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CASSAVA CULTURAL PRACTICES

Proceedings of a workshop held in Salvador, Bahía, Brazil, 18-21 March 1980

Editors:
Edward J. Weber, Julio Cesar Toro M., and Michael Graham

Organized by:
Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA)
Centro Internacional de Agricultura Tropical (CIAT)
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Contents

Cultural Practices for Large Cassava Plantations

Hélio Correa[1]

The development of the national alcohol program (PROALCOOL) in Brazil opened new perspectives for cassava production expansion with many socioeconomic benefits expected and some production problems to be solved. The frontier known as the Cerrado located in central Brazil was chosen for the site of the first cassava alcohol plant because of its underutilization and good geographic situation. This land represents about 17% of the total area of the country and is characterized by variable rainfall (from 80 to 1500 mm/year). Rainfall is higher between October and March. The soil, classified as an oxisol, has low pH and lacks nutrients, especially P. In general, the topography is excellent for mechanization. The first cassava alcohol plant was installed by PETROBRAS in 1976 in Curvelo, Minas Gerais, with a capacity of 60 000 l/ha. Large cassava plantations were needed to keep the plant operating 330 days a year; specifically enough planting material was needed so that 2000 ha could be cultivated the first year. Thus, the cassava producers brought stakes from all over the central and southern part of the country and in the process brought cassava bacterial blight (CBB) as well. This situation motivated research to find CBB-resistant varieties. Another problem that arose was infestation by pests, especially hornworm and lace bug. Agronomic practices including fertilization, stake selection and treatment, good weed control, and modification of plant densities to 16 000 plants/ha are helping to solve production problems. Heavy machinery is used in soil preparation from felling to disking, and mechanical planters and harvesters increase efficiency. In addition, high dosages of limestone and phosphorus are currently being added to the soil.

The selection of cassava as a raw material for fuel alcohol production brings as an immediate consequence the need to adapt the production of this crop to the requirements of the alcohol industry. Cassava has traditionally been used as a subsistence crop or as raw material for small- to medium-sized industries, and its production technology has remained simple. No investments have been made on inputs or equipment for it, because it has been produced for a poor and unsteady market. However, the development of the Programa Nacional do Alcool (PROALCOOL) (created in November 1974) produced new perspectives for cassava production. Alcohol production using sugarcane, cassava, or any other raw materials will be given incentive by expanding supplies. However, for cassava, the expansion of supply must occur without causing a reduction in any other crop; it must allow a better distribution of socioeconomic benefits; make use of areas with poor soils and erratic rainfall conditions; and expand the agricultural frontier by incorporating new areas into production, especially those soils under Cerrado-type vegetation.

With these constraints in mind, PETROBRAS constructed the first cassava alcohol plant in Curvelo, Minas Gerais. The plan was to use the process developed by the Instituto Nacional de Tecnología (INT). The construction of the plant gave impetus to several new activities, including the development and optimization of an industrial process using cassava for alcohol production; the large-scale production of cassava for the alcohol industry; and the incorporation of the Cerrado into the productive process. The problems that were encountered and the technology that is used by the large-scale producers are dealt with in this paper.

The Cerrado

The Cerrado constitutes a large portion of the area available for agricultural and forestry ac-

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tivities in central Brazil; in Minas Gerais, it is 308 000 km², or 53% of the state's total area. Located near large consuming centres, it is the most feasible area for expansion of the agricultural frontier.

Rainfall in the region varies from 80 to 1500 mm/year and is mostly between October and March, although during this time dry intervals called veranicos can last more than 20 days and be accompanied by high temperatures. The mean annual temperature is 20–24 °C, July and February being the coldest and hottest months, respectively.

According to the Köppen classification, the major climates of Brazil are tropical, humid (Aw) and temperate, rainy (Cwa). Soils are poor, but they are deep and have good texture. They are normally acid (pH 4.0–5.0), high in Al and Mn, and low in Ca, Mg, P, S, and micronutrients. In general, the topography is well suited for mechanization, as the land is slightly undulating.

The vegetation is characteristic of campo, cerrado, and cerradão soils, which are typical of large-scale plantations (often more than 2500 ha).

Soil Preparation

Soil preparation depends on whether or not the area is already under cultivation. For agricultural frontier expansion, it includes felling of trees; firewood utilization; windrowing; elimination of rows and withdrawing or burning of residues; lime application; deep subsoiling; heavy disking; erosion control practices; and final disking.

Felling of Trees

Felling involves overturning all woody material, the most appropriate equipment for the job simultaneously withdraws the roots. This work is better accomplished when it is not preceded by removal of the firewood, which causes detruncation and makes for very tedious work. The most common methods of felling use either a flat blade or chains. A tractor equipped with a flat blade is used in soils where vegetation is moderately dense. The tractor operator must be very careful to avoid removing the superficial layer of soil, which contains a large percentage of the organic matter. The flat blade helps in opening roads as well as other services but cannot be used to cut down big trees because its efficiency is low. Tractors used for this work must have a capacity of 70–140 h.p. Depending on the type of vegetation, one 140-h.p. tractor is able to clear 1 ha, in 1–2 h.

If the firewood is removed before felling, clearing time is increased considerably because the machinery is used for trunk pulling only — a less efficient operation.

The use of chains is very common in areas to be planted with cassava, especially when the areas are extensive. This method is more efficient for large areas than is the one using flat blades. Two or three tractors weighing more than 13 t with at least 140 h.p. are normally used. The chains are attached to the hitches of the tractors, which move in parallel lines at the same speed and carry the chain 30 cm above the ground. The chains weigh between 60 and 120 kg/m, and the length must be 2 or 3 times the width of the work strip — a factor dependent on the power of the tractors. For a distance of 30 m between tractors, the chain must be 60–90 m long. The curve provided by the chain improves the traction, and weights such as rail pieces or iron balls are attached to the chain so that it cannot pass over obstacles. Felling with chains is most efficient when two passes are made in opposite directions. The second pass is called arrepio.

Firewood Utilization

The removal of firewood or timber can be done before or after windrowing. Crosscut saws are used for cutting the trees; the wood pieces are taken to a wood deposit by tractor-pulled trailers. Service roads surrounding the plots make the execution of this type of work easier.

The quantity of wood depends on the previous use of the land. In dense cerrados, firewood yields of 50–60 m²/ha are common and are used for charcoal production.

Initially it had been planned that this material would be used as an energy source for alcohol production, but the presence of different species hindered woodchipping machines and caused undesirable variations in steam production because of the different wood densities.

Once the wood has been collected, windrowing the remaining vegetation begins. The firewood that is obtained helps offset the costs of soil preparation.

Windrowing

The next step is to pile the plant material that is left on the ground. If the material is raked into even rows, the following operations are easier and less costly. Windrows are made by a frontal rake which does not remove the superficial layer of the soil. It is possible to use the flat blade when felling and windrowing are done at the same time, but great care is required. The distance between rows varies, but it must never be more than 60 m, as larger distances mean unnecessary movements of tractors and reduced efficiency.

Elimination of Rows

The elimination of rows is made initially by fire; then the unburned material is scattered by a tractor using a frontal rake. The scattered materials dry quickly and can then be burned. After this, all remaining roots and stems are removed.

Limestone Application

Cerrado soils are generally acid, and a limestone application is necessary. This can be done either before or after the disking operation. Liming is done with special spreaders that are attached to the power takeoff of the tractor. The equipment used for this operation has a capacity of more than 2 t and can lime 1 ha in approximately 30 minutes.

The limestone should be deposited in sites selected for ease in equipment loading, and the efficiency of the operation is improved when a 65-h.p. tractor equipped with a loader is used.

Usually, some yellowing can be observed in plants grown where the limestone was deposited due to pH modifications of the soil and the obstruction of micronutrient absorption.

Deep Subsoiling

Subsoiling is not a common practice in the region. It was adopted specifically to obtain better soil preparation for cassava production. A machine, called a subsoiler, is used; it has 3–4 tines, 60–70 cm long, 70–80 cm apart and is attached to the hydraulic system of a 140–200-h.p. tractor. The tines, which curve forward, are tied to the toolbar. Their function is to break up the soil and at the same time to pull out the roots that remain in the soil after felling.

To pull out the roots, the tractor must raise the subsoiler occasionally. The tractor stops and goes backward to release the roots, and the hydraulic system is activated to start the operation again. Removing the roots, which are usually numerous in cerrado soils, increases the soil's water retention and aeration as well as facilitating disking and planting. After the subsoiling, which generally takes 2 h/ha, it is necessary to collect all the roots that have been brought to the surface.

Heavy Disking

Harrowing produces a soil structure that allows good water retention, provides adequate air capacity and gas exchange, and facilitates future operations. Harrowing also cuts up any plant residues and promotes high yields. Depending on the weight of the harrow, the speed of the tractor, and the disk diameter, the depth varies from 20 to 30 cm.

A heavy plow is better than a harrow, especially in relation to root fragmentation, and soils prepared with heavy plows show a higher sprouting rate.

Generally, 12–20 disks, 28–36 inches (71–92 cm) in diameter, are used for heavy disking; cutout blade disks work best.

The efficiency of the harrow depends on the tractor used. With a Fiat AD 7, harrowing takes 2 h/ha; with a Fiat AD-14, 1.5 h/ha. Four-wheel drive, 300 h.p. tire-type tractors are also used. After disking is completed, any woody materials that have been brought to the surface are collected.

Erosion Control

Heavy disking is followed by measures to control erosion. Terraces are shaped by bulldozers and completed by a carrier-type scraper, which is more efficient. The fields have a mean area of 20 ha. Any conservation practices must be based on soil conditions, topography, and climatic data. Terrace distribution should be such that farmers do not have to drive over the terraces to have access to the field.

Final Disking

Final disking is done a few days before planting, and a 60–90-h.p. tractor with a harrow (32 × 20 inches) is generally used. The disking eliminates any sprouts and conditions soil for mechanized planting. If needed, phosphorus must be applied just before final disking so that it is incorporated in the soil but not as deeply as limestone.

In previously cultivated soils where limestone and, in some cases phosphorus have been applied, heavy disking and plowing are done first (if the appropriate machinery is available), and then, a few days before the cassava is planted, light disking is done.

Fields where the last crop was cassava must be cleared by a mechanical rake before plowing. This mechanical rake or windrower pulls together all plant material, which is later burned. A hectare can be cleaned with this equipment in 40–60 minutes, depending on the amount of plant material. If not cleared from the field, cassava residues produce irregular sprouting, which is a problem for future work.

Stake Selection

Stake selection is one of the most important steps in the establishment of a new culture. Branches must be subjected to phytosanitary controls and come from healthy cultures; 10–12-month-old branches are the best if they are mature, well developed, and 2–3 cm in diameter. Vigorous stakes with perfect buds produce healthy plants. Stakes must be mature because if they are not well lignified, they are more susceptible to insects, diseases, and adverse climatic conditions.

A practical way to determine the maturity of a plant is to compare the diameters of the pith and the stem. If the pith is smaller than 50% of the stem diameter, then the stake is at the recommended stage of maturity. The presence of pentagonal forms or foliate scars indicates that the material is immature.

Other precautions that must be taken involve protecting the stakes from mechanical damage during transportation, preparation, storage, and planting. Damaged stakes are more susceptible to microorganisms and are less likely to survive. Because insects and pathogens may be present in the stakes but not visible (bacteriosis), trained personnel must conduct the stake selection.

Stake Preparation

Once the branches have been selected, they must be cut. Usually they are cut 10–15 cm above the ground, the labourer using a machete or a motorized saw. Then, they are bundled together in groups of 50, tied with string, and stored away from direct sunlight. The mean branch yields vary with the cultivar, soil fertility, age, and spacing of the plants.

Stake Transportation

Transporting stakes from the field to where they are going to be planted or stored is done by trailer or truck. Stake bundles must be carefully arranged so that the buds are not damaged, and their drop off places at planting areas must be predetermined so that transportation costs and material handling are minimized.

Transportation must be completed as quickly as possible, especially if the cutting coincides with hot weather, because exposure of the buds to the sun's rays can lower sprouting percentages. When the stems are not in bundles, loading is difficult and time-consuming: to load a 50-m^3 capacity tractor takes 3–5 men/day; an 80-m^3 trailer needs 12 men/day. In contrast, loading a 50-m^3 truck with bundles takes 5 men 2 h.

Discharge at the storage place is done with the help of wood stakes and steel wire pulled by a tractor; it takes less than 15 minutes. Storing, however, requires 6 men/day.

A 20-m^3 truck has sufficient capacity to feed four Martins-type planters (whole stake) and to haul fertilizer if working within 3–4 km of the planting area.

Stake Preservation

In cassava cultivation, insects or diseases that might affect the stems after harvesting must be considered. Storage problems are of considerable importance in regions where the stakes must be preserved for use later as planting material. Stake preservation, no matter what method is used, causes dehydration and favours insect and disease attacks, especially among immature stakes. Thus, losses by dehydration and insects or diseases are related to the selection of stems.

Some chemical applications may prevent damage to the stakes during storage. Dithane M-45 (200 g/100 l water) in a mixture with insecticides is recommended. In large-scale plantations the treatment is done while the stems are in storage. Sometimes stored stakes harbour *Diploidea manihotis*, which causes plant death a few weeks after planting. The symptons are lodging, rot, and vessel darkening.

When storage is necessary, the stems must be bundled, placed in the shade in a vertical position, their base covered with moist, loose soil and grass as protection against dehydration. Shoots that emerge at the apical end and small roots at the base are eliminated at planting. Storage varies from 30 to 60 days, and all data show that losses are in direct relation to storage time. In large-scale plantations it is recommended that the stems be distributed throughout the field, with their bases slightly buried in the soil and the sides and top covered with palm tree leaves or grass (Fig. 1). Losses up to 30% have been reported.

Storing stems horizontally in warm areas such as Felixlândia (Minas Gerais) is not recommended for more than 30 days, because sprouting begins and the buds can be easily damaged.

Preparation of Stakes

The establishment of a cassava plantation requires very special attention of the stake preparation step because productivity is based on selection and manipulation of planting material.

Cutting stakes horizontally is recommended because a slanted cut increases tissue exposure and dehydration. The operation should not take place in direct sunlight, especially if the stakes are being cut from stems that have been stored. Two men using a circular saw powered by an electric, gasoline, or diesel motor can cut 50 000–60 000 stakes a day; two more men are required for selection and packing (Fig. 2). Working together, they can supply enough planting material for a Sans planter operating 11 h/day. When the stakes are to be 20 cm long, they should be cut 1–2 cm longer as compensation for losses due to the cutting operation. After being cut, the stakes are placed in plastic boxes that hold 250–300 stakes.

When stakes are transported, the trailers and turcks must be covered, and once the boxes are discharged at the planting sites, they must be covered on sunny days.

Planting the Stakes

The equipment available in Brazil for mechanized planting only allows horizontal planting of the stakes, which are 20 cm long. When the soil is dry, the planting depth is increased so that the stakes do not become dehydrated. The mean planting depth in large-scale plantations is about 10 cm.

Adding Lime, Phosphorus, and Fertilizer

Limestone is needed in the cerrado soils, but how much is still uncertain because the amount varies with different cultures and soils. Data on the effects of lime on cassava are contradictory, possibly because of the lack of detailed studies on the interactions of lime × zinc, lime × phosphorus, and lime × phosphorus × zinc. At present, the quantity of limestone to be applied is

Fig. 1. The system used for stem storage in Minas Gerais, Brazil.

Table 1. Fertilizer recommendations for Minas Gerais.

Soil texture	Soil analysis (ppm)		Fertilizer (kg/ha)		
	P	K	N	P_2O_5	K_2O
Loamy and Sandy	0–10	0–30	30	90	90
	11–20	31–60	30	60	60
	20	60	30	30	30
Clayey	0–5	—	30	90	—
	6–10	—	30	60	—
	10	—	30	30	—

calculated on the basis of interchangeable Al and Ca + Mg meq/100 g of soil.

In general, in areas that have just been cleared, 2–3 t/ha of lime are applied. Dolomitic or Mg-rich lime is rarely used because of high costs. It is possible that these rates are not the best for cassava plantations, but they are used in anticipation of future uses of the land, especially crop rotation. Limestone is applied to a depth of 20–30 cm at least 10 days before planting.

Application of phosphorus, called corrective fertilization, is recommended for soils with phosphorus levels lower than 5 ppm; recommended doses of P_2O_5 are 100, 150, and 250 kg/ha for sandy, silty, and clayey soils, respectively.

Phosphorus fertilizers, preferably thermophosphates with micronutrients, are broadcast and incorporated with a light disking to a depth of 0–10 cm. This operation allows better utilization of the P_2O_5 applied to the rows. Even though phosphate application is recommended, it is not widely practiced because of its high costs.

Table 1 shows the fertilization schedule for the state of Minas Gerais. As no adequate method exists for determining available N in the soil, recommendations for this nutrient are based on experimentation. Half the nitrogen is applied during planting and the rest, 40–60 days later. As positive responses to nitrogen have not been observed, some farmers do not use it. When it is used, it is applied as ammonium sulfate or urea.

Fig. 2. Stake preparation, Minas Gerais, Brazil.

Fig. 3. The Sans planter.

In some areas, lime spreaders are used for nitrogen application, but we recommend against this procedure, especially for the second application, because it may cause foliar damage and is less effective than application during planting.

Plants in soils with less than 1 ppm Zn show positive responses to Zn applications of 10–20 kg/ha (45–90 kg of zinc sulfate). There are some commercial fertilizers that include zinc, which makes its application easier. When dolomitic limestone is not applied, magnesium sulfate is recommended, although it is not widely applied.

Planting Equipment

The Sans planter plants two rows at a time and requires two men to feed the roller. It is most commonly operated at 2 km/h. A third man follows the planter to cover stakes that have not been well covered with soil and to correct any mistakes. The machine must be regulated in such a way that depth and spacing are as recommended by the manufacturer. One 60-hp tractor plants 2.5–3.0 ha in 10 h (Fig. 3).

The Martins planter, manufactured at Campos, Rio de Janeiro, is a modified sugarcane planter, developed as a result of demands from farmers after the formation of PROALCOOL (Fig. 4). This planter opens furrows, applies fertilizer, cuts and treats stakes, plants and covers the stakes, and compacts the soil. It can plant 5 ha/day. The operation of this equipment requires two men at the cutting section and two more at the feeding section. The stakes are sprayed with a solution of Dithane M-45 or Manzate (100 g/100 l H_2O) at the same time as they are being cut.

Spacing

Spacing depends on soil fertility, plant architecture, cultivation system, future use, and climate. According to Normanha and Pereira (1950), Nunes and Oliveira (1972), Mattos et al. (1973), Siqueira (1973), Correa (1971), Silva (1971), and Sampaio and Conceição (1972), best spacings are 0.60–1.40 m between rows and 0.40–1.00 m between plants. Between 1.00 × 0.60 and 1.00 × 0.50 m is generally recommended. In cerrado soils, 1.00 × 0.50 m (20 000 plants/ha) has been adopted. With this spacing, although losses of up to 20% still occur, the planting density is within the range considered ideal for this type of soil. However, in cerrado soils Correa (1971) showed that higher yields were obtained in closer spacings (Table 2). These conditions at the same time reduced quality, diameter, and size of roots.

Cassava Pruning

Cassava pruning is a cultural practice adopted in some regions, especially South Brazil, mainly as protection against frost. The effects have been more noxious than beneficial because pruning helps disease spread; diminishes root production and carbohydrate levels; increases branch numbers and, hence, competition; and increases fibre levels in the roots. Besides protection against frost, its positive effects include insect control (stemborer) and increased branches for use as forage. Also, emerging stems tend to grow faster and more erect than the old ones and, thus, are at times better as planting material. Although a source of good planting material, pruning increases production costs and reduces yields. A better method of obtaining planting material is to select stakes during root harvest.

Table 2. Mean root and stem production (t/ha) with different populations of cassava cultivar Riqueza (Correa 1971).

Spacing (m)	Population/ha	Roots (t/ha)	Stem (t/ha)
1.00 × 0.30	33 330	26.1	31.1
1.00 × 0.60	16 660	24.1	27.2
1.00 × 0.90	11 110	15.5	17.3
1.00 × 1.20	8 330	13.3	13.5

Weed Control

When cassava is planted in newly cleared areas, weed control is restricted to the elimination of emerging sprouts. Herbicide applications are not necessary, as manual or mechanical control is satisfactory. With time, fields become infested with *Melinis minutiflora*, *Cenchrus echinata*, *Brachiaria plantaginea*, *Cynodon dactilon*, *Digitaria sanguinalis*, *Panicum* sp., and *Portulaca oleracea*. Different experiments have been carried out in the region to determine the most appropriate herbicides and their application rates. Diuron and Alachlor or a mixture of both

Fig. 4. The Martins planter.

have given the best results at preemergence. Other products are being tested.

Although specific herbicide recommendations exist, they are not being followed. In demonstration areas, herbicides have provided good weed control up to 70 days. One reason for not utilizing herbicides more extensively is that mechanical weeding is usually done 40–50 days after planting.

Another aspect to be considered is that cassava does not grow fast enough to shade the soil and, thus, to complement the weed-killing action of the herbicide. Mechanical weeding is generally done when the plants are 20 cm tall and the number of times depends on weed infestation.

The cultivator normally used weeds 3 rows at a time, penetrating 10 cm deep between rows and moving soil toward the cassava to eliminate emerging weeds. One 85-h.p. tractor pulling a 3-hoe cultivator is able to clean 1 ha in 40 minutes. When additional weeding is necessary, it takes 5 men/day. Weeding is more effective on sunny days. With added equipment on the cultivator, it is possible to apply fertilizers at the same time.

During the second vegetative cycle the weed problem is worse than during the first cycle. The weeds grow before cassava recovers to shade the soil. At this stage hand weeding is the only possibility. Weeds compete with plants for nutrients, water, and light, reducing productivity and making cassava harvesting very difficult and expensive. Hand harvesting at this stage demands at least 10 men/ha/day.

Insect Control

Large-scale cassava production leads to ecosystem imbalances and heavy insect infestations, especially of cassava hornworm (*Erinnyis ello* and *E. alope*), the most important pest. Besides the direct damage it causes, the hornworm is one of the principal agents of bacteriosis dissemination.

Chemical control has been done with Sevin powder (Carbaryl), Thuricide (*Bacillus thuringiensis*), and finally with Methil Parathion 1% + Endrin 1.5% (7 kg/ha). Methil Parathion + Endrin (powder) were applied using a duster covering from 50 to 100 ha/day. At present, hornworm is controlled biologically. Those responsible for phytosanitary control keep records of pest levels and introduce control measures only when absolutely necessary. Moderate use of insecticides has been recommended.

The white ant (*Syntermes* sp.), which attacks the cassava planting material, is not currently prevalent enough to warrant control measures, which would contaminate the soil with chlorinated insecticides. Recently, small aircraft have been used for pesticide applications, but arthropods, the natural enemies of the cassava hornworm, have been killed as well.

Measures to control ants (*Atta* sp. and *Acromyrmex* sp.) are undertaken at two stages: first, during soil preparations and, second, during the cassava growth cycle. Initial control is before woody areas are cleared (felling), again 40 days after, and once more during the last disking. During the cassava growth cycle, any new nests should be eliminated; gases, dusts, and baits are normally used.

Control measures are occasionally needed against thrips, mites, and lace bedbugs. The lace bedbug (*Vatiga illudens*) causes the most severe damage and so far the control systems have been unsuccessful.

Diseases

Most of the cultivars introduced into the Cerrado were infected with bacteriosis (*Xanthomonas manihotis*), the most serious disease in the region. It limits production and has even been known to cause 100% losses. It is more prevalent during the rainy season when relative humidity is higher and thermal variations greater. Some cultivars, such as Sonora, Caapora, Mico, IAC 12-829, Iracema (IAC 7-127), Mantiqueira, Engana Ladrao, are considered to be resistant to bacteriosis; they have been introduced and are under observation.

Some farmers carry out roguing to eliminate plants infected with bacteriosis.

Among fungal diseases the most common are caused by *Cercospora* and *Oidium*, but there are no quantitative evaluations of the damage caused.

Stake Treatment

The following products have been recommended for stake treatment: Dithane M-45, 2 g/l; Vitigram, 2 g/l; and zinc sulfate, 20 g/l. The solution is compatible but tends to deteriorate with time. In a study of treatments, stakes were immersed in the solution for 15 minutes as protection against zinc deficiencies and pathogenic attacks. This operation added one more step to the production process; treatment was done in a 1000-l water container by immersion of small boxes containing the stakes. The treatment system varies according to production scale, with the most efficient including four 1000-l treatment containers plus a solution container placed above the others so that the solution flows by gravity. After stake treatment, the solution is pumped into another container for reuse.

At the end of a working day, the solution is completely dirty, and the impurities reduce treatment efficiency and bactericide action. Therefore, the solution is changed every day. The principle of this method is used in the Martins planter where the stakes are cut and sprayed simultaneously with Dithane M-45 or Manzate (100 g/l).

Harvesting

With the initiation of the Programa Nacional do Alcool and the possibilities of root utilization year round, harvesting criteria have changed. Harvesting in a large plantation is a complicated task that demands careful programing to satisfy both the farmer and the consumer.

Harvest Planning

When harvesting takes place on more than 300 days a year, some criteria are taken into account to improve its execution: harvest according to cultivar and characteristics (early, medium, or late); sample sections to be harvested to determine different harvesting options; harvest plots earlier where climatic conditions make the task difficult during rainy periods; harvest those plots with low stand and infested with weeds; immediately harvest those plots with phytosanitary problems and eliminate all vegetative material; conserve the best plots for planting material according to needs; if possible, harvest at the same time as planting to avoid stake storage; utilize aerial part as forage or for other purposes; and harvest according to economic factors.

Hand Harvesting

Hand harvesting is very common in large plantations; it involves two stages: pruning the aerial part of the plant and harvesting the roots with the help of mechanical tools.

Branch pruning is the first step, although it is not always done for erect cultivars. It involves removal of the aerial part of the plant — an operation that facilitates root harvest; a machete or other cutting device is usually used. Pruning is done 30–50 cm above the soil surface, and a crew of 7–8 can prune approximately 15 000 plants a day.

Roots are harvested by hand oscillation, sometimes with the help of a hoe. The handle serves as a lever when the tool is in the soil under the stump. Roots remaining in the soil are extracted with the help of a mattock (hoe) and piled nearby along with the stumps.

The detachment of the roots from the stump is done by hand or with a machete. The stumps are piled and are later burned or removed. The roots from 4–5 rows are collected in piles every 20 m along one row. Then, they are packed in plastic boxes or placed in trailers to be taken to the main transportation system.

Harvesting Efficiency

Harvesting efficiency depends on many factors. One man may harvest 800–1000 kg/day but if working conditions are not optimal, the amount may be 500 kg/day.

Plastic boxes with a capacity of 25 kg have been used for packing the roots. Packing and loading a yield of 16 t/ha requires 16–20 men/day, which increases production cost.

Trailers carry the roots from the field to the final transportation system. Roots must be taken to a factory in less than 48 h because of root rot risks from handling.

Semimechanized Harvesting

Branches are either cut by hand or by machine. Some cutters convert the aerial part into forage or silage and deposit the material in trailers for transport to the silos. One factory produced 400 t of silage uing 2/3 of the aerial part of the plants. The quality of the product was very good and cattle were fed up to 32 kg of silage a day without any problems.

Mechanical Harvesting

Harvesters attached to the hydraulic system of a tractor are still under development and have not given satisfactory yields. The ones used at Felixlãndia were responsible for root losses up to 40%. The most promising harvesters, developed by Ceará Maquina Agricolas (CEMAG) with INT support, are being tested in farm trials.

In an effort to overcome the problems in harvesting, one farmer from Cordisburgo imported a cassava harvester from Agri-Project International and is testing it. Results so far indicate that the machine is a very efficient cassava harvester. Meanwhile, mechanical harvesting is still under development.

Crop Rotation

Crop rotation is commonly recommended for all crops in every type of soil and is being adopted in large-scale commercial plantations. It avoids imbalances in soil nutrients; controls some pests and diseases, and allows the utilization of residues left by other crops as manure. Soybeans are widely used in crop rotation systems.

Principal Problems

Although some cassava technology exists, changing from a typically subsistence crop to more extensive production has produced problems in Curvelo; the most important are that: (1) in new areas, the farmers' lack of experience may bring negative consequences to cassava production; (2) the lack of selected planting material in the region may affect the agroindustrial operation; (3) inadequate mechanization in areas of agricultural frontier expansion may affect the planting schemes, reducing productivity; (4) high input costs, especially of fertilizers and correctives, may lead farmers to use them improperly; and (5) climatic conditions and the presence of insects and diseases caused by changes in the ecological balance in the region may affect the crop.