# A Field Comparison of Conventional Suckers With Tissue Culture Banana Planting Material Over Three Crop Cycles

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## Abstract

*A randomised block split-plot experiment was established at Burgershall Research Station to compare 3 cultivars (Williams, Dwarf Cavendish and Grand Nain) and 3 types of planting material (conventional 2 kg pared suckers, 200 and 500 mm high tissue-cultured plants rooted in bags). In the first crop cycle (P), tissue-culture (TC) plants were up to 300 mm taller than conventional suckers (CON) at flowering. Over all 3 cultivars, TC plants yielded 56 t/ha/annum which was 20.4% higher than CON plants, due to larger bunches and a shorter cycle to harvest. Williams and Grand Nain yielded similarly at 54 t/ha/annum which was 9% more than Dwarf Cavendish. There were 1.76% distinct somaclonal mutants in the plantation of 1,700 plants. In the second crop cycle (R1), there was a significant carry-over effect with TC plants, as shown by the increased vigor and size of the first ratoon followers selected on TC mother plants. Such TC followers outyielded CON followers by 18.6% in the second cycle, almost matching the first cycle. In the third crop cycle (R2) there was no difference in plant size between TC and CON, although a yield increase of 9.6% in favor of TC was obtained, indicating a reduced carry-over effect of TC by the third cycle. After 3 cycles, the average annual yield increase with TC was 19.4% for Dwarf Cavendish, 15.0% for Williams and 13% for Grand Nain.*

## Introduction

There has recently been an increasing interest in the use of *in vitro*, tissue-cultured (TC) banana planting material in South Africa, as a possible replacement for conventional (CON) planting material in the form of "bits" or "suckers." The use of TC plants offers certain inherent advantages, namely that a large quantity of uniform disease-free plants can be produced rapidly from a single plant showing good genetic potential (Vuylsteke and De Langhe, 1985). Against this, however, must be weighed the disadvantage of somaclonal mutations which can result in non-productive, off-type plants (Smith, 1988; Krikorian, 1989).

The morphology, phenology and production potential of TC bananas in the field, compared with CON material, seems to vary as shown by studies in different countries. In Israel, Israeli et al. (1986) found that with spring planting, CON plants flowered earlier, were taller and produced larger bunches than TC plants. From summer planting, the opposite occurred, with TC plants superior to CON plants in all respects. There is evidence that TC plants are larger than CON plants in the first crop cycle, according to work in Israel (Israeli et al., 1986) and Australia (Daniells, 1988; Drew and Smith, 1990). However, in Costa Rica, Arias and Valverde (1987) found that CON plants were larger, and in Taiwan, Hwang et al. (1984) found no difference. There is a similar lack of agreement on the vegetative cycle duration, which is evidently ascribed to differences in the respective size of planting materials being compared.

In terms of yield potential, there is widespread agreement that TC plants produce larger bunches than CON plants in the first crop cycle.

These increases were in the order of 2% (Hwang et al., 1984); 5% (Arias and Valverde, 1987); 7% (Daniells, 1988); 10% ( the summer plantings of Israeli et al., 1986) and 17% (Drew and Smith, 1990).

The performance of TC compared with CON in the second crop cycle has not been widely reported. However, Israeli *et al.* (1986) obtained a bunch mass increase of 18% in favor of TC which surpassed the 10% bunch mass increase in the first cycle of the same planting. In contrast, Drew and Smith (1990) found no significant increase in bunch mass with TC in the second cycle.

The present study was conducted in order to compare the morphology, phenology and production potential of a TC and CON plantation over 3 successive crop cycles, using 3 Cavendish sub-group cultivars.



## Materials and Methods

A cultivar/planting material experiment was established in January 1988, on a uniform and well-prepared block of land at Burgershall Research Station (65 km north of Nelspruit; altitude 720 m; latitude 25°7' south; annual average rainfall 970 mm). Experimental design was a randomised block split-plot with 3 main plots (cultivars Williams, Dwarf Cavendish and Grand Nain) and 3 sub-plots (conventional 2 kg prepared suckers, 200 mm and 500 mm high TC plants rooted in 2 l bags). There were 4 replications of each treatment combination, 15 data plants/sub plot,and double guard between main plots and around the perimeter. The standard density was 2,222 plants/ha. The area of the randomised experiment was 0.44 ha with another 0.62 ha planted with extra TC plants for mutation evaluation.

Apart from experimental treatments, extreme care was taken to apply uniform and optimal management throughout in order to minimize block effects. Fertilizers were applied by hand according to soil and leaf analyses, and desuckering was done monthly in summer. Selection of a uniform first ratoon sucker on each plant was made nine months after planting. Irrigation water was applied uniformly to the experimental area through permanent, undercanopy, low-pressure sprinklers, delivering 20 mm approximately every four days in summer.

Data collected during the first crop cycle comprised plant height at flowering (from soil level to curve of bunch stalk), stem circumference at flowering (300 mm above soil level), leaf emergence rate per month and total leaf production per plant, flowering date and harvest date, functional leaves at flowering, bunch mass, hands per bunch and fingers/third hand. Similar data were collected during the R1 and R2 cycles except that finger and leaf counts were ommitted. The number and type of identifiable somaclonal mutations in TC plants were counted at flowering stage of the first cycle.

## Results

### Vegetative Morphology and Phenology

Vegetative morphological data are presented in Table 1. Williams and Grand Nain were significantly taller than Dwarf Cavendish although stem circumferences were similar. In the P and R1 cycles, TC plants were significantly taller and thicker than CON plants ($P < 0.001$) but

Table 1. Vegetative morphology of banana plants over three crop cycles, according to cultivar and type of planting material. P = Plant Crop; R1 and R2 = first and second cycles; n.s. = non-significant

| Treatment | Plant height at flowering (m) | | | Stem circumference at flowering (m) | | | Functional leaves per plant at flowering |
|---|---|---|---|---|---|---|---|
| | P | R1 | R2 | P | R1 | R2 | P |
| **Cultivars (main plots)** | | | | | | | |
| Williams | 2.86 | 3.52 | 3.38 | 0.82 | 0.94 | 0.99 | 15.2 |
| Dwarf Cavendish | 2.19 | 2.59 | 2.40 | 0.81 | 0.93 | 0.95 | 15.9 |
| Grand Nain | 2.87 | 3.48 | 3.27 | 0.82 | 0.92 | 0.96 | 15.0 |
| Significance | P<0.001 | P<0.001 | P<0.001 | n.s. | P<0.05 | P<0.05 | P<0.01 |
| L.S.D. (P=0.05) | 0.030 | 0.097 | 0.067 | | 0.015 | 0.020 | 0.47 |
| **Planting materials (sub-plots)** | | | | | | | |
| 2 kg suckers (CON) | 2.49 | 2.98 | 2.98 | 0.79 | 0.90 | 0.96 | 14.6 |
| 200 mm TC | 2.70 | 3.27 | 3.07 | 0.83 | 0.94 | 0.98 | 15.7 |
| 500 mm TC | 2.74 | 3.35 | 3.00 | 0.83 | 0.95 | 0.96 | 15.8 |
| Significance | P<0.001 | P<0.001 | n.s. | P<0.001 | P<0.001 | n.s. | P<0.001 |
| L.S.D. (P=0.05) | 0.048 | 0.107 | | 0.010 | 0.011 | | 0.41 |
| Interaction | P<0.01 | n.s. | n.s. | P<0.05 | P<0.05 | n.s. | n.s. |



there were no morphological differences in the R2. TC plants had the benefit of about 1 extra functional leaf at flowering in the first cycle.

Vegetative phenological data were analysed for the first cycle only (Table 2), and there were no significant differences between cultivars. TC plants produced 6 to 7 more leaves before flowering and these leaves emerged slower than with CON plants, but in reality TC plants flowered 2 to 3 weeks earlier (Table 2). This is because TC plants were established as undisturbed whole plants with several of their leaves already present at planting. Six weeks after planting there were 14 leaves on TC plants compared with only 4 on CON plants which had only just emerged through the soil surface.

**Bunch Characteristics and Yield**

Bunch mass, cycling and yield data are presented in Table 3. Bunch mass and yield/annum of Williams and Grand Nain were almost identical over all 3 cycles, while those of Dwarf Cavendish were significantly smaller in the first and third cycles.

TC plants produced significantly larger bunches than those from CON plants in all 3 cycles. This was due to the fact that more hands per bunch and more fingers per hand were set on TC plants at flower initiation. In the P cycle, hands per bunch were 11.3, 12.4 and 11.9 for CON, small TC and large TC respectively, over all cultivars. In the R1 cycle, the respective values were 11.2, 11.9 and 11.9 hands. In the P cycle, there were 19.6 and 21.4 fingers per third hand on CON and TC bunches respectively, over all 3 cultivars. Finger length did not differ on TC and CON bunches.

Overall yield/annum of TC was 20.4, 18.6 and 9.6% higher than CON in the P, R1 and R2 cycles respectively (Tables 3 and 4). The components of this increased yield/annum were the significantly heavier bunches and the shorter cycle times. Bunch mass was also more uniform with TC (9 to 11% coefficient of variation compared with 11 and 15% for CON).

The increases in yield/annum with TC over CON are summarised in Table 4 for each cycle/cultivar combination. The trend was for TC Williams to maintain a consistent yield advantage over CON for all 3 cycles, whereas TC Dwarf Cavendish and Grand Nain showed a very high yield increase in the P cycle followed by progressively reduced increases in the ratoons. However, the carry-over effect of TC was very

Table 2. Vegetetive phenology of banana plants in the first crop cycle according to cultivar and type of planting material. n.s. = non-significant

| Treatment | Planting to flower emergence (months) | Leaf emergence rate (leaves year$^{-1}$) | Total leaves produced (leaves plant$^{-1}$) |
|---|---|---|---|
| **Cultivars (main plots)** | | | |
| Williams | 13.4 | 35.5 | 45.1 |
| Dwarf Cavendish | 13.2 | 36.6 | 45.7 |
| Grand Nain | 13.3 | 36.0 | 45.2 |
| Significance | n.s. | n.s. | n.s. |
| **Planting materials (sub-plots)** | | | |
| 2 kg suckers (CON) | 13.7 | 37.1 | 41.4 |
| 200 mm TC | 13.2 | 36.1 | 48.1 |
| 500 mm TC | 12.9 | 34.7 | 46.5 |
| Significance | P<0.001 | P<0.001 | P<0.001 |
| LSD (P=0.05) | 0.18 | 0.48 | 0.43 |
| Interaction | P<0.01 | n.s. | P<0.01 |



Table 3. Bunch mass, cycle time and yield per annum over three crop cycles, according to cultivar and type of planting material. P = plant crop; R1 and R2 = first and second ratoon cycles. n.s. = non- significant

| Treatment | Bunch mass (kg) | | | Planting to harvest and harvest to harvest (months) | | | Bunch yield/annum (t ha$^{-1}$annum$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | P | R1 | R2 | Pt-H(P) | H(P)-H(R1) | H(R1)-H(R2) | P | R1 | R2 |
| **Cultivars (main plots)** | | | | | | | | | |
| Williams | 40.7 | 44.2 | 42.8 | 19.8 | 13.8 | 15.6 | 54.7 | 86.1 | 73.4 |
| Dwarf Cavendish | 36.3 | 41.3 | 38.1 | 19.3 | 13.6 | 15.6 | 50.2 | 81.1 | 65.1 |
| Grand Nain | 39.8 | 44.1 | 42.0 | 19.6 | 13.8 | 15.3 | 54.4 | 85.4 | 73.3 |
| Significance | P<0.001 | n.s. | P<0.05 | P<0.05 | n.s. | n.s. | P<0.01 | n.s. | n.s. |
| L.S.D. (P=0.05) | 1.49 | | 3.04 | 0.30 | | | 2.00 | | |
| **Planting materials (sub-plots)** | | | | | | | | | |
| 2 kg suckers (CON) | 35.3 | 39.9 | 39.0 | 20.1 | 14.2 | 15.7 | 46.9 | 75.0 | 66.4 |
| 200 mm TC | 41.4 | 45.0 | 42.8 | 19.7 | 13.0 | 15.4 | 56.1 | 92.4 | 74.2 |
| 500 mm TC | 39.9 | 44.7 | 41.1 | 18.9 | 14.0 | 15.4 | 56.4 | 85.3 | 71.1 |
| Significance | P<0.001 | P<0.001 | P<0.05 | P<0.001 | P<0.001 | n.s. | P<0.001 | P<0.001 | P<0.05 |
| L.S.D. (P=0.05) | 1.10 | 2.50 | 2.31 | 0.36 | 0.46 | | 1.69 | 5.38 | 5.09 |
| Interaction | n.s. | n.s. | n.s. | P<0.01 | n.s. | n.s. | P<0.05 | n.s. | n.s. |

Table 4. Summary of percentage annual yield increases with TC plants over CON plants according to cultivar and crop cycle. For TC yields, the data for sub-plot 2 (200 mm plants) and sub-plot 3 (500 mm plants) are combined

| Crop cycle | Cultivars | | | Mean |
|---|---|---|---|---|
| | Williams | Dwarf Cavendish | Grand Nain | |
| Plant crop (P) | 11.9 | 28.6 | 20.8 | 20.4 |
| First ratoon (R1) | 20.6 | 22.3 | 12.8 | 18.6 |
| Second ratoon (R2) | 15.5 | 8.7 | 4.7 | 9.6 |
| P + R1 + R2 cumulative | 15.0 | 19.4 | 13.0 | 15.8 |



pronounced, especially in the R1. The average annual yield increase with TC over CON for the entire study was 15.8%.

**Somaclonal Mutations**

The overall mutation rate on 1700 TC plants surveyed at flowering, was 1.76%. However, visible mutations were discarded before planting. On the section in which plants less than 100 mm tall were established, the mutation was 9.6%, due evidently to identification difficulties before planting. The most frequent mutation type was characterised by narrow leathery leaves which were speckled with green and black blotches. The petioles were also more striated than usual. Other plants exhibited slight to medium dwarfing and it was unclear whether such plants were dwarf mutants or just somewhat delayed in development.

## Discussion

Under the conditions of this trial, bunch mass and yield/annum were clearly superior with TC plants. This was manifested in terms of more hands/bunch, more fingers/hand and a shorter cycle time to harvest. The bunch mass advantages are, in turn, thought to be due to the physiological efficiency of TC plants which leads to the development of taller and thicker plants, capable of setting large bunches. Eckstein and Robinson (1993) demonstrated that TC plants had a higher photosynthetic rate, dry matter assimilation rate and root growth, than CON plants, and that this persisted for several months after planting. Further evidence that TC plants are larger than CON plants in the first cycle, was shown by Israeli et al. (1986), Daniells (1988) and Drew and Smith (1990).

The shorter cycle time advantage of TC in the first cycle can be ascribed to the establishment of whole plants, with a vigorous root system and a physiologically-efficient leaf area which can function immediately after planting. CON plants, on the other hand, have to develop roots and leaves from the underground rhizome, and these plants can only start photosynthesising 4 to 6 weeks after planting. Thus, the larger TC plants (500 mm) with a greater functional leaf area at planting, reached harvest stage nearly a month earlier than the smaller TC plants (Table 3).

The overall yield increase of 20.4% with TC plants in the first cycle was obtained from a summer planting. Israeli, et al. (1986) also found a TC yield advantage of 12% from a summer planting, but they found a yield increase of 22% in favor of CON, from a spring planting. In a multiple planting date trial in South Africa, Robinson and Fraser (1992) found no such seasonal interaction with planting materials, and instead found that TC Grand Nain outyielded CON in 12 successive monthly planting dates.

A pronounced carry-over effect was obtained in this study whereby R1 suckers from TC plants produced a yield/annum of 18.6% higher than did R1 suckers from CON plants, almost matching the 20.4% increase in the first cycle. This carry-over is thought to be due to a combination of direct and indirect effects. TC plants produce ratoon suckers earlier and with greater vigor than those from CON plants (Eckstein and Robinson, 1993), thus such TC suckers also produce significantly larger R1 plants than those from CON suckers (Table 1). Secondly, these vigorous R1 suckers from TC plants were released from overhead competition up to a month earlier than CON suckers due to the earlier harvest date of TC mother plants. The same explanations could also apply, to a lesser extent, in the third cycle.

The overall mutation rate of 1.76% was considerably less than that quoted by other workers (Reuveni et al., 1985; Israeli, et al., 1986; Hwang and Ko, 1987; Stover, 1987; and Vuylsteke, et al., 1988). However, the latter studies involved up to 40,000 TC plants. The mutation rate in the present trial is considered tentative because only 1,700 plants were surveyed, severe mutants were already discarded before planting, and were thus not counted, and only obvious dwarfs were counted as mutants. This aspect needs further intensive evaluation in respect of cultivar and clone variability, degrees of dwarfism, early identification at the nursery stage, and year to year variation using large numbers of plants.

An economic analysis has shown that a 20% increase in yield is required with TC plants in the first cycle in order to recover the increased costs of planting material and more intensive early management. However, yield carry-over effect such as obtained in this study, confirms the use of TC planting material as a cost-effective recommendation, provided soil and management are optimal.



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