CHAPTER 4

Cassava Planting Materials

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Introduction

Cassava propagates vegetatively. This enables it to form clones, where all plants of a variety are the same, both externally and in root and foliage production. However, biotic (pests and diseases) and abiotic (climate and soil) environmental factors can considerably modify individual plants, changing, for example, their height, vigor, flowering, branching, root production, and starch and hydrocyanic acid (HCN)[2] contents. One significant feature that the environment can affect is the quality of planting materials, degrading them, even to the point where a given variety may disappear.

Factors that can reduce yields of cassava plants include systemic diseases such as those caused by viruses, bacteria, and phytoplasmas; low soil-fertility; nutritional imbalances; and even moderate levels of soil salinity. These factors can also reduce the capacity of planting materials to express the genotypes' respective yield potential.

The effect of such negative factors during several vegetative propagation cycles of the cassava crop can result in a cumulative reduction of quality in planting materials, leading to their gradual deterioration (Lozano et al. 1984). Introducing the use of good-quality planting stakes as part of the package of "best" farming practices would permit the acquisition of healthy vigorous plantings, with yields that are close to the respective genotypes' potential.

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2. For an explanation of this and other acronyms and abbreviations, see *Appendix 1: Acronyms, Abbreviations, and Technical Terminology*, this volume.

Situation of Cassava "Seed"

The timely availability of good quality planting materials constitutes a decisive factor for the dissemination and use of new cassava varieties. The lack of improved seed (i.e., planting stakes) is often a feature of crops of simple asexual propagation, but is accentuated in cassava because of its biology, farmers' socioeconomic status, and lack of organized seed-supply systems.

Biological aspects

Cassava is one of the few crops whose planting materials, in themselves, have no economic value. In grain crops (e.g., maize and beans) and even in crops with vegetative propagation such as potato, yam, and sugarcane, planting materials that are not used as seed still have value as food. Even seeds, such as those of horticultural crops, that have no other use, at least have the advantage of occupying very little space, and the potential for being conserved over prolonged periods under good storage conditions. Cassava, in contrast, is planted for its roots, and stems that are not used as seed have no other attribute of value. Cassava also has other characteristics that hamper large or medium-scale seed production.

Low storage potential

Cassava planting materials deteriorate during storage as stems dehydrate, reserves are lost through sprouting, and pests and other pathogens attack. The result is a gradual reduction in the number of usable stakes, as the storage period increases. To date, despite considerable research, no technology is available that solves these problems. However, the potential for storage is known to be a varietal characteristic. Some cultivars such as M Col 1468 (previously called CMC 40) can be stored for as long as 6 months, while others such as M Col 1684 can deteriorate in as quickly as 2 or 3 weeks.

Growth habit is related to such varietal differences. For example, stems from non-branching or late-branching clones can be stored for longer periods than those from early branching clones. The nutritional status of the mother plants may also affect the stems' storage potential.

Low multiplication rate

On the average, a mature cassava plant in good condition produces only 10 or so 20-cm-long commercial stakes. Cropping conditions can reduce this figure to 5 or even fewer stakes. This means that, from 1 ha, over 1 year, only enough stakes to plant 10 new hectares can be obtained. Such figures represent a very low multiplication rate when compared with grain crops (Table 4-1). Such a situation has the following consequences:

1. Expanding the planted area rapidly is very difficult.
2. The costs incurred to produce 1 ha of crop for seed acquisition must be divided among a low number of stakes.
3. The seed producer must dedicate a considerable amount of land to obtain planting materials (Table 4-1).

Weight and volume

The handling and transportation of cassava stakes are wasteful and expensive operations because of the planting materials' considerable weight and volume. A single cassava stake weighs the equivalent of 230 maize seeds. Planting materials for 1 ha (10,000 stakes) weigh about 0.7 t and occupy a volume of about 2 m^3. Hence, many farmers tend to use small stakes. Table 4-2 compares the weight and volume of cassava seed with those of seed of four other species.

Table 4-1. Seed plot area needed to plant 100 ha and multiplication rates for cassava and four other crops.

Crop	Area (ha)	Multiplication rate[c]
Cassava	12.5[a]	10
Bean	6.7[b]	225
Soybean	4.0[b]	600
Rice	2.5[b]	1600
Maize	0.7[b]	22,500

a. Land occupied for 1 year.
b. Land occupied for 1 semester.
c. Number of stakes (or seeds) obtained from one stake (or seed over 1 year.

Table 4-2. Approximate weight and volume of seed of some crops.

Crop	Weight of 100 stakes (g)	Weight of 100 seeds (g)	Seed for 1 ha	
			Weight (kg)	Volume (m^3)
Cassava	7000		700	2.00
Rice		2.4	150	0.26
Soybean		16	90	0.12
Bean		45	80	0.10
Maize		30	20	0.03

Cultivation by small farmers

Most cassava production is carried out by small farmers, who use traditional production systems that result in low, but stable, yields. Cassava-growing areas are characterized as having little infrastructure and usually poor soils that are sometimes marginal for crop production. Poor soil fertility leads to both reduced root production and poor quality planting materials, mainly because of insufficient nutritional reserves. Small farmers use intensive-labor agronomic practices, as they possess few resources to exploit in their work.

Uncertain demand

Cassava farmers habitually produce their own planting materials as, cassava being a crop with vegetative propagation, usually produces seed at the same time that the previous crop is harvested. Farmers who buy cassava seed either:

- Are planting for the first time
- Have stopped planting long enough so that no planting materials are conserved
- Wish to change varieties
- Wish to considerably increase the planting area

The volume of sales of a cassava seed producer depends on variations in the planted area, which, in its turn, depends on how root prices are performing.

Stake Quality

For seed to be a highly productive technological component, it must have quality. Experience has demonstrated that good quality seed will give good results in the field, whereas poor quality seed will lead to unsatisfactory results and failure. *Quality* is that set of genetic, physiological, and health attributes that enable stakes to give rise to productive plants. The presence of high levels of these three essential components of quality indicates that seed is at its maximum integrated quality. In contrast, weakness in any component introduces a constraint. Thus, perfect genotypes cannot express their true potential if their seed has physiologically deteriorated and shows poor germination.

The qualitative attributes of a variety, generated by genetic improvement, will be transferred to the farmer only where its characteristics do not deteriorate from one generation to the next through seed multiplication.

Genetic quality

Genetic quality is produced through improvement. Crosses, selections, and regional trials are all used to develop materials that contain a genetic program that is appropriate for the conditions found in different agroecological areas. When the selected materials are crystallized into varieties acceptable to users, they are then recommended for mass and commercial use. To be useful to the agricultural community, mass quantities of stakes will be needed for each such variety. It is during multiplication that the need for maintaining genetic identity appears.

Genetic quality can be ensured by planting authentic seed, that is, when planting materials are chosen from crops certified by entities such as the Colombian Institute of Agriculture (ICA, its Spanish acronym). Varietal mixes are avoided, and authenticity is maintained through preventive methodologies such as not planting immediately into land previously planted with different cassava varieties. Inspections are also carried out to rogue out atypical plants.

The genetic factors that most affect the seed production of a cassava variety are general vigor and branching habit. Vigor affects the total growth of a plant's aerial parts and, as a result, the number of branches from which stakes can be obtained. Branching habit influences the availability of primary and secondary stems, which are the parts most used for planting materials.

In general, vigorous varieties produce more stakes than non-vigorous ones. However, the greatest difference lies in the type of branching. Late-branching varieties have a larger proportion of primary and secondary stems than early branching genotypes. Hence, increased branching leads to more and heavier stakes.

Physiological quality

The tangible result of physiological quality is the stake's ability to sprout and give rise to a vigorous plant. Physiological quality involves seed nutrition, seed age, and seed viability:

Seed nutrition. The nutritional status of a stake is fundamental to the initiation of a new plant because, in the 20 days following planting, the stake's growth into a plant is exclusively at the expense of the reserves accumulated in the stem. Three weeks after planting, with the appearance of the first leaves and roots, photosynthesis begins to contribute to plant growth, which, however, continues to use the stake's nutrient reserves until day 40 (Hunt et al. 1977).

Soil fertility markedly affects the growth of aerial parts in cassava and, especially, the nutritional status of the stems used as planting materials. In low-fertility soils, stem length and quality are diminished, but can be considerably improved through fertilizer applications. Such applications increase the level of nutrient reserves in the stems, thus improving their performance when used as planting materials.

Indeed, different levels of N, P, and K have been studied in plots planted with seed. Results showed that both the concentration and contents of N, P, and K in stems vary with levels of N, P, and K in the soil. Thus, cassava plants grown in a low-fertility soil produce stems with low contents of N, P, and K. When that soil is given applications of high levels of fertilizers, the resulting stems present high contents, not only of N, P, and K, but also of starch, reducing sugars, and total sugars (Table 4-3). When such stems are used as planting materials, the percentage of stakes germinating is strongly influenced by K levels and the balance of K with N and P.

Table 4-3. Nutrient contents of stakes according to levels of fertilizer applied to the soil from which they were obtained (mg/stake).

Nutrient	Level of fertilizer application		
	Low	Intermediate	High
N	70	131	139
P	10	23	25
K	19	49	72
Starch	2620	3390	4290
Reducing sugars	330	460	500
Total sugars	390	520	680

We point out that the stakes' capacity for germination is not affected by whether or not they are planted in a soil with fertilizer applications. What is important are the stake's levels of nutrient reserves. If stakes with high nutrient contents are used, then a higher production of stems, suitable for use as planting materials, is possible. This is very important for seed production programs because of cassava's low multiplication rate (Table 4-4).

In addition, an application of fertilizer to the seed plot, emphasizing K, will result in stakes that produce, in their turn, denser foliage—a factor of special interest for sustainable agriculture in hillside regions, where, by increasing soil cover, it reduces hydric erosion.

Finally, the use of stakes with adequate nutrient contents will increase the total production of fresh roots, mainly because roots will be larger and, to a lesser extent, more numerous (Table 4-4).

Figure 4-1 shows two plants of the same variety (M Col 1684) and age (12 months). The plant on the left came from a stake with low nutrient contents ($N_0P_0K_0$), while that on the right came from a stake with high nutrient contents ($N_2P_2K_2$). Both stakes were planted in an acid low-fertility soil with no fertilizer applications. Thus, the difference between these two plants would be exclusively in terms of the quantity of nutrient reserves the stakes had.

Table 4-4. Effect of nutrient contents of stakes on the average production of stems and roots, using cassava variety M Col 1684.

Nutrient contents	Average production (fresh weight)	
	Stems (kg/ha)	Roots (t/ha)
Low	3252	16,260
Intermediate	3611	21,180
High	4658	27,160

Figure 4-1. Differences between a plant developing from well-nourished seed (at right) and that from poorly nourished seed (at left), when both are grown in similar low-fertility soils that did not receive fertilizer applications, as indicated by the sign "SIN" (Spanish for "without").

Hence, the photograph demonstrates that the use of stakes having good nutritional status will likely ensure that the variety's true yield potential is reached. Such a low-cost technological component would enable farmers to increase cassava production, together with adequate soil conservation.

What was described above is highly significant to seed production programs, particularly those directed towards regions with soils classified as acid and of low fertility, namely Oxisols and Ultisols. Such soils are found in the current or potential cassava-growing areas of Bolivia, Brazil, Colombia, and Venezuela.

Seed age. One cassava stake normally forms one to four shoots, which form the primary stems. The appearance of flowers produces branching in these primary stems, with the consequent formation of secondary, tertiary, and other stems, according to that variety's flowering and branching cycle. Consequently, the plant's primary stems represent the oldest tissue, while the secondary, tertiary, and more recent stems represent the youngest tissues.

Increasing tissue age results in increased thickness and lignification of the xylem, together with a proportional reduction of medullary tissue. When this process is sufficiently advanced, the stems are considered mature enough and suitable as seed, as the thickness and lignification provide them with sufficient nutrient reserves and resistance to dehydration.

Indeed, any section of a stem from basal parts to the apical meristem can give rise to new plants. However, commercially, herbaceous parts are discarded because of their low dry matter content and high probability of becoming dehydrated in the field after planting. The rest of the stem, however, can be used as seed. Nevertheless, a direct relationship apparently exists between age of seed and the performance of the new plant. Most researchers believe that stakes taken from primary stems or basal parts give rise to plants with higher yields than those developed from stakes taken from apical parts.

This difference in yields may be attributed to differences in the stakes' nutrient reserves, as their chemical composition (N, P, K, Ca, and Mg) varies between different sections of the stem. Increases in yield, the older the stakes, may result from a higher concentration of nutrients, mainly N and K, and a higher dry matter content (Table 4-5) (Enyi 1970). Hence, the highest total quantities of N, P, K, starch, and fiber accumulates in the oldest parts of the stems.

Seed viability. Stake viability is directly related to its moisture content. In a 10 to 12-month-old plant, stems have about 70% moisture. The stakes they produce will have a viability of almost 100%. Once the stakes are cut, dehydration starts, and accelerates when they are stored in a place with high temperatures and low relative humidity. The effect can be so severe that a reduction of 20% in moisture content can reduce sprouting of the seed by 50% (Table 4-6).

A visual indicator for estimating moisture content and, thus, stake viability is the speed at which latex, a characteristic of euphorbias, flows from a recently cut stake. If it flows immediately, then the stake has sufficient moisture and, thus, good germination power. As the stake becomes dehydrated, the latex appears more slowly and its quantity is less.

Quality of plant health

In seed production, health problems may arise, induced by pathogens (fungi, bacteria, phytoplasmas, and viruses) and pests (insects and mites). These not only reduce the quantity of stakes that a plant can produce, but also reduce their quality, which is later reflected in low yields. They also pose a risk when introduced into areas free of such problems (Lozano et al. 1986).

Table 4-5. Dry weight of stakes, and root yield in cassava.

Stake section	Dry weight of stakes (g/stake)	Root yield (kg/plant)
1 (basal)	47.2	3.47
2	41.0	2.65
3	36.6	2.35
4	32.6	1.98
5	27.2	1.65
6 (apical)	24.2	1.80

SOURCE: Enyi (1970).

Table 4-6. Influence of moisture loss on the viability of cassava stakes.

Moisture loss (%)	Reduction in shoots (%)
10	10
20	50
60	100

Diseases transmitted by stakes. Cassava can be attacked by several pathogens, either systemic or localized, that are transmitted through planting materials, reducing crop yields by:

- Reducing sprouting in stakes
- Killing stakes after sprouting
- Reducing normal plant vigor
- Reducing the number of bulked roots
- Permanently harboring potential inocula that attack future plantings

Systemic pathogens. These are capable of invading the entire plant. They usually do not produce symptoms in lignified and mature tissues, hindering identification once the diseased material is cut. Symptoms almost always develop in the leaf system, or unlignified young branches, or even in the root system (Lozano and Jayasinghe [1983]). These plants constitute the source of primary inocula in new plantings. The systemic pathogens spread by planting materials include:

Fungi. The most important systemic fungal pathogen of cassava is *Diplodia manihotis,* which produces brown necrotic streaks throughout the affected vascular system. Other less important fungi are *Fusarium solani* and *F. oxysporum*. *Sphaceloma manihoticola*, causal agent of superelongation disease, although not properly systemic, produces a large quantity of spores in epidermal cankers on mature stem tissues. The spores are so tiny that the pathogen is unidentifiable. Their large numbers make them appear systemic (Lozano and Jayasinghe [1983]).

Bacteria. The most important bacterial disease and one of the most serious for the crop is cassava bacterial blight (CBB), caused by *Xanthomonas axonopodis* pv. *manihotis*. The disease can cause economic losses of more than 50%. When cassava stakes are infected with blight, germination losses may be more than 25%. This pathogen is restricted to the xylem tissues of the host's immature stems, as the bacterium cannot degrade the stem's lignified tissues. It is therefore very difficult to detect this bacterium's presence in the lignified stems normally chosen for planting, particularly when they are already cut as seed.

However, the severity of the disease is considerably reduced during dry periods. Hence, during such periods, visually selecting healthy planting materials from an infected crop is sometimes impossible. Its capacity to disseminate through rain, insects, tools, and infested soil means that the pathogen can disperse relatively quickly from a few diseased plants (Lozano [1983]).

Phytoplasmas. Witches' broom, caused by a phytoplasma, has been found in Brazil, Mexico, the Peruvian Amazon, and Venezuela. Although its incidence is not significant, the disease reduces yield in infected plants by as much as 80% (Lozano [1983]).

Viruses. Leaf symptoms may occur in plants infected by viruses such as the African and American common mosaics, leaf vein mosaic, and the Caribbean mosaic. They can also cause symptoms in roots, such as frogskin disease. Viroses also exist that, in some cultivars (carriers), do not show apparent visible symptoms but gradually and slightly reduce the plants' normal vigor and production.

Although healthy plants can be produced, testing for their health is advisable, using laboratory techniques such as serology, electronmicroscopy, and hybridization of nucleic acids (Lozano and Jayasinghe [1983]).

Localized pathogens. These pathogens' invasive capacity is not systemic, that is, they invade only limited areas or stem parts. Their presence is characterized by the formation of cankers, galls, and necrotic areas.

This category of pathogens includes *Erwinia carotovora* pv. *carotovora* (bacterial stem rot), which causes degradation of the pith, which becomes yellowish, reddish, or dark brown; *Agrobacterium tumefaciens* (bacterial stem gall), which produces galls in stem nodes; and *Colletotrichum* spp. (anthracnose) and *Phoma* spp. (concentric-ring leaf spot), which cause epidermal and cortical lesions (Lozano and Jayasinghe [1983]). Localized pathogens enter the stem through wounds caused by mechanical means or insects, directly through stomata, or through petiole invasion. Attack from these pathogens usually decreases as the stem lignifies.

That part of the stem that is healthy can be used as planting material. Consequently, when selecting stakes, care should be taken to discard those parts of the stem affected by pathogens (CIAT 1987b). As a guideline, cassava planting materials should be collected from plantings that are apparently free of systemic pathogens. This apparent health must be confirmed through crop inspections during climatic conditions that favor disease development. For example, from the middle until the end of the rainy season, symptoms of superelongation disease, bacterial blight, and mosaics caused by viruses are more noticeable than during dry periods. The most vigorous and healthiest plants in the crop should be identified before collection (Lozano and Jayasinghe [1983]).

Pests transmitted through stakes. Damage caused by insects attacking cassava planting materials includes reduced germination and plant establishment. Dissemination of insect and mite eggs is more probable than that of larvae and adults, as the former travel on the stem epidermis. Such a location makes eggs relatively easy to detect. However, stemborers, scale insects, and mite eggs are easily disseminated through planting materials (Lozano [1983]).

The risk of disseminating mites to other regions is higher when a severe outbreak occurs in one area and seed is transported to another. The mite *Mononychellus tanajoa* was possibly introduced into Africa this way. Scale insects and mealybugs also spread this way. According to the degree of infestation, these insects may reduce germination of stakes by 70%. The eggs and larvae of other insects, such as thrips, can also be found in buds on stems and branches, and are spread as infected stakes are transported (CIAT 1987b).

Mites and insects that adhere to stems.

Mites are probably the most serious pest of cassava. They frequently attack the crop during the dry season, and cause severe damage in most cassava-producing regions of the world. The principal species are *M. tanajoa* (green mite), *Tetranychus urticae* (red spider mite), and *Oligonychus peruvianus*. Mite infestations at the Centro Internacional de Agricultura Tropical (CIAT) include these three species and, experimentally, losses in yield have ranged from 20% to 53%, depending on the duration of attack (Bellotti et al. [1983]).

Scale insects. Several species of scale insects have been identified as attacking cassava stems in almost all cassava-producing regions of the world. The most important are white scale *Aonidomytilus albus*, which is spread worldwide, probably through planting materials; and Caribbean black scale *Saissetia miranda*. The most severe damage that these insects cause appear to be loss of planting materials through bud death. CIAT studies of stakes heavily infected with *A. albus* showed a 50% to 60% loss in germination (Bellotti and Schoonhoven 1978).

Thrips attack plants at their growing points, reducing yield. For eight susceptible cassava varieties in Colombia, average yield loss was 17.27% (Bellotti and Schoonhoven 1978). The production of planting materials can be reduced by as much as 57% (Lozano et al. 1986). The most important species is *Frankliniella williamsi*.

Insects found within stems.

Fruit fly. Two species of fruit fly attack cassava in America: *Anastrepha pickeli* and *A. manihoti*. The larvae of this fly tunnels within the stems of cassava plants, forming brown-colored galleries in the pith area. A bacterial pathogen (*Erwinia carotovora* pv. *carotovora*) is frequently found in association with fruit fly larvae, causing severe stem rot. This secondary rot can reduce germination of stakes by as much as 16%, causing reduced yields and loss of planting materials. Yield of plants from damaged stakes are about 17% lower than that of plants from healthy materials (Bellotti and Schoonhoven 1978).

Stemborers. Planting materials can also suffer from stemborers, mainly larvae of Coleopteras such as *Coleosternus* spp. and *Lagochirus* spp., and of lepidopterans such as *Chilomima* sp. that usually cause sporadic or localized damage. Infestations may occur in growing plants, but also during storage of stems, requiring careful inspection of planting materials before their use (Bellotti et al. [1983]).

Termites. Termites attack cassava, mainly in the lowland tropics. They have been reported as a pest in various regions of the world, but mainly in Africa. In Colombia, *Coptotermes niger* feeds on planting materials; roots; or growing plants with parts that have dried up or become necrotic because of unfavorable climatic conditions, pathogens, or poor quality seed.

In studies conducted at CIAT, termites destroyed almost 50% of stored planting materials, and losses in germination ranged between 25% and 30% (Bellotti and Schoonhoven 1978). On the Colombian Caribbean coast, termites attack stored stems, causing severe loss of planting materials, and also reducing the germination and establishment rates of stakes when these are planted with the insect inside. Stakes free of termites may also be attacked if a dry period comes after planting.

Stake Production

A. Field phase

The principal objective of a multiplication plot is to obtain the largest possible number of stakes per plant. Efforts must be made to avoid those factors or circumstances that will reduce root yield of the plants directly affected; or that will reduce the capacity of planting materials, derived from those plants, to express the yield potential of the genotypes planted.

The agronomic management of multiplication plots implies the use of all farming practices recommended for obtaining high root yields, carrying them out at minimal cost. Hence, with sales of roots, sufficient income would be acquired to cover production costs of both roots and stakes. Usually, a profit margin remains that is significant for commercial seed producers and even for basic seed producers. To achieve these objectives, the management of seed multiplication plots should incorporate the following recommendations:

Selection of land. The land for seed production should, ideally, be isolated from commercial cassava crops to prevent risk of contamination from insects and, especially, pathogens.

Land where cassava has been planted for 3 consecutive years or more should not be used, as, over the long run, with continuous planting, the land's capacity to produce both planting materials and roots becomes notably reduced, regardless of soil fertility. This is probably due to increased numbers of soil pathogens and to reduced numbers of beneficial microorganisms such as mycorrhizae.

For such land, the first recommended step is to reduce the potential inocula load of pathogens present in the soil. Continuous cassava cropping can be interrupted by planting, for at least 2 years, crops such as sorghum and maize, whose pathogens are not usually pathogenic to cassava. Where forest crops are felled, these gramineous crops should be planted for 1 or 2 years before planting cassava.

Soil salinity and stake quality. Traditionally, a normal soil is considered as having an electrical conductivity of less than 4 dS/m and a sodium saturation of less than 15%. However, cassava is affected by much smaller levels. Howeler (1981) points out that the critical levels for this crop are a conductivity of 0.7 dS/m and a sodium saturation of 2.5%.

The performance of planting materials was studied in plots with moderate levels of salinity. Cultivar HCM-1 was planted in two types of soil: one with a conductivity of 0.5 dS/m and sodium saturation of 1.3%, and the other with a conductivity of 0.8 dS/m and saturation of 3.0%. The plants in the plots with the higher level of sodium not only had smaller growth (thus reducing the quantity of stakes produced—see Table 4-7), but also, when they were used as seed source for a new planting in a normal soil, gave rise to plants with a smaller production of both stakes and roots (Table 4-7).

Other desirable characteristics of land destined for seed production are:

1. That they be owned: when land is rented and the completed contract is not extended, there is a risk of having to dig up the cassava in advance and store the stems. Hence, planting materials are lost in proportional to storage time.

2. That they are distant from people and roads to prevent theft of cassava by neighbors and transients, with consequent loss of seed.

3. That they are well fenced to prevent damage from livestock, especially cattle and pigs.

Soil fertility. The seed plot should preferably be located in a soil of good natural fertility. Otherwise, a complete fertilizer application should be carried out, as soil fertility decisively influences both the amount and quality of the seed produced. In poor soils, the production of planting materials is low, but increases in both number and weight of stakes can be obtained by applying fertilizers (Table 4-8).

The study on seed nutrient contents mentioned above found that, compared with seed having low levels, seed with high contents planted in a soil with no fertilizer applications could result in 53% more stems suitable for use as planting materials. However, when such seed was planted on a soil that received fertilizer, the percentage was 100% (Table 4-9).

Planting density. The cassava multiplication rate can be increased notably by increasing planting density in seed plots. According to Villamayor Jr (1983), when the number of plants per hectare is increased beyond the density normally used in commercial crops, each plant tends to maintain a stable number of primary stems. This permits a higher production of stakes, even though they have a slightly smaller weight, as the

Table 4-8. Influence of fertilizer applications (fertil.) on cassava stake production.

Cultivar	No. of stakes/ plant		Average stake weight (g)	
	No fertil.	Fertil.	No fertil.	Fertil.
M Mex 59	6.3	9.4	59	68
M Ven 218	8.9	11.3	67	70
M Col 63	4.9	6.7	46	54
M Col 22	5.2	6.2	58	60
M Col 1684	4.2	8.4	53	63
CM 91-3	4.9	4.4	46	63

SOURCE: Leihner (1986).

Table 4-9. Weight (kg/ha) of stems grown from seed with two levels of nutrient contents, using cassava variety M Col 1684 grown in an acid low-fertility soil.

Nutrient contents	Weight in soil with:		
	Fertilizer	No fertilizer	Difference
High	6222	3095	3127
Low	4487	2017	2470
Difference	1735	1078	

Table 4-7. Characteristics of stakes, and plants derived from those stakes, in two types of soil at the CIAT–Palmira experiment station, using cassava variety HCM-1 at 12 months old.

Characteristic	Performance of:			
	Stakes growing in soil[a]		Plants derived from stakes growing in soil[a]	
	A	B	A	B
Plant height (cm)	340.0	130.0	185.0	182.0
Weight of aerial parts (t/ha)	38.1	7.4	21.6	14.2
Seed produced (stakes/plant)	15.7	2.5		
Root production (t/ha)			35.9	29.1
Weight of seeds (t/ha)	8.7	1.3		
Weight per stake (g)	55.5	51.0		

a. Conductivity is 0.5 dS/m for soil A and 0.8 dS/m for soil B; sodium saturation is 1.3% for soil A and 3.0% for soil B.

SOURCE: López (1990).

stems are slimmer. However, the yield of crops planted with these stakes is not affected.

An increased planting density, however, reduces the average root size. Under the conditions of Valle del Cauca, Colombia, the maximum production of commercial roots (i.e., of a size currently acceptable to the market) is achieved at 5000 plants per hectare in tall branching varieties, and at 10,000 plants per hectare in erect varieties that are either short or tall (CIAT 1975).

Weed control. That weed competition reduces yield is well known, not only for cassava but also for other crops. It is also clear that ineffectual weed control will proportionally affect stake production.

A trial used different levels of weed control over the first 2 months of growth (CIAT 1983). Efficiency of weed control, expressed in terms of different levels of competition between weeds and cassava, was reflected by the weight of aerial plant parts dropping as the percentage of control declined. The number of stakes produced per plant was proportional to the weight of aerial parts.

When weeds were not controlled, the growth of aerial parts was reduced to such low levels that only one in three plants produced a stake of an acceptable size and quality. In contrast, with no competition from weeds, almost six stakes per plant were obtained (Table 4-10). Hence, maintaining good weed control is doubly of interest for optimizing stake and root production.

Weed control is expensive, although costs vary considerably, with direct expenses ranging between 20% and 50%. Costs depend on the class of weeds present, their size at planting, planting density, seed quality, and rain distribution during the crop's first months, among other factors. Under normal conditions, the application of a preemergent herbicide, complemented with one or two passes of manual weeding or applications of postemergent herbicides, should be sufficient to maintain the crop free of weeds throughout its growing period. The labor needed to apply preemergent herbicide, using a back fumigator, is reduced to 1 workday per hectare if planting density is 1 × 1 m, a TK5 fan nozzle is used, a 2-m-wide path per pass is covered, and the herbicidal volume is 150 L/ha.

Table 4-10. Effect of competition with weeds on the production of cassava stakes.

Control system	Weed control (%) at 59 DAP[a]	Stakes/ plant	Fresh weight (t/ha)	
			Branches	Roots
Continuous manual control	100	5.9	18.8	28.4
Preemergent herbicide[b]	62	4.9	16.7	19.2
No weed control	0	0.3	2.6	3.5

a. DAP = days after planting.
b. Diuron + alachlor at 1 kg and 2 L, respectively, per hectare.
SOURCE: CIAT (1983).

For manual weeding, the number of workdays depends on the class of weeds, their height, and the tools used (machete, shovel, or hoe), but it can be budgeted on an average of 15 workdays per hectare for each weeding. We point out that none of the herbicides recommended for cassava, whether preemergent or postemergent (including glyphosate), damage the stakes, whether planted horizontally or vertically, even when applied 8 days after planting.

Intercropping with maize. The practice of incorporating other species in a cassava crop usually reduces the production of both roots and aerial parts in direct proportion to competition from the other crops. It also reduces the average weight of stakes.

At CIAT, in 1989, an on-farm experiment was carried out with five farmers located in different areas over 2 years. To evaluate the influence of maize as an intercrop on the quality of cassava planting materials, stakes were taken from both a monoculture and an intercrop. These stakes were planted in the following season as a monoculture. Neither plant height nor branch or root production was affected by the origin of the planting materials (Table 4-11).

This finding demonstrated that the quality of planting materials, whether obtained from cassava planted in monoculture or associated with maize, was not significantly different. Although the intercrop led to a reduced number of stakes, this cropping system is currently used in many regions throughout the

Table 4-11. Effect of intercropping with maize on cassava stake quality.[†]

Origin of planting material	Plant height (m)	Weight (t/ha)	
		Branches	Roots
Monoculture	1.79 a	8.20 a	17.32 a
Intercrop	1.73 a	8.00 a	16.56 a

†. Values with the same letters in a column are not significantly different.

world and could also be used in the commercial production of cassava seed. Thus, small artisanal businesses could obtain seed from both cassava and maize.

Irrigation. Cassava has a reputation of being a hardy crop, resistant to drought. Indeed, when the dry season begins, the plant reduces its production of new leaves while continually dropping its old leaves. If the dry period becomes accentuated, more leaves fall, decreasing leaf area to a minimum and growth declines to an extent that the plant practically enters a period of latency. When the rains return, the plant uses its carbohydrate reserves to produce leaves again and thus resumes growth (Cock 1989).

Normally, cassava does not have critical periods in which the absence of rains may cause a total harvest loss. However, if drought is so prolonged that plants die—as in the midyear dry periods of western Colombia—some varieties will drastically reduce the production of both roots and planting materials. For example, a 10-week dry period, beginning 12 weeks after planting, when roots begin storing starch, caused variety M Col 22 to reduce root production by almost 30%, and branch and leaf production by almost 50% (Figures 4-2 and 4-3).

As a result, although cassava has traditionally been cultivated exclusively with rainwater, its full yield potential can only be reached if water management is included as a cultural practice. If irrigation is provided during dry periods, at a rate of 20 mm per week, root yields will increase by almost 60% (Mohankumar et al. 1984).

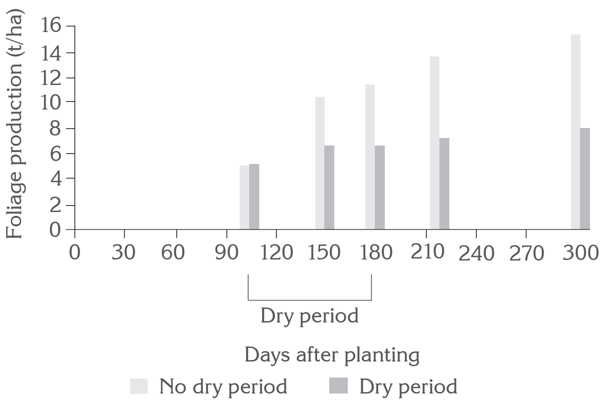

Figure 4-2. Effect of a dry period on the production of branches and leaves in cassava clone M Col 22 (adapted from Connor et al. 1981).

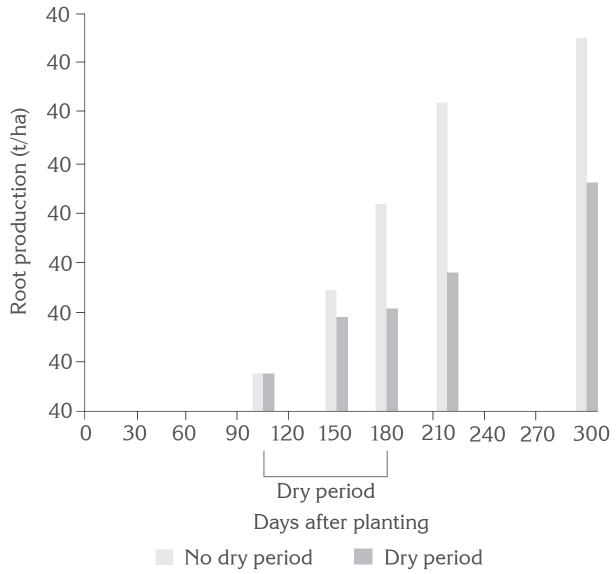

Figure 4-3. Effect of a dry period on root production in cassava clone M Col 22 (adapted from Connor et al. 1981).

B. Harvest and postharvest phases

Maturation and harvest. The quantity of seed that can be produced at any given age is determined by genotype, climatic conditions (higher temperatures lead to faster growth), soil fertility, weed control, and cropping system (competition from an intercrop delays the growth of aerial parts). However, regardless of circumstances, the number of usable stakes per plant is very low, increasing only as tissues lignify. Under CIAT conditions (Palmira), the number of stakes per plant in some varieties increases gradually, even after 12 months, while in other varieties, after this age, the number begins to decline as excessive lignification covers buds, or the buds sprout (Table 4-12).

Storage. If a seed production plot completes 12 months of growth before harvest, the following could be obtained:

- Fresh seed for the establishment of a new planting
- Maximum stake production
- Maximum root production

Table 4-12. Seed production (stakes/plant) in cassava, according to the age of the mother plant. Planting density is 1 × 1 m.

Cultivar	Months after planting					
	7	8	9	10	11	12
M Col 1468	4.6	6.5	10.8	11.1	11.5	11.0
M Col 1505	5.9	6.1	6.5	7.1	8.6	10.5
HMC-1	5.3	6.7	7.0	8.5	11.7	12.0

Given that maximizing income through sales of roots is recommended, then, to fix a reasonable price for stakes, the seed producer must decide on the best time to harvest. Early harvesting to take advantage of high root prices, whether varieties are early or late, tends to result in low stake numbers per plant. That is, the earlier the harvesting, the smaller the possible number of stakes—and the more immature the stems and the longer the storage needed.

The problems that occur during storage are dehydration, loss of reserves by sprouting, and attack by pests and pathogens. These problems gradually reduce the planting materials available, the longer the storage is. Currently, no technology is available that solves these problems. However, some principles help reduce their negative effects:

- The branches to be stored should be cut to lengths that are as long as possible. The longer the storage period, the larger the portions that must be eliminated, because the extremes inevitably dry up, especially apical parts. The usable central parts thus become shorter. Hence, the more cuts a branch is stored as, the smaller the central parts, representing the entire branch, will be.
- Storing branches vertically is preferable to horizontal storage, as fewer planting materials will be lost and reductions in weight of usable stakes will be smaller (Table 4-13).
- Chemical treatment with an insecticide-fungicide solution will, when storage conditions are unfavorable, help prevent deterioration of the seed (Table 4-14).
- In some varieties, plant age at storage affects the proportion of usable planting materials (Table 4-15).
- Branches should be taken to the storage place as soon as the crop is harvested, as exposure to the sun in the field reduces the seed's capacity for storage (Table 4-16).

Table 4-13. Condition of cassava planting materials after 103 days of storage, North Coast Region, Colombia, using variety M Col 2215.

Factor	Before storage	After storage	
		Vertical	Horizontal
Weight/branch (g)	340	307	240
Stakes/branch (no.)	3.4	2.7	2.4
Weight/stake (g)	76	63	54

Storage of stems is facilitated when late-branching varieties are used. The long primary stems (about 1 m) are easy to manage (Figure 4-4), with good yields when cut and facilitating the use of motorized saws. They also store well. Figure 4-5 illustrates vertical storage in a semi-shaded place. The stems are supported upright by a horizontal bar set at 60 cm from the ground.

Before storage, soil should be scuffed and dampened so that each stem makes good contact with the soil. If, in the region, wood-eating insects (e.g., termites) proliferate, an insecticide should be sprinkled over the soil.

About 1 month after storage begins, apical buds start to appear in all the stems, with foliage resuming growth. The stored stems shown in the center of Figure 4-5 have just begun budding, whereas the stored branches at the right have been stored for a longer period and are presenting dense foliage.

Table 4-14. Effect of chemical treatment on stored cassava planting materials, using variety M Col 1684.

Days of storage	Seed loss (%)	
	No treatment	With treatment
30	34	23
60	52	50
90	63	55

SOURCE: Luna (1984).

Table 4-15. Influence of plant age on stored cassava branches over 4 months.

Variety	Age at storage (months)	Seed loss (%)
M Col 22	8	31
	18	8
M Mex 11	8	4
	18	2

Table 4-16. Effect of direct solar exposure on cassava planting materials, using variety M Col 1505, and stored over 2 months.

Time of storage	Seed loss (%)
Immediately after harvest	10
8 days after harvest	23

Figure 4-4. Late-branching variety, with long primary stems that facilitate storage.

Figure 4-5. Storing cassava stems.

Should a prolonged dry season occur, this foliage becomes dry and appears burned. This means that the stems must be irrigated every week. However, if the season becomes rainy, a warm microclimate of high relative humidity is created, favoring the development of diseases. Hence, wide-spectrum fungicides should be applied.

On terminating storage and cutting up the stems, apical extremes that have sprouted should be discarded. This is why stems should be stored vertically because, this way, only two or three apical buds sprout. In contrast, when stems are left in a slanting position, all the buds tend to sprout. Thus, the entire branch is lost.

An environment suitable for storing branches is one where the planting itself will be carried out, especially for late-branching varieties. In addition to the above-mentioned advantages, this type of branching enables workers to move within the crop without becoming entangled in the branches. Hence, part of the crop is left without harvesting, and the branches to be stored are taken into the crop's interior and arranged vertically, as previously described. In this case, the stored stems are supported by a cassava branch held horizontally by tying to plants that are still standing (Figures 4-6 and 4-7). Growing the crop on ridges will facilitate any eventual irrigation for the stored stems.

Selecting planting materials. Because of its long growing cycle, cassava is continually subject to pressure from biotic (pests and diseases) and abiotic (climate and soil) factors. The quality of planting materials is thus reduced. Traditional varieties have been under this type of pressure over considerable

Figure 4-6. Storing stems within the crop.

Figure 4-7. Detail of the way in which cassava stems should be supported.

periods and its effect leads to a cumulative decrease in the quality of planting materials after many cycles of vegetative propagation (Lozano et al. 1984). The effect of poor quality seed on production is unpredictable but, sometimes, yields are reduced by much more than 50% (Lozano 1987).

Hence, a positive selection of plants destined as planting materials for seed plots is recommended. According to CIAT (1987a), yields, especially of traditional varieties, may be increased only by using planting materials taken from vigorous and apparently disease-free plants. This selection system is less effective for new clones than for traditional ones (Table 4-17).

However, apparently healthy plants can be infected by latent viruses that do not show visible symptoms or by harmful endophytic fungi (Lozano and Laberry 1993). They may also have suffered disorders that are too recent to show symptoms. Hence, in addition to their external appearance, plants that serve as sources of stakes are also selected for their high root production, on the basis of the simple principle that plants with the highest yields should also be the healthiest (Lozano 1987). This type of selection has proven to be highly successful, and its advantage is more effective for clones that are susceptible to several production constraints (Table 4-18) (CIAT 1987a).

Table 4-17. Yield (t/ha) of two traditional cassava clones and two new hybrids, using visually selected stakes from the healthiest plants in a crop.

Clone	Visual selection	
	No selection	Selection
Traditional		
M Col 22	18	24
M Col 1438	9	13
New		
CM 523-7	26	27
CM 342-170	21	23

SOURCE: CIAT (1987a).

Processing the seed.

Cut. To cut the stakes, two aspects should be taken into account: length and age or stake's location in the plant. Stake length is important in terms of the number of nodes and the amount of nutrient reserves and moisture they contain. Node number is closely related to variety, and age of both plant and stake. A mature plant has a larger number of nodes than a young plant. In addition, in mature plants, nodes in basal parts are shorter than in apical parts.

Theoretically, obtaining a new plant would require planting only a piece of stem that is barely large enough to contain a node. However, the possibility of such a short stake germinating and rooting under field conditions is remote because, to prevent dehydration, the soil must be continually kept moist for the first weeks after planting. In contrast, long stakes of 60 cm or more are highly likely to root and germinate. However, their bulk presents difficulties for handling and transport. Moreover, each mother plant would yield a smaller number of stakes.

The influence that stake length has on yield has been a topic of research in several countries. Results show trends towards slightly increased yields with long stakes, probably because they have a higher nutritional content, which permits a better starting growth in plants and, thus, better bulking in roots. Most researchers believe that 20-cm stakes with at least five nodes would have sufficient nutrient reserves and an adequate number of buds to ensure good establishment and crop yield.

Table 4-18. Yield (t/ha) of three cassava varieties when seed was selected according to yield of mother plants.

Variety	Yield of mother plants		Increase (%)
	Low	High	
M Col 113	17.1	18.7	6
M Col 22	33.9	38.9	17
M Col 1438	18.6	29.5	58

Stakes with fewer than five nodes have fewer bulked roots per plant and a smaller average weight than those from stakes with five or more nodes (Table 4-19) (Gurnah 1974).

Chemical treatment. The stakes, once planted, may be attacked by insects and soil pathogens that usually affect buds first. They may also penetrate fine roots, bases of shoots, extremes of the stakes, and wounds caused by handling.

Practices that help reduce risk of damage caused by disease pathogens and insects include selecting planting materials, avoiding those introduced from regions where diseases or insects, transmissible by stakes, are present; and applying chemical treatment. The last acts in several ways:

- *Eradicates pathogens that are present.* Use of planting materials infected by *Sphaceloma manihoticola* (superelongation disease) or *Diplodia manihotis* (dry rot) is not recommended. However, where this is absolutely necessary, those plants least affected by superelongation should be chosen and treated with captafol or copper-based products. For dry rot, stakes should be treated with benomyl, which is a systemic fungicide. It is also useful in the curative treatment of stakes affected by *Fusarium* spp. and *Scytalidium* spp. (Lozano 1991).

- *Inactivates a present pathogen*. When a planting material is not known to be free of bacterial blight, it should be treated with copper-based fungicides. The copper in these fungicides exerts a bacteriostatic effect that inhibits the proliferation of the bacterium (Lozano 1991).

Table 4-19. Effect of number of nodes in cassava stakes on yield and its components.

Number of nodes	Yield (t/ha)	Roots/ plant	Average root weight (kg)
2	5.10	3.45	0.12
3	6.10	3.80	0.14
4	11.26	4.84	0.19
5	13.71	5.49	0.20
6	13.73	5.29	0.21
7	14.17	5.31	0.21
8	14.26	5.27	0.22

- *Eliminates mites and adhering insects*. Eggs and adults of mites and insects such as scales, mealybugs (*Phenacoccus* sp.), and thrips can be eliminated by immersing the stakes in a solution of an insecticide such as malathion (CIAT 1987b).

- *Protects stakes from pathogens and insects in the planting site*. Table 4-20 illustrates different treatments that can be given to stakes, including two that do not require chemical products.

Differences in production attributed to selection and stake treatment are more noticeable when susceptible or infected clones are used than when resistant clones are used. However, with the selection and treatment of stakes, beneficial effects sometimes cannot be seen, as in the following examples:

- When selecting and treating stems from vigorous plants growing in a region with no or only mild pathological or entomological problems.

- When an incorrect product is used for treatment against a pathogen infecting the stake or infesting the soil where planting will take place.

C. Production costs

Production costs for a crop designed to produce planting materials are much the same as those incurred to produce only roots. Additional protection needs to be given to aerial parts to ensure that the seed is free of pests and pathogens. Disease control is preventive, achieved almost exclusively through the use of healthy seed and treatment with fungicides. In the field, additional costs include roguing contaminated plants and possibly applying insecticides to control insect vectors.

Pest control, in contrast, requires habitual use of inputs, whether biological or chemical. The acquisition of seed free of adults or eggs of insects and mites implies the use of about an extra 10% more of inputs. However, this category represents a very low (<5%) proportion of production costs, so that to establish adult cassava plants destined for seed production, costs would be only slightly more than that of root production.

Table 4-20. Treatment of cassava stakes before planting.

Problem	Product or method	Dosage
Soil pathogens	Derosal + Orthocide®	6 cc + 6 g/L of water[a]
Root rots (*Phytophthora* spp.)	Ridomil® + Orthocide®	3 g/L + 3 g/L[b]
Bacterial blight (*Xanthomonas campestris*)	Kocide® (a bacteriostatic copper fungicide)	3 g/L[a]
Dry rot (*Diplodia manihotis*)	Benlate® + Orthocide®	3 g/L + 3 g/L[a]
Superelongation disease (*Sphaceloma manihoticola*)	Difolatan®	6 g/L[c]
Insects and mites	Malathion (or Sistemin®)	3 cc/L (3 cc/L)[c]
Bacterial blight Root rots Insects and mites	Thermotherapy: immersion of stakes in water at 49 °C for 49 min[d]	
Pathogens of the vascular system (*Fusarium* spp., *Diplodia manihotis*, and *Phytophthora* spp.)	Immersion in suspension of *Trichoderma* (1 kg/bucket) for 10 min[d]	

a. CIAT (1987a).
b. Álvarez et al. (1998).
c. Lozano (1991).
d. Álvarez (pers. comm.).

If production costs of seed plants are defrayed by selling the roots, seed production costs would be then represented in postharvest activities (Table 4-21), with the costs being smaller if the materials are cut and packed immediately after harvest, and higher if they must be stored. In the latter case, the longer the storage, the higher the cost per stake, as increased stake deterioration leads to a higher proportion of waste.

Although, in the field, the best plants can produce up to 12 stakes at 12 months (2.3 branches per plant and 5 to 6 stakes per branch), in practice, 1 hectare planted at 1 × 1 m does not yield 120,000 stakes for the following reasons:

1. Most crops usually have some less developed plants that have one or more branches that do not meet the conditions for use as seed.

2. Waiting until plants are 12 months old before harvesting is neither practical nor profitable. Harvesting when plants are about 10 months old will give time to complete the harvest and prepare the land for a new planting. Commercially, 17,000 branches, that is, about 80,000 stakes, would be obtained from 1 ha (Table 4-22).

Collecting stems. If workers do not have to travel far, then, in 14 workdays, they can gather from 1 ha about 16,000 stems as suitable seed.

Cutting stems. Once having gathered the stems, these are cut into stakes 20 cm long. The number of workdays varies with the method used, such as:

- A worker, sustaining a stem in one hand and cutting it with a machete in the other would obtain 3000 soft-stem stakes in 1 workday.

- A worker, using a machete, but supporting the stem on a log, would obtain up to 8000 stakes per day.

- An operator, using a circular saw activated by a 3-hp motor, can cut between 15,000 and 18,000 stakes per day, depending on the variety. Those varieties that do not branch or branch late and have long stems yield more stakes.

Packaging. Consistently packing the same number of stakes in each sack is advisable, as this measure helps control the number of cut stakes (total and per workday), the number of stakes transported, and the number of stakes planted (total and per workday).

The way stakes are packed depends on the distance from the planting site. Thus, seed traveling a short distance can be packed without taking too many precautions, but seed being transported to distant sites should be packed in an orderly way, as illustrated in Figure 4-8. This method allows placing several bundles

Table 4-21. Estimate of direct production costs (in Colombian pesos) of cassava seed per hectare.

Item	Unit	Quantity	Unit cost	Total value
Additional costs during cropping				
Insecticides	Liter	1.5	24,000	36,000
Application	Workday	1.5	10,000	15,000
Subtotal				**$51,000**
Postharvest costs				
1. Collection of 16,000 branches				
Labor	Workday	14	10,000	140,000
Subtotal				**$140,000**
2. Treatment and storage				
Labor	Workday	7	10,000	70,000
Benlate®	Kilogram	0.5	86,000	43,000
Orthocide®	Kilogram	0.5	14,000	7,000
Sistemin®	Liter	0.5	24,000	12,000
Subtotal				**$132,000**
3. Conditioning				
Cut 80,000 stakes	Workday	16	10,000	160,000
Treatment	Workday	4	10,000	40,000
Benlate®	Kilogram	1	86,000	86,000
Orthocide®	Kilogram	1	14,000	14,000
Sistemin®	Liter	1	24,000	24,000
Zinc sulfate	Kilogram	6.5	2,000	13,000
Polypropylene sacks	Sack	160	500	80,000
Subtotal				**$417,000**
Total 1: direct costs, including storage				$740,000
Cost per stake				9.25
Total 2: direct costs, no storage				$608,000
Cost per stake				7.60

Table 4-22. Production of cassava stakes in a commercial plot.

Variety	Branches per plant	Number of stakes per:	
		Branch	Hectare
HMC-1	1.54	4.5	69,300
M Col 1468	1.47	4.5	66,100
M Col 1505	1.78	5.0	89,000
M Col 2215	1.60	4.5	72,000
CM 523-7	1.60	4.5	72,000
M Ven 77	1.61	5.5	88,500

of seed, one on top of the other, without causing physical damage to the stakes during loading, transport, and unloading. For 1 workday, about 20,000 stakes can be casually packed, and 10,000 in an orderly fashion.

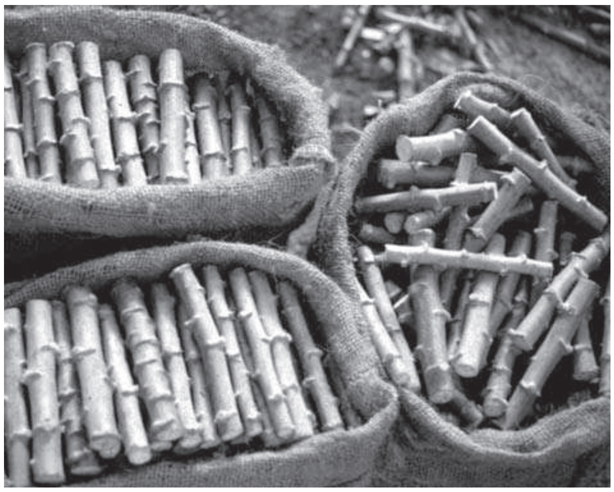

Figure 4-8. Cassava stakes should be packed in an orderly way, as seen in the sacks to the left.

Treating the stakes. The material with which the sacks are made influences the final cost of the stakes because of the cost of the sack itself on the one hand, and, on the other, the quantity of an aqueous solution of insecticides and fungicides (Table 4-22) used to treat the stakes. Although highly suitable for packing stakes, sisal sacks are the least recommendable as they cost five times as much, and absorb almost 10 times more solution than polypropylene sacks. Thus, 10,000 cassava stakes, placed in sisal sacks that are then soaked in solution, require 35 L of solution for adequate treatment. Only 10 L of these actually treat the stakes, with the other 25 L having soaked into the sacks themselves at a rate of 1 L per sack. In contrast, 10,000 stakes in polypropylene sacks need less than 15 L for adequate treatment.

Seed-Supply Systems

Improved seeds are the biological input through which new biogenetic technologies are incorporated into production systems. Consequently, scarcity can seriously constrain the dissemination and use of new varieties. In contrast, availability where and when seed is needed can decisively influence the adoption of technologies and agricultural development.

The development of organized seed-supply systems where crops have unstable and atomized markets is an under-researched field and almost non-existent for crops such as cassava. At best, some research on biological technologies is conducted on seed production and conservation. However, little attention has been given to the development of those essential functions that (1) enable the implementation of an organized system and (2) accelerate the flow of genetic technologies from research to widespread use.

Compounding this situation are the facts that cassava is mostly grown by farmers of few resources, the crop has a year-long growing period, and its multiplication rate is very low at 5–10 stakes per planted stake. The supply system is predominantly traditional, that is, farmers save their seed, having no tradition of buying and selling seed. The seed's bulkiness restricts its movement between regions and communities.

The appearance of improved varieties and the crop's incorporation into new industrial markets constitute positive factors that will help generate interest for improved seed. However, given the characteristics of the crop and its production systems, the organization and production technology of seed supply systems clearly must be adjusted to ensure operation under the crop's real conditions. In particular, cassava should not have imposed on it the formal requirements that exist for other crops with long histories of seed development.

Cassava seed production clearly does not attract large amounts of capital as does hybrid maize or rice. This means that thought must be given to creating subsidized governmental programs to produce and distribute seed, or to developing sustainable systems for the circumstances of the cassava farmer. Special attention must be paid to the farmer's socioeconomic status, the biological nature of the crop and its seed, and the limited availability of human, physical, and institutional resources in the targeted regions.

Importance and characteristics

Establishing a supply system of good quality stakes is important because it will:

- Increase the crop's productivity
- Reduce pest and disease dissemination
- Increase the genotypes' life cycle
- Permit more efficient use of agricultural inputs

Furthermore, if farmers have good quality seed, research projects in different fields (e.g., improvement, entomology, and pathology) will have an improved chance of producing the desired technological and economic impact.

Overall, a seed program will determine the possibility of guaranteeing supply in a region by establishing technical procedures and an organization that favors effective technology transfer with positive effects on cassava production. The following characteristics are desirable in a seed program:

- Ability to produce significant quantities of seed that will permit rapid expansion of the cultivated area or of new varieties.

- Possession of an efficient quality control mechanism.

- Production of seed at a quality that is at least equivalent to the best available source.

- Ability to sell seed at acceptable prices for users.

- Production of seed through a self-sustaining organizational scheme.

- Possession of efficient mechanisms to access new varieties, technical assistance, and training, among others.

Colombian case study

To produce high quality cassava stakes that would meet the category of certified, already established seed companies should preferably be in charge. These are well organized to distribute, have quality control systems, and can offer guarantees to produce high quality seed. In the absence of such companies, this work could be commissioned to progressive farmers who have experience in seed production.

Hence, a document was prepared, which established the minimum requirements that cassava stakes of different categories (basic, certified, and selected) should have. Production of this planting material was started. However, the scheme did not operate satisfactorily because:

a. The price of cassava roots is not stable over time. Root prices depend on the area planted. Larger or smaller areas lead to higher or lower supply, thus changing the price. When the price is high and farmers see an increased profitability of the crop, the demand for stakes increases and farmers are more willing to pay for them. But when the price for roots is low, demand for seed is not so high, thus discouraging farmers who may even opt to abandon the activity.

b. The farmer who purchases cassava stakes for the first time tries to continue to produce his or her own seed where possible. Conventional seed producers prefer crops for which seed hybrids can be produced that farmers cannot multiply. Thus, they maintain their clients "captive".

c. The production of cassava planting materials is, for conventional seed producers, a totally foreign activity, as they cannot use their current infrastructure of cleaning, conditioning, drying, storage, and other activities.

d. Seed companies centralize production to supply large areas. This is reasonable for grains but not for cassava stakes, which, because of their great weight and volume, hamper handling and transportation. Furthermore, they cannot be stored over prolonged periods.

A proposed system

Market conditions and the biological nature of this type of seed clearly suggest the need for an alternative production and distribution system. The proposed scheme is conceived as an organized system, in which different participants carry out different but complementary functions and, together, pursue a common objective: to ensure availability of good quality seed at the right time and at a reasonable price. These functions, which should relate to each other as links of a chain, are the generation of new varieties, production of basic seed, production and distribution of commercial seed, and use of that seed by farmers.

Generating varieties. National and international entities of research on plant breeding are responsible for generating varieties. Research includes activities such as trials on adaptation to different agroecosystems, pest and disease resistance, yield, and root quality.

Producing basic seed. This task should be carried out by national entities for research or seed production. Given the adaptation of varieties to specific regions and the bulky and perishable nature of the seed, such production should be regionalized. This stage can be successfully carried out, using a revolving fund with sales of roots and stakes maintaining the fund. The use of rapid propagation would be recommendable only for this stage because of the high costs of producing this type of planting material.

Producing commercial seed. Because a major aspect of seed production is continuity of offer, this activity should be carried out by experienced cassava farmers who grow cassava for the long term. Farmers who habitually produce crops other than cassava do not guarantee continuity of seed supply, as, given the first difficulty such as reduced root price, they will change to another crop.

Long-term cassava farmers have, as their main economic purpose, root production. They would also be able to produce seed, with technical assistance. Thus, in times of limited or no demand for seed, they would ensure their income through sales of roots until the seasons when demand for seed is high, which would then constitute an important additional income.

To avoid the drawbacks of extensive crops in terms of storing and transporting planting materials and the harvesting and marketing of large quantities of roots, production should not concentrate on a few producers to supply large areas. Instead, farmers should be strategically selected for their location in the region to supply small neighboring areas.

In areas with plant health problems and low-fertility soils, seed of traditional and improved varieties can be multiplied, producing high-quality stakes in terms of health and nutritional contents. They will then perform better than the region's usual seed. In those regions free of plant health problems and with acceptable soil fertility, the greatest impact is achieved through new varieties, as the quality of stakes from seed plots would be similar to that the farmers themselves produce.

Rapid propagation. Because cassava's low multiplication rate does not permit quick production of an abundant quantity of stakes from new varieties or from healthy stakes of traditional varieties, a methodology was implemented to help solve this problem. Although several variants have recently been developed, rapid propagation of cassava stakes can be carried out through two basic systems:

a. Shoot induction method. It consists of inducing shoots and their later rooting from stakes carrying two nodes. Adult plants are used, obtaining about 100 stakes from late-branching varieties or about 80 from early branching varieties. The two-noded stakes are planted in propagation chambers to produce shoots in quantities that depend on the variety and type of stake used. Thus, varieties with little vigor soon cease to produce shoots, while others continue producing them even after 1 year.

On the average, a stake with two buds produces eight shoots a year, cutting every 20 days, in alternate form, a shoot from each bud. This means that, from one late-branching adult plant about 800 shoots can be obtained in 1 year. The procedure is as follows:

- High-yielding, healthy, and mature plants of about 10 months old are selected from the field.

- Stakes with two buds are cut, using a saw disinfected with sodium hypochlorite, formol, or alcohol.

- The stakes are chemically treated by immersion for 5 min in a solution of one or more fungicides and including insecticides.

- The stakes are planted in a horizontal position in a substrate composed of sand and soil, placed on a gravel base that provides good drainage. The substrate must be placed into beds that measure 2.3 × 1.2 × 0.2 m, surrounded by a narrow groove into which water is deposited that, on evaporating, maintains high relative humidity.

- A roof of transparent plastic covers the container and groove, being placed in such a way that it forms a propagation chamber. The high temperature and high relative humidity stimulate sprouting in the buds (Figure 4-9).

- When they are 5–10 cm tall, the shoots are cut at 1 cm above the neck, using a sharp blade that has been disinfected with one of the products mentioned above. Each stake of two buds can provide about eight shoots, depending on the variety and vigor of the stake.

- From each shoot, leaves are cut off, leaving only those of the crown to prevent wilting. The little stem is cut exactly below a bud to stimulate rooting. Immediately afterwards, the shoots are placed in a container of cold boiled water to stop latex from escaping (Figure 4-10).

- To encourage rooting, the shoots are passed to bottles containing water, which are then placed in a rooting chamber, comprising a table carrying an aluminum or wooden structure that supports a plastic cover.

Figure 4-9. Humid chamber.

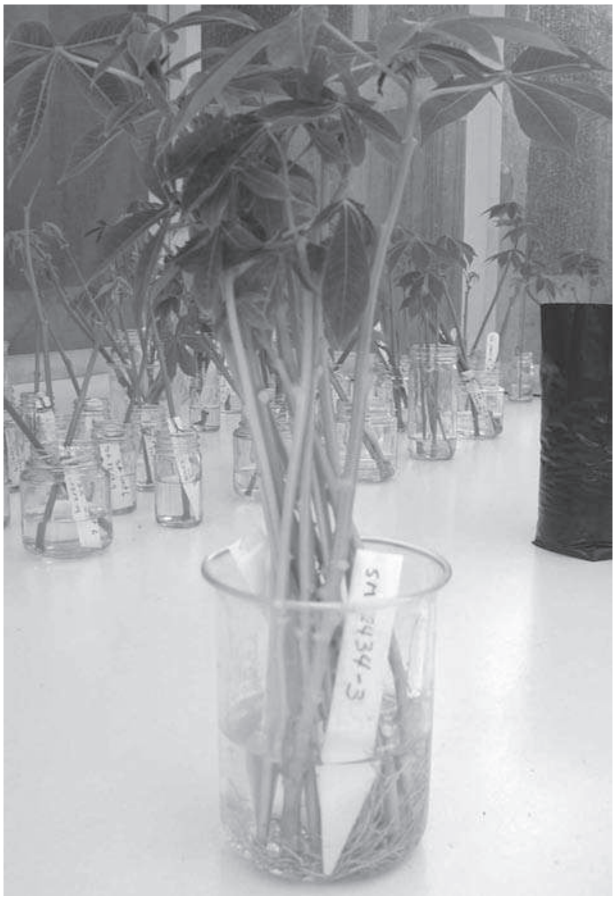

Figure 4-10. Shoots in water for rooting.

Figure 4-11. Plants in plastic bags.

- After 2 or 3 weeks, the shoots are ready for planting, either directly in the field or in plastic bags, where they acclimatize for their later transplanting (Figure 4-11). Acclimatization should preferably be done in a screenhouse with a special mesh that prevents entry of insects such as whiteflies that carry viral diseases (Figure 4-12).

Figure 4-12. Screenhouse with a special mesh to prevent the transmission of viruses by insect vectors.

One of two work modalities can be chosen. The first is *continuous production of planting materials*, where, every 3 weeks—the frequency of the cut—workers take to the field those shoots already acclimatized, in such a way that, by the 18th cut, 1 year has been completed. The shoots of the first cut will have become adult plants. The final total would be 8000 stakes, 20 cm long, from each mother plant.

The second modality is the *acquisition of shoots over 9 weeks*. If we take as an example planting in the first semester (April–May), then the next planting must be done in January, in humid chambers, as, at this time, the mother plants planted in the previous season will be 8 to 9 months old. Planting in the chambers cannot be carried out any earlier because the mother plants will have little planting material.

On planting in January, the first cut is made in February. If cuts are made every 20 days, then a total of four cuts of shoots would be ready for planting before the rainy season ends. Under these conditions, about 300 shoots would be obtained and converted into plants and harvested all at the same time a year later, producing about 3000 commercial stakes.

b. Leaf-and-bud cuttings. Although more equipment is required than for the shoot acquisition system, its potential for propagation is much greater. That is, in 1½ years, about 60,000 stakes can be produced from a single mother plant. It consists of inducing the rooting of a bud that is removed, together with its corresponding leaf. The procedure is as follows:

- Well-developed leaves are cut from selected 3 to 4-month-old plants, using a sharp disinfected blade. The cut must include a small piece of stem. The folioles are also trimmed to less than half their length.
- The cuttings are immediately placed in a container with cold boiled water to prevent latex from escaping.
- They are then taken to the rooting chamber, which consists of a metallic table provided with an aluminum structure that is itself covered with plastic. The chamber has two sides where the plastic can be opened like a curtain to place or remove materials and permit aeration. In the upper part of the structure, very fine sprinklers are placed to continually mist the cuttings for 12 h per day.
- The cuttings are planted in plastic or asbestos trays, containing a substrate of sterilized coarse sand. The trays are placed on the table. The leaves are left at an angle, supported by wire rows placed at 20 cm from the table's surface.
- Between 8 and 15 days, when the roots are about 1 cm long and the petiole has detached, the shoots are ready for planting into plastic bags for acclimatization over 3 weeks in a screenhouse. They are then taken to the field and in 5 months will become new mother plants from which new leaf-and-bud cuttings may be obtained for propagation.

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To save space, the acronym "CIAT" is used instead of "Centro Internaccional de Agricultura tropical".

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