Storage Effects on Planting Material and Subsequent Growth and Root Yield of Cassava (*Manihot esculenta* Crantz)

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ABSTRACT

Storage of cassava planting material is necessary when harvest and subsequent plantings are separated in time due to drought, flood periods or low temperature.

Stakes lost viability when dehydration reduced moisture content to less than 60%. Storing cassava planting material as 100 cm or longer stems was highly effective to avoid dehydration and maintain viability for several months. Besides moisture, stakes lost carbohydrate reserves during storage, mainly in the form of total and reducing sugars. Mineral element concentration varied during storage, however, a relative increase of N, P and K concentrations in stake tissue was noticed, possibly as a result of total dry matter loss.

Stakes with good nutritional status showed better sprouting and crop establishment than those from a poorly nourished crop. Sprouting and establishment could also be aided by rehydration and bioactivator treatments, resulting in equal or even superior yields with stored than with fresh planting material.

Introduction

In cassava production, problem of stake storage arise when harvest and subsequent plantings are separated by time often as long as several months. Drought, low temperature or floods are most frequently responsible. Use of fresh stakes is normally preferable to stored planting material (Correa, 1970, 1977a, b; Lozano et al, 1977; Narintaraporn, K. et al, 1978; Silva, 1970), however, with harvest and planting separated in time, a portion of the crop would have to be set aside for later cutting of stakes. This may lead to an undesirable carry over of pest problems and cause difficulties to small farmers both economically and when land availability is limited. Stake storage may therefore be inevitable in certain situations.

In view of scarce information on improved stake conservation methods, a variety of aspects of stake storage was investigated to obtain a better understanding of the transformation and deterioration processes which the planting material suffers during storage. Also, an attempt was made to design practices to improve stake quality before and after storage.

Materials and Methods

Characteristics of the Experimental Sites. Trials were at CIAT Palmira and Quilichao stations in the Cauca Valley of Colombia, South America, as well as at Caribia, on the Colombian north coast. CIAT-Palmira is at 1,000 m.a.s.l. and has annual precipitation of 1,025 mm in biemodal distribution, 23.7 C annual mean temperature and 72% mean annual relative humidity. The soil is a vertic calcustoll (mollisol) with a silty clay texture, pH 6.0, organic matter 4,1% and a generally high base status and fertility. CIAT-Quilichao, at 1,035 m.a.s.l., has annual precipitation of 1,590 mm, a mean annual temperature of 23.6 C and a mean annual relative humidity of 69.1%. The soil is a typic dystropept (inceptisol) with a clayey texture, pH 4.1, organic matter 6.3% and low P and base status but high aluminum and manganese saturation. Caribia is at 30 m.a.s.l. and has 1,393 mm total annual rainfall, an annual mean temperature of 27.2 C, and 84% mean annual relative humidity. The soil is an unclassified entisol with a sandy loam texture, pH 6.0, organic matter 1.6%, high available P but intermediate to low base status.

Experiment 1: Moisture content and viability of stakes.

Long (120 cm) and short (20 cm) stakes were cut from cassava variety M Mex 11 grown at CIAT-Palmira. Both materials were treated with BCM and Captan at 3,000 ppm each to prevent fungal infestation and then exposed to dehydration in the open during the day, being transferred to a dry room during the night and during rainy periods.

At weekly intervals, material from both long and short stakes was dried at 70 C in a forced draft oven to determine moisture content. Simultaneously, 20 cm stakes of the two groups were planted in the field and their viability assessed. A stake that had not sprouted 2 weeks after planting as counted as not sprouted.

Experiment 2: Changes in mineral element and carbohydrate concentration of stakes during a 6-month storage period.

During 6 month of storage, samples of three entire stems of cultivar M Ven 218 grown at Palmira under high fertility and at Quilichao under low fertility with and without P fertilizer were taken at monthly intervals. Ten cm from each end of a stem was discarded. The remaining 100 cm stem was cut into pieces, weighed, dried and weighed again for moisture determination. Samples were then ground and analyzed for N, P, K, total and reducing sugars, and starch. Mineral element, carbohydrate and cyanide analyses were by CIAT laboratory standard procedures. A description of methodologies is available from CIAT on request.

Experiment 3: Influence of stake nutritional status on sprouting, growth and yield.

After 6 month storage, stakes stored at CIAT-Palmira and CIAT-Quilichao as described for Experiment 2, were taken to a field site near CIAT-Palmira Station and cut into 20 cm planting pieces. A visual classification into good, intermediate and poor quality stakes according to degree of dehydration (fingernail probe for latex emanation), premature sprouting and microbial deterioration was done prior to planting. Stakes were planted vertically in a 1x1 m arrangement on ridges together with fresh stakes of the same variety (M Ven 218) produced at CIAT.

A fertilization of 50, 44, 83, 10 and 1 kg/ha of N, P, K, Zn and B was given at planting and an additional 50 kg N/ha were applied 60 days after planting. Sprouting was monitored during the first month after planting, and plant height, total dry matter and leaf area were determined at intervals of 2, 5, 9 and 11 months after planting. At the 9 and 11 months harvests, root numbers, root sizes and total root weight was also recorded.

Experiment 4: The effect of rehydration and bioactivators on sprouting, growth and yield of cassava grown from stored planting material.

Planting material of variety CMC 40 produced at CIAT-Palmira under non-fertilized conditions was harvested at 12 months age and stored under shady field conditions for 201 days. The approximately 100 cm long stems received a treatment of BCM and Captan (3,000 ppm each) prior to storage. At the end of storage, stored stems were cut into 20 cm long stakes and divided into six groups, each of which received a different pre-planting treatment: Stakes of group 1, 2 and 3 were water-soaked for 0, 60 and 240 min and then treated for 15 min in a fungicide-insecticide solution whereas stakes of group 4, 5 and 6 were soaked in a 1% biactivator solution for 0, 60, and 240 min and then treated for 15 min in a fungicide-insecticide-bioactivator solution.

Fresh stakes of the same variety were also cut and treated for 15 min in either a pesticide solution only or in a pesticide-bioactivator solution.

All stakes were planted at CIAT-Palmira on ridges in a 1x1 m arrangement and a fertilization of 50, 22, 83 and 10 kg/ha of N, P, K and Zn was given with planting. The sprouting process as well as root and top yield at harvest were recorded.

Results

Stake dehydration. Under sun exposure and without possibility of absorbing moisture from soil or from rain or dew, moisture percentage in the 20 cm stake material declined rapidly from fresh stake value of 72.5% to 15.2% at 70 days after starting exposure. On the other hand, long stakes lost moisture at a much slower rate, moisture percentage never falling below 58% during observation period (Table 1). Viability of planting material stored as 20 cm stakes was seriously affected by dehydration. When moisture fell below 60%, sprouting percentage started to decline sharply and approached zero when 50% moisture was reached, after less than one month of exposure. This finding is in agreement with Wholey (1977) who showed that stakes of variety M Col 1438 lost their viability when moisture content of otherwise healthy stakes approached 50% as a result of dehydration during storage. In contrast, stakes stored as long stems, maintained complete viability over 2 months and a decline in sprouting percentage became noticeable after 70 days of storage. This observation is again in accordance with Wholey (1977) who found long sections of stakes to loose fresh weight and viability slower than short sections.

Changes in element and carbohydrate status. Mineral analysis of stakes showed clear differences in nutritional status according to site and condition of production. In general, stakes produced at CIAT-Palmira had the highest concentrations of all major elements, the advantage being particularly large with respect to N and P. During the 6 months of storage, the concentrations of N, P and K showed a clear tendency of increase.

Table 1. Moisture content and viability of long and short cassava stakes of variety M Mex 11 affected by storage.

Days of Storage	20 cm Stake Moisture %	20 cm Stake Sprouting %	120 cm Stake Moisture %	120 cm Stake Sprouting %
1	72.5	100	72.5	100
8	62.3	85	68.4	100
15	59.7	30	67.8	95
22	51.8	25	65.6	95
29	48.6	5	66.7	95
36	47.3	10	63.6	95
43	27.0	5	61.5	95
50	25.2	0	59.0	95
57	20.4	0	58.0	100
70	15.2	0	58.3	80

Carbohydrates showed a marked reduction during storage at both sites, losses being mostly in the form of soluble carbohydrates (total and reducing sugars). These losses were greatest during the first 60 days of storage and rather small thereafter. Starch percentage showed a strong fluctuation with no specific trend being recognized.

Influence of stake nutritional condition. The visual evaluation of stake quality revealed a clear influence of stake nutritional status on preservation characteristics. Planting material produced at the poor soil site Quilichao showed a low portion of good and intermediate quality stakes and a large quantity of poor stakes. This was even observed when P, the nutrient which is most limiting at Quilichao, had been applied to the plants, no big differences being observed between the 0 and 132 kg/ha P level. On the other hand, the portion of stakes rated "good" was much higher and the portion rated "poor" was lower in the Palmira produced material. Fresh stakes from Palmira had the highest portion of good stakes. Final sprouting percentage taken 2 months after planting confirmed results of visual quality rating, but numerical differences between treatments were small, the Quilichao OP material showing 20.6%, the Quilichao 132 P stakes 20.8% and the Palmira stakes 27.1% sprouting. Fresh stakes reached 100% sprouting on day 21 after planting whereas stored stakes reached their final percentages only after 30 days or later.

Early crop growth as measured by plant height, total plant dry weight and leaf area 2 months after planting was also affected by stake nutritional status. Stored stakes from the fertile site Palmira performed relatively better than from the infertile, non-fertilized Quilichao site. Stakes from Quilichao produced with high P fertilization showed an intermediate position. Differences in early development were numerically visible but could not be secured statistically. On the other hand, data from the 9 months harvest indicated that stakes which started to grow better initially also performed significantly better at harvest. Observation of harvest index, total plant dry weight, total root dry weight and commercial root number per plant showed that, in general, stake material produced under the best nutritional conditions (Palmira) also produced the heaviest plants with the greatest root numbers and root weights. However, ranking from best (Palmira) to worst (Quilichao 0 P) was not always strictly preserved (Table 2). Harvest data at 11 months after planting did not show further increases in important yield parameters, therefore, only 9 months-data are reported.

Table 2. Effect of stake nutritional status on harvest index, total plant dry weight, total root dry weight and commercial root number per plant, nine months after planting. CIAT-Palmira-Amaime 1981-1982.

Stake origin and characteristics	Nutritional status	Harvest index (%)	Total dry weight per plant (kg)	Root dry weight per plant (kg)	No. commercial roots per plant
Stakes grown and stored in Palmira	Good	61 b[1]	4.6 a	2.5 a	9.1 a
Stakes produced with 132 kg P/ha grown and stored in Quilichao	Intermediate	67 a	2.9 b	2.0 ab	8.2 ab
Stakes produced without P fertilizer, grown and stored in Quilichao	Poor	54 c	3.3 ab	1.8 ab	6.7 b

[1]Means in the same column followed by the same letter are not significantly different at P = 0.05 according to Duncan's multiple range test.

<u>Improvement of stake quality</u>. Rehydration in either water or bioactivator solution was successful in increasing mean stake weight (20 cm length) from 41 g to 44 g after a 240 min soaking period. Rehydration prior to planting also clearly influenced rate of sprouting, the longer the stakes were submerged the faster was sprouting, reaching approximately the rate of fresh stakes with 240 min soaking. Final sprouting percentage was near 100% in all treatments. However, rehydration in water or bioactivator solution did not result in different sprouting patterns.

Vegetative growth expressed as plant height 2 months after planting still reflected differences that treatments imposed during sprouting and crop establishment. Plants from fresh stakes and those from stored stakes subjected to long soaking periods grew more vigorously and taller than those from stored stakes with no or short rehydration periods (Table 3). Although differences in plant height disappeared later during the season (plant height 150 DAP), they persisted in terms of total top weight until harvest.

Plants from fresh stakes treated with bioactivator solution showed the greatest top weights whereas plants from stored stakes without bioactivator treatment produced the least. Overly heavy foliage and branches combined with a relatively small number and consequently weight of commercial roots per plant resulted in a low harvest index, particularly where plants were grown from fresh stakes treated with the bioactivator. On the other hand, a more moderate growth of tops together with a large number of commercial size roots per plants gave a high harvest index in those treatments where stored stakes had been rehydrated in bioactivator solution.

Table 3. Influence of rehydration and bioactivator solution treatments of stored stakes on subsequent vegetative and root growth of cassava cv, CMC 40. CIAT. 1980.

Treatments	Plant height (cm) 60 DAP[1]	150 DAP	Weight of tops at harvest (t/ha)	Commercial roots number/plant	Harvest index %
Stored stakes					
0 min water soaking + 15 min pesticides in water	48.8 d[2]	195.7 a	44.1 abc	7.0 abcd	48.5 a
60 min water soaking + 15 min pesticides in water	52.0 bc	210.7 a	39.4 c	6.6 cd	49.0 a
240 min water soaking + 15 min pesticides in water	48.8 c	206.0 a	40.4 bc	6.8 bcd	49.2 a
0 min bioactivator soaking + 15 min pesticides + nutrients	47.7 cd	202.7 a	45.2 abc	6.8 bcd	47.4 a
60 min bioactivator soaking + 15 min pesticides + nutrients	47.2 cd	204.7 a	47.0 ab	7.5 abc	48.1 a
240 min bioactivator soaking + 15 min pesticides + nutrients	53.5 bc	210.5 a	45.5 abc	7.9 a	49.7 a
Fresh stakes					
Pesticides in water 15 min	63.5 a	214.3 a	49.7 a	7.6 ab	45.1 ab
Pesticides + bioactivator 15 min	57.7 ab	211.8 a	50.2 a	6.5 d	41.5 b

[1]DAP = Days after planting.

[2]Means in the same column followed by the same letter are not significantly different at P = 0.05 according to Duncan's multiple range test.

Total fresh root production of 40.6 t/ha obtained from fresh stakes without bioactivator treatment was similar to the whole trial average of 41.2 t/ha, and no yield from a stored stake planting was significantly inferior to that of the check. On the contrary, there was a tendency of yield to improve over the non-bioactivator-treated check when stored stakes were soaked in bioactivator solution for longer periods of time (Figure 1). On the other hand, the surprisingly low yield of the fresh stake with bioactivator treatment was significantly inferior to most other treatments. Plants of this treatment grew vigorously from early on, forming a dark green, healthy looking canopy. Leafliness throughout the growing season probably resulted in a greater than optimum leaf area for maximum root growth, so that high leaf and branch but low root yield was obtained.

Discussion

One important process that occurs in cassava planting material during storage is loss of moisture which has a strong influence on stake viability while probably also affecting biochemical transformations within the stakes. Moisture, once lost from a stake, is reabsorbed only in small quantities when dehydrated stakes are submerged in water and rehydration only improves sprouting, growth and eventually yield when the moisture content had not fallen below a critical level. There was a surprising consistency of data obtained in the present studies with those reported by at least one other worker, indicating that the threshold moisture content of stakes was around 50%; below that level, viability suffered seriously. With regard to practical aspects of stake storage, these findings emphasize the importance of creating storage conditions that avoid dehydration since the viability of planting material is irreversibly affected when this process is allowed to advance beyond established limits.

A second, important transformation occurs in stored stakes as a result of continued respiration. As any other living plant tissue, stored stakes continue to respire and thus lose carbohydrates during storage. Rate of loss is particularly high at the beginning of storage and slows down later, the cause for this probably being reduced moisture status of the stakes after longer storage periods. It is probably within this context that increases in major element concentrations may be interpreted, the loss of carbohydrate, detected in the present studies as a reduction mainly of total and reducing sugar concentration resulting in relatively higher concentrations as dry matter losses continued.

With regard to carbohydrate loss, these data show the practical importance of selecting storage conditions that keep respiration at a low level since respiration losses reduce reserves available to stakes after planting and thus diminish sprouting vigor and establishment. In particular, cool storage conditions (but not cold room temperatures) appear desirable.

Furthermore, nutritional status of stakes which was shown to vary according to natural soil fertility levels in different locations and also as a result of fertilizer applications, proved to have an influence both on keeping properties of stakes and on subsequent sprouting, growth and yield. Keeping properties were definitely superior when stakes came from well nourished plants, being vegetatively better developed and consequently showing less moisture and carbohydrate depletion as well as pathogenic deterioration than stakes from poorly nourished plants. The effect of stake nutrition on initial crop growth was small but apparently accumulated over the whole growth cycle resulting in significantly better performance at harvest of stakes with a good rather than with a poor nutritional status. For practical purposes, this means that plants whose stakes are to be cut

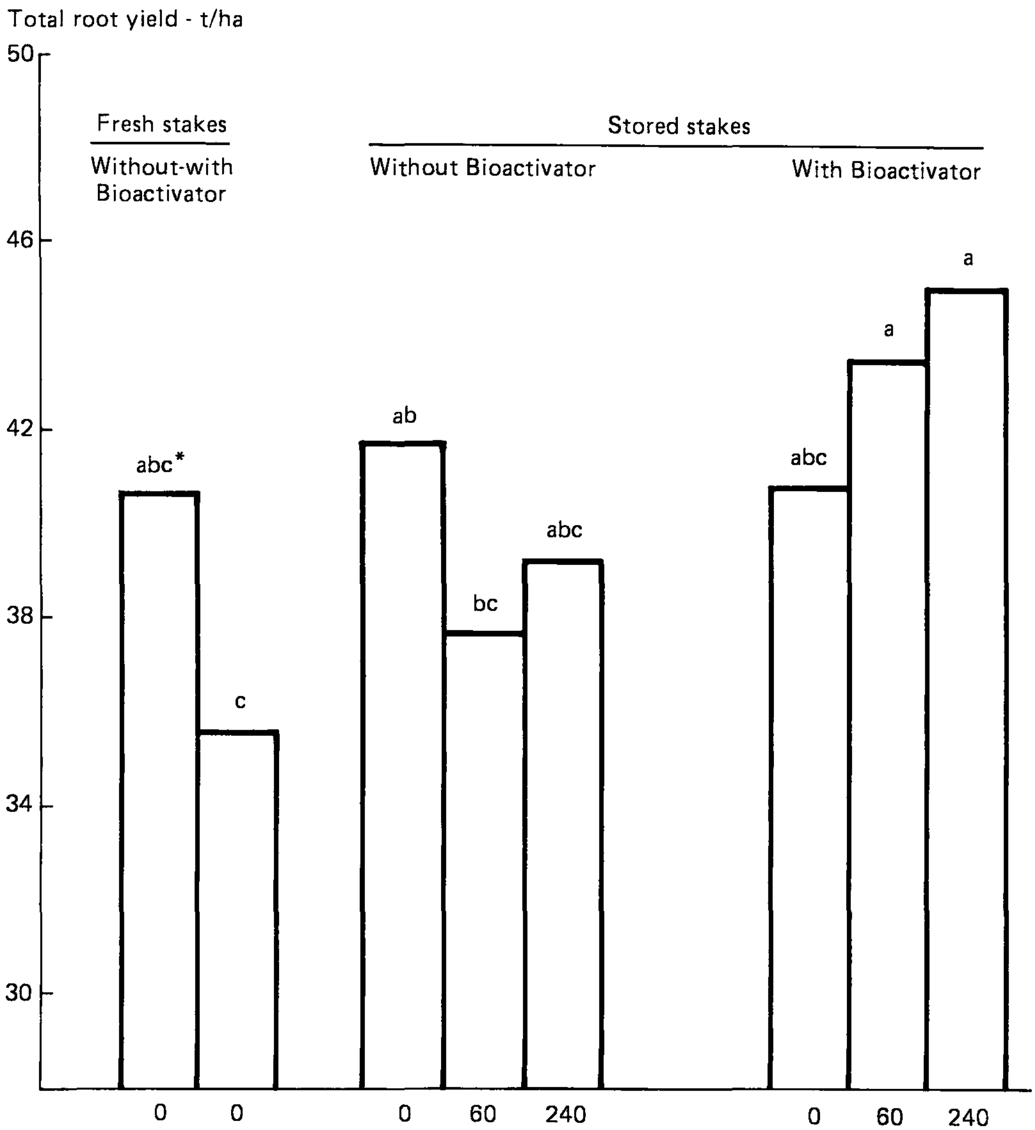

Figure 1. Effect of post-storage treatments on total fresh root yield of cassava cv. CMC 40 grown from stems stored for 201 days. Figures in columns indicate duration of soaking in minutes.

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*Columns headed by the same letter represent means not significantly different at P = 0.05, according to Dundan's multiple range test.

and stored away for later use as planting material, should receive a special treatment, either by selecting the most fertile area within a field for stake production or by a more complete and somewhat more abundant fertilization of those areas from where the planting material is to be obtained.

Finally, stakes produced and stored under good conditions can be further upgraded with a combined rehydration-bioactivator treatment which apparently helps to bring them back almost to an "as fresh" condition. The treatment was effective in promoting a favorable balance between top and root growth in plants grown from stored stakes, resulting in high harvest indices and root yields in these plants, the high productivity being particularly surprising in view of the low storage duration of over 6 months. The procedures appear to be time-consuming and to impose high technology requirements but in fact it is simple to carry out and inexpensive (US$25.00/ha), being particularly suited for cassava producers who plant small to medium size areas and consequently need not move overly large quantities of stakes.

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