planted[a] (ha)	Varieties
Ibadan	3	50495
		4(2)1425
		60142
Ijebu-Ife	62	30572
		30555
		30001
Ikenne	45	30572
		30158
Ikorodu	10	30572
		4488
Ogere	5	30572
		30555
Umudike	30	30211
		30572
		60506
		30555
		U/41044
Ubiaja	20	30555
		30572
		13791
Ugwuoba	5	30572
		U/41044
		60142

a. Each hectare should produce enough stakes to plant 10 hectares.
Source: National Seed Service, Progress report on cassava, 1983.

visits, and ensuring prompt payment of staff claims. They also follow specific husbandry practices that include using clean planting material obtained from approved sources and labeling varieties to avoid mixing during distribution. Other guidelines followed are establishing the plots with the early rains to assure good canopy development before the onset of the dry season when mealybug and mite infestation begins, and using approved insecticides such as Furadan before the end of the rains so as to minimize the effect of mealybug attack. Participating states also agree to ratoon the crop at the 9th month in order to increase the supply of planting materials.

Table 6. **Federal government-assisted Cassava Multiplication Programme in 1983, 15 ha per state.**

State	Location of cassava plot	Varieties
Anambra	Abakaliki	30572
	Ezillo	U/41044
		30211
Imo	Mbato	30572
	Bende	U/41044
	Ikagwa	30555
	Ihiagwa	30211
Cross River	Ikot Ekang	30211
	Awa	30572
	Akpap	30555
Rivers	Choba	30572
	Agbeta	30211
	Rumuodomoya	30555
Benue	Ayangba	60506
	Yandev	30211
	Alaive	30572
Oyo	Ilesha	50395
	Ilora	30211
	Ibaden	30558
Gongola	Muhi	60506
	Yola	30211
		30572
Ogun	Ilewo	50395
	Coker	30572
	Adodo	30158
	Ikenne	4488
Ondo	Ile-Oluji	30211
	Ijero	30555
	Owo	30572
Lagos	Ilogha	30572
	Egan	5660
	Ikorodu	4488
		1379
Kwara	Sare	30572
	Osare	30211
	Ajase	50395
Niger	Mokwa	60506
	Bida	30211
Bendel	Asaba	30555
	Ogba	1379
	Agbarho	30572
Plateau	Lafia	60506
	Shendam	30572
	Bukuru	30211

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Production of Cassava Planting Material in Zaire

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Introduction

Zaire is the third largest country in Africa after Sudan and Algeria. It has an annual average temperature of between 24-28°C and most of the country has an annual rainfall of at least 1200 mm. Only 2.7% of the total land area of 226.7 million hectares is classified as arable or tree crop land; 11% is pasture land and 50% is under natural forest.

Zaire has the largest population base in Central Africa with 418 people per km^2 of cropland, and a rapid growth rate of 2.85% per year. It has four semi-distinct climatic zones:

- The humid, semi-hot equatorial zone in central Zaire
- the humid, semi-hot tropical zone in Bas-Zaire and Bandundu
- the hot tropical northern tier
- the temperate zone in the south

The river valley soils in the Zaire Basin are Inceptisols of varying suitability for agriculture. The upland soils are mainly Oxisols and Entisols, both of low agricultural value, with some Ultisols, which are agriculturally more useful.

Only the southern part of the country is suitable for arable crops. This area is marginally suitable for maize, soya, beans, peanuts, and cotton, and somewhat better suited to cassava and sweet potato. Arable land in the remaining regions is even less fertile and is considered only marginally suitable for cassava and sweet potato.

Cassava is the most important crop in Zaire, occupying 95% of the area under root crop production. Annual production is 11 million tons with an

average yield of 6-7 t/ha. It is grown throughout the country both for its leaves and its roots. Investment in fertilizer, pesticides, and farm machinery is almost nonexistent; crop production is dependent upon natural weather conditions and those crop management practices which can be carried out using manual labor. Due to lack of better farm tools, poor or no transportation (there are no draft animals and only a few bicycles), and long distances to markets, family labor is extremely stretched to cope with cassava production and competing activities.

Research program

The main cause of low yields in cassava is the susceptibility of almost all the local varieties to pests and diseases. Cassava bacterial blight (CBB) is the most serious of the pests, causing a 60-90% loss, followed by the cassava mealybug. In 1974, due to the problems with CBB, the International Institute of Tropical Agriculture (IITA) and the Government of Zaire provided improved clones to the national cassava program, Programme National de Manioc (PRONAM). Research stations at M'vuazi, Kiyaka, and Gandajika received the improved clones, and some planting material was also distributed throughout the country in order for others to develop their own varieties.

After several years, clones with multiple resistance to CBB and mosaic and anthracnose diseases were developed at the research stations. At about the same time, these stations also identified other clones with resistance to mosaic disease and mites. In addition to this work, PRONAM is carrying out studies on stake type, age, length, and storage duration. Some results of the research and testing are described in the following paragraphs.

Stake age

Cassava stakes from plants 1, 2, 7, and 12 months old, and ratooned plant stock were compared for their sprouting, growth, and yield. The stakes from very young mother plants had a low sprouting percentage in comparison to the stakes from mature plants, (7 and 12 months and ratooned stock), which have a greater carbohydrate reserve. The cassava plants produced from the young mother plants also had less vigor, that is, they were shorter and had fewer leaves, in comparison with those from older plants (Table 1). With regard to yield, results over 2 previous years confirmed that the stakes from plants between 7 and 12 months old and the ratooned root stock gave a greater yield (Table 2).

Table 1. **Effect of mother plant age on plant vigor 120 days after planting, Mpelolongi clone.**

Mother plant age (months)	Plant height (cm)	Leaf no.
1	5.8	6
2	31.2	15
7	116.3	74
12	118.3	97
Ratooned root stock	134.5	113
Mean	81.2	61
SD	52.2	43.1

Table 2. **Effect of mother plant age on yield, Mpelolongi clone.**

Mother plant age (months)	Yield (t/ha) % yield of			Yield of ratooned stock (%)
	1980	1981	Mean	
1	5.0	4.0	4.5	44
2	6.1	6.9	6.5	63
7	8.9	14.4	11.6	112
12	10.9	16.9	13.8	133
Ratooned root stock	8.8	11.8	10.3	100
Mean	7.9	10.8		
SD	2.0	4.7		

Stake length

Due to the poor sprouting percentage of stakes on the sandy soils, farmers use longer stakes than those of the recommended size (25 cm). They also tend to use all the cassava branches for stakes, except those parts which are still green and unripe. An experiment was carried out at M'vuazi to compare plant performances produced from stakes of varying length (15, 25, 35, 45, 55, 65, 75, and 85 cm), and varying physiological age (primary, secondary, and tertiary stems).

The sprouting percentage was higher for stakes 35-85 cm long (96-100%) produced from primary stems, although the stakes from secondary and tertiary stems, which were 45 cm long or more, also showed good sprouting (91-100% and 73-94%, respectively).

At 180 days after planting, plants from stakes which had been produced from primary stems were in general taller than those from secondary and tertiary stems. The number of leaves after 180 days increased with stake length and varied with the stem type (66 leaves per plant for the primary stem plants, 62 for the secondary stem plants, and 50 for the tertiary stem plants).

Stake length did not affect yield 12 months after planting, but physiological age did; the average yield was 5.1, 4.0, and 2.2 t/ha respectively, for the primary, secondary, and tertiary stems (Table 3).

Table 3. **Effect of stake length and stem type on yield, Mpelolongi clone.**

Stake length (cm)	Yield (t/ha)		
	Primary stem	Secondary stem	Tertiary stem
15	4.1	3.1	1.3
25	4.8	3.4	2.1
35	5.8	3.4	3.5
45	5.4	3.4	1.0
55	4.0	4.5	3.0
65	5.4	4.3	3.3
75	5.5	5.0	1.6
85	5.3	5.4	1.8
Mean	5.1	4.0	2.2
SD	0.6	0.8	0.9

Stake storage

The delay between root harvest and the new planting of stakes requires that the stakes be stored for several days, or sometimes weeks. However, cassava propagating material is very susceptible to adverse climatic conditions, pests, and diseases, and in addition it can easily lose its vigor and sprouting potential if exposed to drying after harvest.

Farmers in Zaire store their planting material in the field by covering it with dead grass, by transplanting it into a moist soil, or by piling it up in the shade of a tree. In order to determine the effects of stake storage, an experiment was carried out at M'vuazi using three cassava varieties: 02864, a standard variety improved by the Institut National pour l'Etude et la Reserche Agronomique (INERA); Mpelolongi, a local variety largely cultivated by the peasants; and A56, a new variety from PRONAM.

Cassava stems 1 m in length originating from these varieties were stored in vertical positions in a moist soil for 15, 30, 45, 60, 75, and 90 days. At planting time, these stems were cut into stakes 25 cm long. This experiment also included fresh material so that comparisons between stored and unstored stakes could be made.

The sprouting percentage was not generally affected by the first 30 storage days (97.3-100%), and the varieties 02864 and Mpelolongi maintained a high germination rate (approximately 98%) right up to the 45th day (Figure 1). However, from the 60th to the 90th storage day sprouting was considerably reduced for all three varieties.

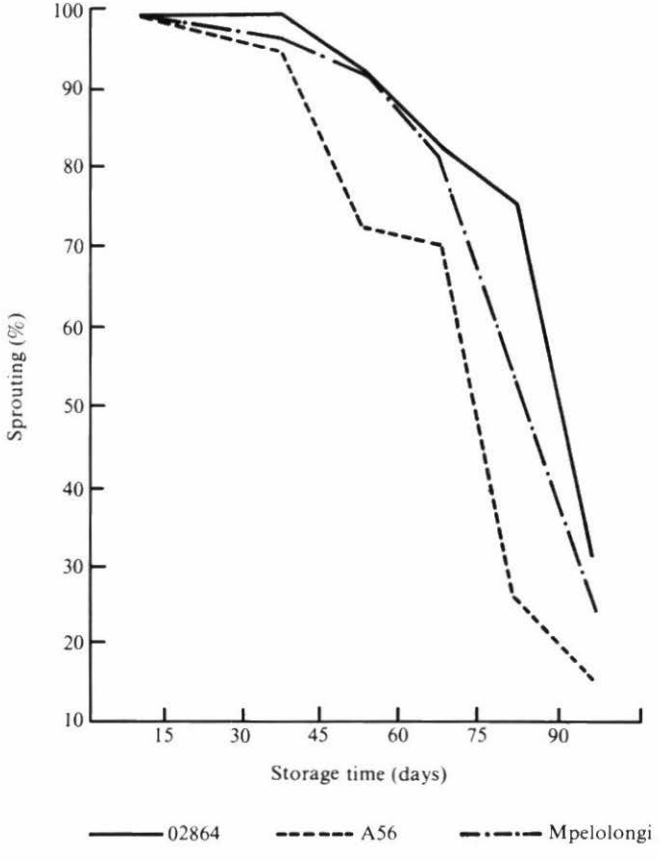

Figure 1. *Effect of storage time on sprouting percentage of stakes.*

Plant height at 120 days after planting varied from an average of 103.2 cm at 0 storage to an average of 88.1 cm at 45 storage days, whereas a strong height reduction was observed from the 60th to the 90th storage day: an average of 79.9 cm to an average of 47.7 cm, respectively (Figure 2). The effect of storage length on the number of leaves at 120 days after planting varied from one variety to another. Storage over 15 days greatly reduced leaf number on variety 02864, while A56 and Mpelolongi showed a fairly steady decline in leaf number as storage length increased (Figure 3).

Fresh root yield also was affected by the length of stake storage (Table 4). An appreciable yield reduction was observed after the 30th day of storage (13.8% reduction) to the 90th day (39.3%). The root number per plant was similarly affected by storage length (Table 5).

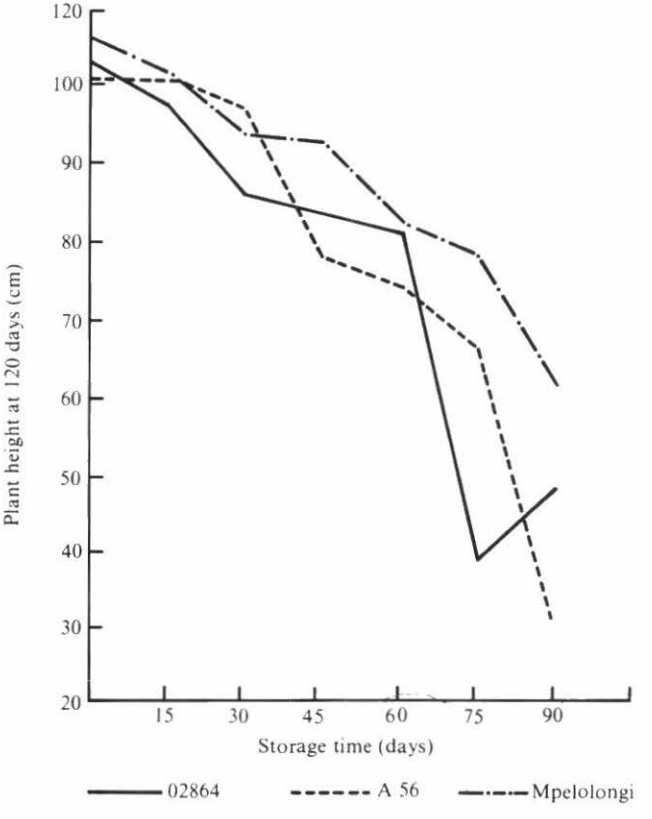

Figure 2. *Effect of storage time on plant height 120 days after planting.*

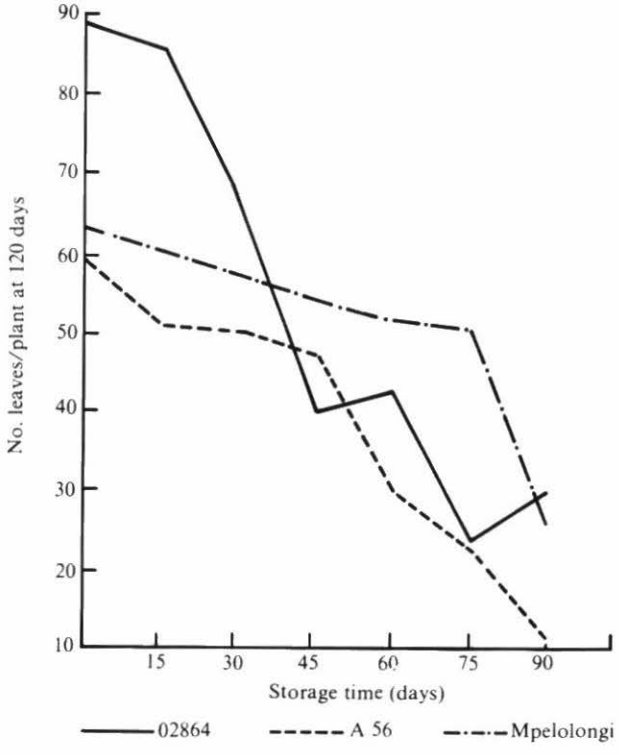

Figure 3. *Effect of storage time on number of leaves 120 days after planting.*

Table 4. **Effect of stake storage period on yield of three clones.**

Storage period (days)	Yield (t/ha)				Average loss[a] (%)
	02864	Mpelolongi	A56	Mean	
0	16.1	12.8	23.0	17.3	0
15	16.0	12.3	21.8	16.7	3.4
30	13.7	11.8	19.3	14.9	13.8
45	13.0	11.4	19.4	14.6	15.6
60	12.4	7.6	18.4	12.8	26.0
75	10.0	7.5	18.3	11.9	31.2
90	10.1	6.5	15.0	10.5	39.3
Mean	13.0	9.9	19.3		
SD	2.4	2.6	2.5		

a. Over three clones.

Table 5. **Effect of storage period on root number of three clones.**

Storage period (days)	Root no./plant				Average loss[a] (%)
	02864	Mpelolongi	A56	Mean	
0	8.4	7.3	9.1	8.3	0
15	7.6	6.8	8.3	7.5	9.6
30	7.8	6.8	8.4	7.6	8.4
45	6.4	4.6	6.8	5.9	28.9
60	6.4	4.6	5.8	5.6	32.5
75	5.8	5.3	5.0	5.3	36.1
90	5.2	3.6	5.0	4.6	44.6
Mean	6.8	5.6	6.9		
SD	1.1	1.3	1.6		

a. Over three clones.

Mosaic disease

A study was carried out with cassava variety Coll 45 (very susceptible to mosaic) to establish the relationship of the levels of mosaic infection to germination and growth. Stakes were obtained from plants in classes 1, 2, 3, 4, and 5 of the disease infection (1 = no symptom and 5 = severe distortion and reduced leaf size). Planting was done at a spacing of 1 x 1 m in Mpalakidi (sandy soil) in a complete randomized block design replicated four times; each experimental plot received 54 cuttings.

The rate of germination was recorded 15 days after planting while the severity and incidence of the disease, and the number of leaves carrying the disease, were recorded 3 and 6 months after planting.

Preliminary results (Table 6) showed that germination is not affected by the disease. The incidence and severity of the disease 3 months and 6 months after planting was higher in stakes from highly infected plants than in stakes from plants showing no symptoms. Class 1 stakes also had less leaves showing disease as compared to stakes from the highest classes of severity after both 3 and 6 months (Figure 4). The height and diameter of plants were also adversely affected by the severity of infection in the mother plant (Table 7).

Anthracnose disease

A study was conducted to investigate the possibility of eliminating anthracnose disease simply by selecting clean, healthy planting material. Two cassava varieties (Mpelolongi and 02864) were used. Stakes were

Table 6. **Effect of mosaic infection level in mother plants on germination of stakes, and incidence and severity of the disease.**

CMD severity of mother plant	Germination (%) 15 days	Severity at 3 months	Severity at 6 months	Incidence (%) at 3 months	Incidence (%) at 6 months
1	94.0	2.0	1.9	80	68
2	93.0	2.7	2.8	88	95
3	89.0	3.1	3.1	100	100
4	95.0	3.5	3.8	100	100
5	92.0	3.6	4.0	100	100

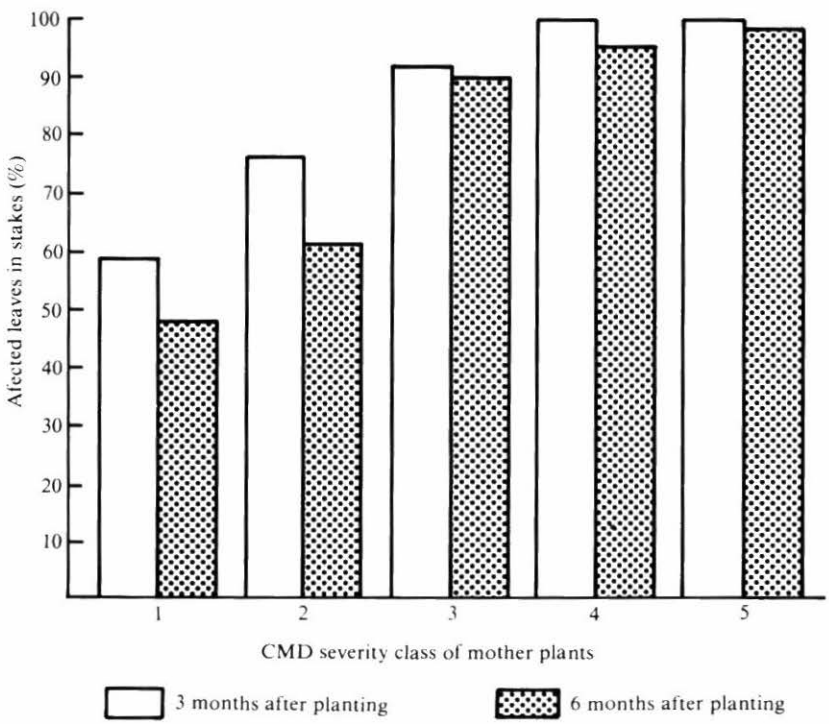

Figure 4. *Effect of mosaic infection level in mother plants on mosaic-affected leaves in stakes.*

Table 7. **Effect of mosaic infection level in mother plants on stake vigor 6 months after planting.**

CMD severity of mother plant	Stake height (m)	Stake diameter (cm) at 15 cm from soil
1	2.2	3.0
2	2.3	3.0
3	1.6	2.8
4	1.6	1.9
5	1.5	1.8

obtained from plants without anthracnose cankers (class 1), those with few cankers (classes 2 and 3), and those with many cankers (classes 4 to 4.5). Planting was done in a randomized complete block experiment containing four replications. At 3, 6, and 9 months after planting, scoring for anthracnose infection was made. The results showed that the disease increased from 3 months to 9 months after planting in all the treatments, including stakes from plants without anthracnose. However, there were no significant differences among the treatments. The findings suggest that using materials free of anthracnose for propagation cannot preclude new infection of the disease. This indicates that insect feeding (*Pseudotheraptus devastus*) may be the most important factor in the evolution of anthracnose.

Multiplication and distribution of clones

In Zaire, the multiplication of improved clones for seed is carried out through cooperating agencies. These agencies are visited regularly by a team of pathologists and entomologists from PRONAM, who check on the cleanliness of the plants being produced for seed. Once the seed has been multiplied, it is scored for diseases and then tested in demonstration plots against local varieties. The emphasis is on producing two or three top varieties.

Multiplication procedures include fertilization and frequent weeding. Weeding is done both manually and chemically. Varietal mixtures of off-types are rogued out, as are plants with mosaic disease, and extremely vigorous examinations take place to screen for freedom from plant pests.

Planting material is distributed in various ways (Table 8). It is encouraging to note the increase in the quantity distributed for experimental trials, demonstration on farmers' plots, and PRONAM's multiplication plots in 1982 compared to 1981.

Table 8. **Distribution of planting material.**

Kind of distribution	Meters of stakes		
	1981	1982	Total
By sale	110,250	39,500	149,750
For experimental trials, farmers' demonstration plots, and PRONAM's multiplication plots	24,200	115,450	139,650
Free distribution to small farmers and interested agencies	8,500	8,000	16,500
Total	142,950	162,950	305,900

Table 9. **Cooperating agencies involved in multiplying improved clones.**

Project	Demonstrations with PRONAM clones on farmers' plots			Multiplication of improved clones (ha)	
	1981-82	1982-83	1983-84	1982-83	1983-84
PNE-FAO	21	55	50		5
Project Agricole (French-aided)		18	50	4	5
Salvation Army		18	25		4
Italo-Zairois		1	5		10[a]
OXFAM			4		5
Church groups			2	1	10
Private farmers	3	3	6	1	12

a. The goal is 1000 ha in 2-3 years.

Area and agencies involved

At the M'vuazi research station in Bas-Zaire in 1981-82, 34.5 ha of improved clones were planted for seed and 14.5 ha of ratooned crops were grown. In the following year, the amount of improved clones increased to 37.7 ha and the amount of ratooned crop decreased to 11.0 ha. This multiplication was carried out through two cooperating agencies: Groupe Economique Rurale (GER) and the Romanian Aid Project (ZAIROM). However, the projects of both agencies were disbanded in 1982.

Work began in 1975 at Kiyaka, in Bandundu, and within a short time there were 16-17 ha under improved clones for seed. However, this station

had difficulties in retaining trained manpower, and the project was stopped. In 1982-83 it was reactivated and at present there are four improved clones being produced for seed on 40 ha. The research station at Gandajika currently has 18 ha of improved clones.

It can be seen from these examples that the problems with multiplication of improved clones in Zaire are being overcome and improvements are being made. Table 9 lists cooperating agencies that are active in multiplying improved clones and through which the number of hectares may be increased in the future.

CHAPTER 9. CASE STUDY: SEED PRODUCTION PROGRAM FOR SWEET POTATO, YAM, AND COCOYAM

Seed Production in Sweet Potato, Yam, and Cocoyam at IITA

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Introduction

The Root and Tuber Improvement Program at IITA has as its main objectives: (1) to improve yield and quality characteristics of cassava, yams, sweet potatoes, and cocoyams, including disease resistance and storage ability; and (2) to provide seeds from various regions to national programs for selection. This paper describes the process of seed production for sweet potato, yam, and cocoyam (cassava is excluded) as practiced at IITA in Ibadan. In contrast with sweet potato, it is only recently that yam and cocoyam seed production has been intensified and problems are yet to be adequately researched.

Sweet Potato

At IITA, the peak flowering period of most sweet potato lines is during the periods of short days (11.7 hours) and the lowest minimum temperature (10-15^{0}C) in the months of December-February, which is also the peak dry season in this area (Figure 1). During this period, most of the seeds from hand crosses and cross-pollinations are produced. Similar trends have been observed in many other areas where sweet potato seeds are produced.

Selected parent plants are either planted in isolation for seed production or in seed nurseries, where crosses are made. These nurseries are maintained by overhead irrigation. Desirable sweet potato lines which flower very sparsely or do not flower naturally in field conditions are grafted onto *Ipomaea setosa* or Brazilian morning glory and subjected to short days of 9 hours. The practice of grafting in combination with

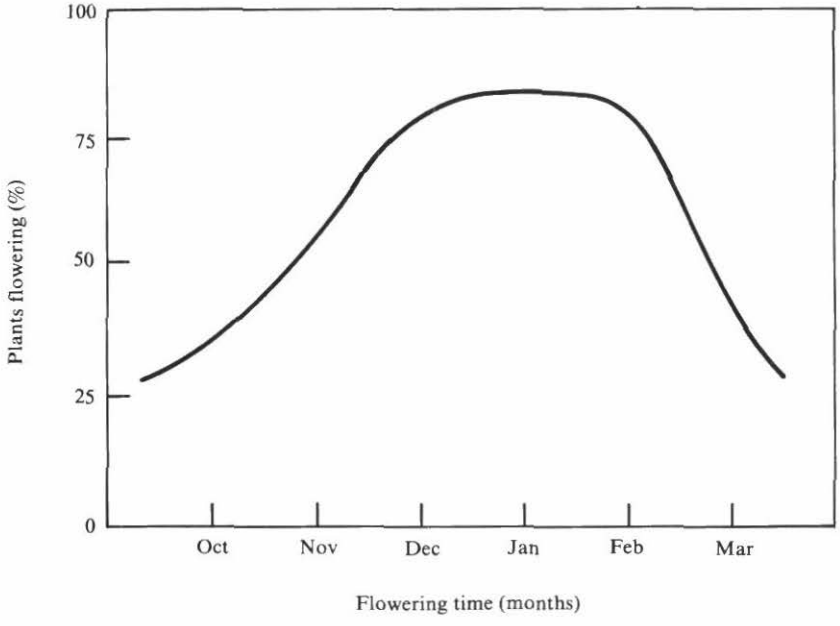

Figure 1. *Phenology of sweet potato flowering at IITA, Ibadan.*

short-day treatment for flower induction in sweet potato is a regular practice in Japan (Shikta, 1982). Hand-crossing is done on all grafted plants, the best time for pollination being between 7:00 a.m. and mid-morning.

Seed set varies among the lines. Under conditions of no hand pollination and no irrigation during the flowering season, some lines gave three times as much seed as others. This variation in seed set can be attributed to many factors such as insect activity, flowers per plant, flowers successfully pollinated, ovule abortion, and attractiveness of the line to the pollinator.

At IITA, pollen transfer is primarily done by honey bees although other insects such as flies are frequent visitors to flowers. Bee activity is highest at mid-morning but they have been observed as early as 7:00 a.m. and up to the time when flowers have faded. Up to 13 different insects have been observed pollinating sweet potato flowers (Thibodeaux et al., 1977).

Some cultural practices to increase seed yield include planting healthy, virus-free material, reducing severe damage by sweet potato weevils during the long dry season, training the vines on trellises or stakes, regular weed

control, and irrigation, particularly at the permanent crossing plot where many hand-crosses are made. Super-optimal nitrogen levels and high moisture encourage excessive top growth and can depress seed yields. Care should be taken to ensure that developed dry capsules are harvested regularly before the capsules fall.

When measures are taken against drought stress and attack on stems and leaves by sweet potato weevils and other pests, thousands of seeds can be produced each season. The seeds produced are enough for use at IITA and for distribution to many national programs.

Yam

Dioscorea rotundata (white yam), *D. alata* (cluster yam), and *D. dumetorum* (cluster yam), all flower and set seeds at IITA. Flowering in these yams starts in June, with most male lines flowering first. Female plants flower 2-4 weeks later in white and cluster yams. Peak flowering occurs in August-September for all except *D. alata*. The water yams begin to flower in August-September and show the same flowering pattern as the other yams, with males flowering first.

The floral morphology of white yams has been described by Sadik and Okereke (1975) and Akoroda (1981). All the other yams discussed are generally dioecious with similar floral biology. The staminate florets are sessile and borne on spikes subtended by small bracts with a variable number of florets per raceme. Similarly, the pistillate flowers are borne on axillary spikes with the sepals and petals lobed above the ovary.

When the florets on a raceme are mature, the raceme will usually maintain viable ovules for a period of 5-14 days, depending on the number of florets on the raceme and to some extent, the temperature. There may be 2-7 florets that open per day per raceme. The effective pollination period which results in fertilization is still being studied.

The number of insect species visiting the flowers is small. The predominant ones are the thrips (*Larothrips dentipes*). Their peak activity is usually during the hottest time of the day when most flowers are open. The highest number of thrips per floret was observed in August. As a measure of the activity of these insects, the mean number of thrips observed per open flower for each species is shown in Table 1. The effectiveness of the insect visit is reflected in percent fruit set per raceme, assuming that after an effective pollination, there is a negligible probability of factors inhibiting fruit set. The thrips appeared to prefer *D. dumetorum* flowers, which are highly pubescent. These flowers received more insect visits, with a resulting higher percentage of fruit set.

Table 1. **Occurrence of thrips (*Larothrips dentipes*) and fruit set on yams (*Dioscorea* spp).**

Species	Sex	Thrips per floret	Mean fruit set/raceme (%)
D. dumetorum	Male	0.24	
D. dumetorum	Female	0.23	91.2
D. rotundata	Male	0.20	
D. rotundata	Female	0.15	44.2
D. alata	Male	0.14	
D. alata	Female[a]	—	21.4

a. Adequate samples were not observed for *D. alata* females.

In 1982, the early onset of the dry season, the high temperature of 32°C, the dry winds during the flowering months of November and December, and the delayed flowering of females in *D. alata* may all have been factors contributing to the very poor seed set relative to 1981. Female flowers were sparse and synchronization was poor. Controlling the flowering time of *D. alata* lines is necessary to ensure that pollen is available throughout the flowering period of the females. Staggering of planting dates, mulching, and provision of moisture have been the techniques used.

Female plants bearing capsules are allowed to dry and turn brown before harvesting. Harvested fruits are placed in cloth bags and dried further in the sun before cleaning. After the seeds are released from the dehisced capsules, they are cleaned by rubbing off the leathery wings and then stored in seed envelopes. Although a capsule has the potential for producing six seeds, the average seed number produced is four. Most seeds produced are from open pollination with a range of 2-38 g of clean seed per plant. Clean seeds weigh about 0.07-0.09 g per 100 seeds and occupy about 2 ml.

The seeds have a short dormancy period of 3 months and once this has been overcome, they will readily germinate (Sadik and Okereke, 1975).

Cocoyam

The process of seed production in cocoyams (*Xanthosoma sagittifolium* and *Colocasia esculenta*) starts with the growing of mother plants from corms or cormels to the three or five leaf stage in the field and then

pro-gibbing them with 15,000 ppm gibberellic acid (GA) using the method described by previous workers (Alamu and McDavid, 1978; Wilson, 1979 and 1980). In a second method, plants are rapidly multiplied in a seed bed and pro-gibbed at the one or two leaf stage with 1000 ppm GA before being transplanted to the field. In a third method, plants are left in the field during the dry season and the first leaves appearing at the beginning of each rainy season are pro-gibbed.

The necessity of controlling the flowering time of individual lines entails the use of gibberellic acid for floral induction since flowering is infrequent. All field-grown plants that were pro-gibbed produced normal flowers 65-120 days after treatment. Plants that were pro-gibbed in seed beds had two phases of flowering: an early phase with only a few flowers and a second phase with an increased number of flowers. The advantages of early gibberellic acid treatment will be studied further.

The nature of the *X. sagittifolium* inflorescence, where the spathe is tightly wrapped around the spadix with a very viscous and sticky stigmatic exudate on the receptive pistillate portion, makes insect pollination very unlikely. In order to obtain seeds, manual pollination is necessary. Most crosses are made between mid-morning and early afternoon. Even though the flowers are protogynous, flowers to be cross-pollinated are emasculated on the day of pollination, which is usually 1-2 days before pollen shed. The techniques have been described by Volin and Zettler (1976), Wilson (1979), and Jos et al. (1980).

Ripe fruits, which are soft and usually light green to yellow, are harvested 30-70 days after pollination. The seeds are extracted by crushing the heads, and are then washed out into a container of water to facilitate the separation of the seeds from the fruit pulp. Following this, they are air-dried on filter paper, and the remaining pulp or fragments and the poorest quality seeds are removed. Crosses among lines of *Xanthosoma* and fertile *Colocasia* at IITA and the Cameroon National Root Crop Research Institute have resulted in thousands of seeds for use in the breeding program and for distribution.

The use of gibberellic acid for flower induction and seed production in cocoyams has greatly influenced the seed yield in this crop. However, it is possible that natural flowering could occur in particular environments, as has been reported from Dominica (Pattanjalidial, personal communication), and in particular varieties, as has been reported by Volin and Zettler (1976). Some seedling lines from crosses made in Cameroon have also flowered naturally.

Conclusions

It is clear that there has been progress in seed production of these crops due to the efforts of the many scientists and breeders who have worked on them. However, there is continued need for superior cultivars with disease resistance. Because of the narrow germplasm base in some of these crops, new plant explorations to collect species are needed.

IITA's strategy in fulfilling its responsibility for crop improvement is to generate improved genotypes and introduce them to national programs, predominantly as true seeds, but also in tissue culture form. The systems described and employed at IITA have given satisfactory results for seed production in all these root crops except *D. alata*. Ways of stabilizing seed production in yams will receive special attention in the future along with efforts that are, at present, underway to investigate methods of improving seed production and quality generally.

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CONCLUSIONS AND RECOMMENDATIONS

- The tropical root and tuber crops are normally propagated asexually. They are generally easy to propagate; however, rates of multiplication are low and storage of propagules is difficult. In addition, the propagating material is often an effective carrier of diseases and pests.

- In order to set up a successful seed certification or rapid propagation program it is necessary to define the varieties or cultivars to be used. This does not mean that a new cultivar must be released; many traditional cultivars show a yield decrease with time that can be renovated using a variety of techniques ranging from simple visual selection to highly sophisticated treatment. However, when new varieties are to be released, it is important to involve farmers in the final stages of selection and evaluation to ensure that they do not reject the variety after considerable time, effort, and expense have been devoted to its propagation. The performance of the 'best' variety in a multilocation uniform yield trial is often used to select the variety to be rapidly propagated. A preferable practice is to select and multiply the best variety for each locality, rather than a good average one.

- Once a variety has been selected it must be propagated. Extremely simple propagation techniques can be highly effective in many cases; more sophisticated techniques can further improve their effectiveness. Techniques such as *in vitro* micropropagation are normally thought of as being highly sophisticated, requiring well-equipped laboratories and trained staff. Although this may be true for certain aspects of micropropagation, it must be emphasized that these techniques can also be effectively used at the village level. Maintenance of varietal purity is important in any propagation scheme; however, it may be difficult to visually assess varietal purity with micropropagation techniques, and extra attention to its maintenance may be required.

- At present, most research to evaluate the efficiency of various techniques for the production of pathogen-free material or the reduction of infection levels is directed towards highly sophisticated techniques. Little is known about the efficiency of such techniques as visual selection over a number of generations. Virologists and pathologists in general should pay more attention to evaluation of these more mundane methods of reducing infection levels in propagation material.

- In order to produce high-quality propagation material, it is advisable to set up special production plots. In general these should be isolated from commercial production zones or fields, and should be located in areas that allow reasonable propagation rates and low degeneration rates of planting material. The isolation may be in geo-

graphically distinct regions, as often occurs in the case of seed potato production, or it may be in isolated fields on a farm where commercial production takes place. When the seed production zone is far from the commercial production area, it is possible that important disease symptoms in the latter area may not appear in the former. Hence, visual selection for disease-free plants may be ineffective. Research is required to determine not only how to produce high-quality planting material but also which sites are optimal for propagation.

- The final phases of propagation may be done in farmers' fields, with rapid propagation techniques being used for the earlier stages of multiplication. In crops with a very slow rate of propagation (e.g., yams) rapid propagation may be required right up to the stage when the material is planted by farmers; whereas in crops with a faster multiplication rate, rapid propagation is only required to produce basic seed stocks. When these are being built up, or whenever field propagation is practiced, the use of positive selection of healthy, high-yielding plants (rather than negative selection or roguing) is strongly recommended.

- Storage is an extremely important part of any propagation scheme. Both the methods and the length of storage can have marked effects on the subsequent establishment and productivity of the crop. Much attention is placed on elimination or reduction of disease and pest levels during propagation; however, little attention is paid to reducing their spread during storage, which may be very rapid. Many storage methods exist; one that is effective, inexpensive, and often overlooked is the use of live plants in the field. This method is particularly appropriate when the propagating material (e.g., sweet potato vines) is extremely perishable. Where the propagating material is different from that used for commercial production (e.g., cassava stakes), losses of quality are generally considered more important than losses of quantity in storage. However, if more care and attention is given to the production of high-quality certified planting material, it will acquire more commercial value, and losses in quantity will become relatively more important.

- Little is known at present about the manner in which different environmental conditions during the growth of the mother plants affect the subsequent growth and development of the progeny. Furthermore, the impact of differing levels of seed quality on production is poorly defined. This makes it difficult to define adequate seed regulations. Frequently these are copied from some other crop with completely different characteristics. Regulations for seed certification must be designed for the specific crop in question and must also fit in with local requirements and capabilities.

- In order to increase the use of good quality seed, it is first necessary to make farmers aware of its advantages, and then to stimulate them to cooperate. For without their cooperation, programs aimed at reducing pathogen levels are likely to fail, and government support for the seed programs will not be promoted.

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