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Effect of Banana (*Musa* AAA cv. Williams, Cavendish Subgroup) Planting Material on Plant Growth and Yield over Eight Crop Cycles

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ABSTRACT

A field experiment was conducted over eight crop cycles comparing whole water suckers (WWS) without root and leaf pruning with tissue-cultured (TC) plants, both planting materials with or without nematicide application on plant growth and yield variables. Averaging the eight crop cycles, TC plants produced heavier (P = 0.0005) bunches with greater number of hands (P = 0.0003) than those originated from WWS plants. The nematicide application did not affect any of those variables in any of both planting materials. Follower sucker height, girth and its number of broad leaves at flower emergence of its mother plant were similar in both planting materials and not affected by the nematicide application. Ratooning index did not differ between planting materials. Bunch weight (P = 0.0001), fruit tick (P = 0.0001), number of fruits in the second hand (P = 0.0001) and leaves at harvest (P = 0.0001) and ratooning index (P = 0.0001) differed among ratoon crops. The percentage of missing plants was higher (P < 0.0331) in WWS plants during the R0, R1 and R2. Between plants treated or untreated with nematicide the percentage of missing plants was similar and low. TC plants had lower *R. similis* than WWS, without differing between nematode control methods, and in the WWS the nematicide application resulted in 53% less nematodes (P < 0.0001) compared to the untreated control. The results encourage continuing with the use of tissue culture plants in areas new to bananas or replanting areas where the fruit is for export markets. However, for domestic consumption or even in plantations where the fruit is advocated to export markets, but if there are restrictions of TC plants by cost or availability, the results obtained with WWS show high potential for their use in frequently replanting areas, especially those areas sowing at high plant densities, where the demand of planting material is high. The WWS health should be improved taken them from plantations free of nematodes in order to reduce the nematode potential infection.

Keywords: bunch weight, nematodes, raatoning, root weight, suckers

INTRODUCTION

Banana for export markets is produce in large scale commercial plantations. For domestic consumption, the fruit is produced in small backyard plots or in small farms, where bananas are planted as a shade of coffee or mixed with other crops. Before, bananas for export markets were originated mainly by sucker peeled corms, bits, suckers-derived plants established in plastic bags, all of which are known as conventional or traditional planting material, and nowadays by tissue culture (*in vitro*) plants. For domestic consumption, any type of traditional planting material is used including whole suckers without leaf and root pruning. Independently of the planting material, cultivars are grown perennially whereby successive crops are derived from shoots (suckers) emerging from lateral buds located at the base of the main plant in the previous crop (Soto *et al*. 1992).

The propagation by traditional planting material is laborious, with very low multiplication rates and slow regeneration cycles of new suckers (Fonsah and Chidebelu 1995). Plants originated from tissue culture have six advantages (Fonsah *et al*. 2007) over traditional planting material: plants can be rapidly multiplied from a mother plant of known and superior genetic features, plants are free of soil borne pathogens, plants will be true-to-type and conform to the characteristics of the mother plant, plants have a better survival rate, a higher yield and shorter plant crop, and finally, plants show uniform growth, resulting in synchronized harvest dates (Stover 1987; Pérez *et al.* 1992).

Reddy and Kummar (2000) found that bananas of the Cavendish subgroup (*Musa* AAA, 'Dwarf Cavendish' and 'Robusta' originated from *in vitro* plants gave a higher yield and were more vigorous than those plants from rhizomes. Similarly, Fonsah *et al.* (2007) found that *in vitro* banana 'Grande Naine', 'Williams' and 'Zelig' cultivars from the Cavendish subgroup gave higher yield than sword suckers with roots trimmed. Furthermore, Eckstein and Robinson (1995), with banana from the Cavendish subgroup (*Musa* AAA, cv. 'Williams') found that *in vitro* plants resulted in higher root mass, functional foliar area, dry matter and number of suckers than plants from rhizomes in the first 5 months of planting. In bananas cv. 'Lakatan', 'Bungulan' and 'Saba' plants originated from *in vitro* showed greater growth, have more suckers, reached flowering first and gave higher yield than plants coming from sword leaf suckers established in plastic bags (Zamora *et al*. 1989). *In vitro* plants of 'Williams', 'Cavendish Enano' and 'Grande Naine' gave 19.4, 15 and 13% higher yield in the first, second and third production cycle than plants from rhizomes, respectively (Robinson *et al*. 1993). In plantain (*Musa* AAB), whole suckers without leaf and root pruning gave similar yield to *in vitro* plants (Grisales 1999; Rojas and Vargas 2002).

All these advantages of *in vitro* plants have encouraged their use in new areas to bananas or replanting areas advocated to export markets. Those plantations are managed as a perennial crop or with renovations every 5 to 10 years. However, this planting material is not feasible for small growers that use the fruit as a food or for domestic markets.

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Original Research Paper

Strategies for banana production that includes high plant densities (Patel *et al*. 2000; Premalatha *et al*. 2000; González 2007) with more frequent replanting (Figueroa *et al*. 1990; Pérez 1999) like that used for plantain (*Musa* AAB) (Belalcázar 1991; Vargas 1994) are nowadays of great interest due to its profit (Robinson 1996).

This approach may have potential for banana production. However, the high demand and cost of the planting material in this potential banana production system motivated the comparison in yield and plant growth of two propagation planting materials: whole water sucker without leaf and root pruning (WWS) and tissue-cultured (TC) plants thought eight crop cycles.

MATERIALS AND METHODS

The experiment was developed from October 2002 to July 2007 considering 8 crop cycles (R0-R7) in the CORBANA Research Station situated in the Costa Rican Caribbean coast at 40 masl. The average annual rainfall from 2002 to 2007 was of 3058 mm evenly distributed throughout each year. The highest rainfall (5026 mm) was in 2002 and the lowest (2607 mm) in 2007. The temperature is fairly constant throughout the year with an average of 26°C. The average annual absolute maximum and minimum temperatures were 31.4 and 21.4°C respectively, and the average daily relative humidity was about 88%.

The field had been under banana FHIA-01 and FHIA-02 (*Musa* AAAB) tetraploid hybrids for the last four years. Then, land was conformed in three domes from 20-23 m wide and 48-51 m long. Under these conditions, the sedimentary soil showed a pH of 6.4, extractable acidity of 0.2, 1.4% of organic matter, and Ca 25.2, Mg 10.9 and K 0.6 cmol L^{-1} and P 22, Fe 395, Cu 8, Zn 2 and Mn 61 mg L^{-1}.

The cultivar sown was 'Williams' (*Musa* AAA Cavendish subgroup) and the type of planting material used in the treatments were: whole water sucker without leaf and root pruning (WWS) treated or untreated with nematicide that were obtained from a ratoon crop within a commercial banana plantation and tissue culture plants (TC) also treated or untreated with nematicide. The plant height for the sowed plants were 19.2 ± 5 and 19.8 ± 3.6 cm, pseudostem girth 19.5 ± 3.4 and 21 ± 2.4 mm, and number of broad leaves 5.3 ± 1 and 6 ± 0.8 leaves for WWS and TC plants, respectively. Plants were arranged in double row with 1.5 m between rows, 2.0 m between plants and 3.5 m between double rows which resulted in 2000 plants ha^{-1}.

Plants from the four treatments were distributed in a Complete Block Design with six replicates. Each dome was split lengthwise into two sections and in each section a block with the four treatments was set up. Each experimental plot consisted of 24 production units from which the 16 centre were the experimental unit.

The experiment was not irrigated. Fertilizer 413 kg N, 92 kg P_2O_5, 510 kg K_2O, and 110 kg S ha $year^{-1}$ was applied around the succeeding suckers, through 17 times each year. Weeds were controlled by hand, and glyphosate sprayed as necessary. Leaf fungi, especially black Sigatoka (*Mycosphaerella fijiensis* Morelet), were controlled by terrestrial spraying with a mist blower (Stihl ®SR400) with 30 l ha^{-1} of a mixture of fungicides (alternative use of mancozeb, tridemorph, propiconazole) and miscible oil (Spraytex®) or water about every 10 days. Deleafing was done weekly to reduce the pressure of black Sigatoka inoculum.

Twenty weeks after planting, all the emerged suckers were killed through injection with kerosene. Then, after emerging of new shoots, one sucker was selected from each mat. The selected sucker was that, kept within the line of the original sowing pattern removing the others. In the first ratoon and thereafter until the end of the experiment, desuckering was done every 6 to 8 weeks throughout each crop cycle, and the follower sucker selected was the first that emerged in a position that kept the line of the planting pattern. In general, each production unit consisted of a bunch-bearing mother plant and a large follower sucker and in few cases also with a small granddaughter or peeper.

In the treatments with nematode control, non-fumigant nematicides were used. The application was done when 3 or 4 plants from the experimental plot were sampled. Fifteen nematicide applications were done during the experimental time alternating the molecules according to its chemical and physical properties, and biodegradation potential. Root samples were taken in the mother plant for root and nematode content. From each experimental unit, 3 to 4 mother plants at flower emergence were sampled in each crop cycle. Sampled plants differed among crop cycles. For taking the root samples, a hole of 15 cm long, 15 cm wide and 30 cm depth (soil volume of 6750 cm^3) was dug in front of each plant with a shovel. The roots originated from this specific soil volume were used for determining the weight (g) of total, functional and non-functional roots. Functional roots were those that had no necrosis or root decay as opposed to non-functional roots. In some roots it was necessary to cut some damaged parts, which were classified as non-functional roots. The remaining part was functional root.

Nematodes were extracted from 25 g of fresh functional roots, which were macerated in a kitchen blender (Taylor and Loegering 1953 method modified by Araya 2002) for 10 sec at low and 10 sec at high speed, and the resulting mixture was washed from the blender through a series of nested sieves of 0.25/0.106/0.025 mm (No 60/140/500 mesh sieves). The residue on the 0.25 and 0.106 mm mesh was discarded and that on the 0.025 mm mesh washed off into a 250 ml beaker and the nematodes were counted from 2 ml aliquots as described in Araya (2002). The number of *R. similis*, *Helicotylenchus* spp., *Meloidogyne* spp., *Pratylenchus* spp. and total nematodes (sum of the four genera) were expressed per 100 g or roots.

At flower emergence, plant height (m) measured from the ground level to the neck of the inflorescence, pseudostem girth (cm) measured at the plant base, number of hands per bunch and number of leaves, were registered. Bunch bagging was carried out one week and dehanding (two hands removal) two weeks after flower emergence. Harvesting took place 84 ± 2 d after bunch bagging and bunch weight (kg), fruit thick (mm) of the centre fruit of the outer line of the second hand, number of fruits in the second hand and number of leaves were registered. In each production unit**,** at flower emergence of the mother plant, it was measured in its follower sucker: plant height (m), pseudostem girth (cm) at the plant base and the number of broad leaves counted. Ratooning index (flower emergence to flower emergence in the same production unit) was estimated dividing the number of days of the year (365) by the number of days between two successive flower emergences. This allowed the ratooning time between the plant crop and first ratoon (R0-R1), first ratoon to second ratoon (R1-R2) and subsequent flower emergence cycles to be calculated. The percentage of missing plants in each cycle was recorded.

Growth and yield data were analyzed considering a factorial structure of two planting materials (WWS and TC plants) x two nematode controls (with and without application of granular nematicide). Contrasts between planting materials and nematode control for each variable were tested. The percentage of missing plants was studied through logistic regression using Genmod procedure (PC-SAS) and then contrasts between planting materials and nematode control was run for each crop cycle. Root weight and nematode counts were analyzed as a trifactorial structure of two propagative materials x two nematode controls × 8 crop cycles. Nematode counts were log transformed before analysis in order to homogenize variances. The first two factors were randomized to experimental units while crop cycles were not.

RESULTS

No interaction ($P > 0.2941$) of treatments by crop cycle was observed for all growth and yield variables measured in the mother plant and those growth variables measured in the follower suckers. Then, data for each variable is presented separately, first by treatments and thereafter by crop cycles.

Averaging the eight crop cycles, mother plants originated from TC plants were higher ($P = 0.0229$), thicker ($P < 0.0001$) and gave greater number of hands ($P = 0.0003$) at flower emergence than those coming from WWS plants (**Table 1**). However, those differences in plant height and pseudostem girth are negligible in the practice. No differences ($P = 0.1360$) in the number of leaves at flower emergence were observed between those planting materials. The nematicide application did not affect any of those variables

Table 1 Mean of growth variables measurements at flower emergence and probabilities of contrasts of banana (*Musa* AAA, cv. 'Williams') plants propagated by whole water suckers (WWS[1]) or tissue culture (TC) plants treated or un-treated with granular nematicide.

Planting materials	**Plant height (m)**	**Pseudostem thickness (cm)**	**Number of hands**	**Number of leaves**
WWS plants with nematicide	3.26	27.4	9.6	12.2
WWS plants without nematicide	3.18	26.8	9.6	12.2
Average	3.22	27.1	9.6	12.2
TC plants with nematicide	3.31	28.2	10.1	12.3
TC plants without nematicide	3.19	28.2	10.1	12.4
Average	3.25	28.2	10.1	12.4
Standard error	0.003	0.182	0.050	0.016
			Probabilities of contrasts	
WWS plants vs TC plants	0.0229	0.0001	0.0003	0.1360
With vs without nematicide	0.1614	0.1296	0.9987	0.6437
			Probabilities of interaction	
Planting materials × nematicide	0.3115	0.2294	0.5378	0.7903

1 = without leaf and root pruning. Each value is the mean of 48 observations (6 repetitions × 8 ratoon crops).

Table 2 Mean of banana (*Musa* AAA cv. 'Williams') yield variables measured at harvest and probability of contrasts of whole water suckers (WWS[1]) or tissue culture (TC) plants treated or un-treated with nematicide.

Planting material	**Bunch weight (kg)**	**Fruit thick (mm) in the second hand**	**Number of fruits in the second hand**	**Number of leaves**
WWS plants with nematicide	25.6	34.2	21.1	4.7
WWS plants without nematicide	25.0	34.1	21.4	4.7
Average	25.3	34.2	21.3	4.7
TC plants with nematicide	27.1	34.3	21.6	4.7
TC plants without nematicide	27.3	34.3	21.7	4.6
Average	27.2	34.3	21.7	4.7
Standard error	0.861	0.038	0.288	0.016
			Probabilities of contrasts	
WWS plants vs TC plants	0.0005	0.0587	0.1482	0.5049
With and without nematicde	0.6584	0.3125	0.5309	0.9227
			Probabilities of interaction	
Planting material × nematicide	0.3280	0.2209	0.5658	0.0286

1 = without leaf and root pruning. Each value is the mean of 48 observations (6 repetitions × 8 ratoon crops).

Table 3 Mean of growth variables, ratooning index and probabilities of contrasts of banana (*Musa* AAA cv. 'Williams') follower suckers from whole water sucker (WWS[1]) or tissue culture (TC) plants treated or un-treated with nematicide.

Treatments	**Follower sucker**			**Ratooning index**
	Pseudostem		**Number of broad leaves**	
	Height (m)	**Girth (cm)**		
WWS plants with nematicide	1.30	14.5	2.0	1.61
WWS plants without nematicide	1.28	14.3	2.0	1.59
Average	1.29	14.4	2.0	1.60
TC plants with nematicide	1.26	14.1	1.7	1.62
TC plants without nematicide	1.30	14.4	2.1	1.60
Average	1.28	14.3	1.9	1.61
Standard error	0.002	0.116	0.005	0.000
			Probabilities of contrasts	
WWS vs TC plants	0.7508	0.4854	0.4951	0.4315
With and without nematicide	0.6215	0.7783	0.1084	0.2519
			Probabilities of interaction	
Planting materials × nematicide	0.1665	0.1579	0.1141	0.7300

1 = without leaf and root pruning. Each value is the mean of 48 observations (6 repetitions × 8 ratoon crops).

in any of both planting materials.

TC plants produced heavier (P = 0.0005) bunches than those originated from WWS plants (**Table 2**). The central fruit thickness of the outer line and the number of fruits of the second hand, and the number of leaves at harvest did not differ between those planting materials. The nematicide application did not affect any of those yield variables in any of both planting materials.

Follower sucker height, girth and its number of broad leaves at flower emergence of its mother plant were similar in both planting materials (**Table 3**). Ratooning index did not differ between planting materials. None of those variables were affected by the nematicide application in any of both planting materials.

Mother plant height (P = 0.0001), pseudostem girth (P = 0.0001), number of hands in the bunch (P = 0.0032) and number of leaves at flower emergence (P = 0.0001) differed among ratoon crops (**Fig. 1A-D**). Plant height, pseudostem girth and hands per bunch increased up to the second ratoon, thereafter stabilized, while the number of leaves at flower emergence reached the peak since the plant crop and started to decrease until the third ratoon, and thereafter seems to stabilize.

Bunch weight (P = 0.0001), fruit thickness (P = 0.0001), number of fruits in the second hand (P = 0.0001) and leaves at harvest (P = 0.0001) differed among ratoon crops (**Fig. 2A-D**). Bunch weight increased up to first ratoon crop and thereafter was very homogeneous throughout the other ratoon crops. Fruit thickness in the second hand was similar in the plant crop and first ratoon crop, then decreased slowly up to the fifth ratoon and thereafter seems to stabilize. The number of fruits in the second hand increased up to the second ratoon crop and thereafter was very homogeneous. The leaves at harvest decreased from the plant crop to the fourth ratoon crop and thereafter tends to stabilize.

Follower sucker height (P = 0.0001), its pseudostem girth (P = 0.0001), and its number of broad leaves (P = 0.0001) at flower emergence of its mother plant differed

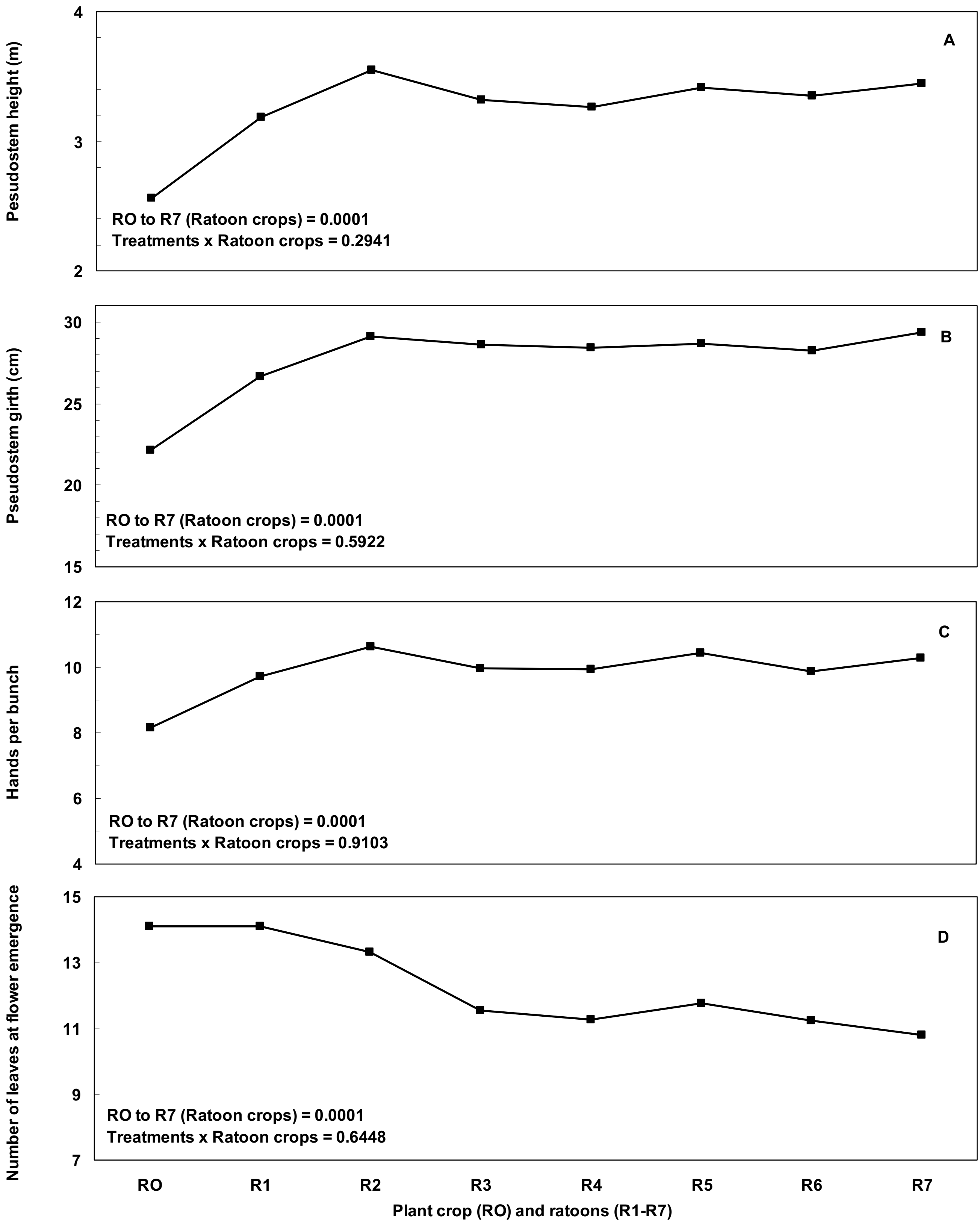

Fig. 1 Average of whole water suckers (WWS) and tissue culture (TC) plants with or without nematicide application of plant height, pseudostem girth, number of leaves, and hands per bunch at flower emergence of banana (*Musa* AAA cv. 'Williams') mother plants over eight crop cycles.

among ratoon crops (**Fig. 3A-D**). Ratooning index (P = 0.0001) among ratoon crops also differed. Follower sucker height and its pseudostem girth increased up to the first ratoon crop and thereafter tend to stabilize. The number of broad leaves in the follower sucker was erratic among ratoon crops without a defined tendency. Ratooning index was also erratic; increasing up to the first ratoon crop, then decreased in the second and starts increasing again up to the fifth ratoon crop and then tends to stabilize.

No interaction of planting material × nematicide was found for the percentage of missing plants. The percentage of missing plants was higher ($P < 0.0331$) in WWS plants during the R0, R1 and R2. Between plants treated or untreated with nematicide the percentage of missing plants was similar and low (**Table 4**).

Differences in plant propagative material for *R. similis* per 100 g of fresh roots depends on nematode control (interaction of plant propagative material × nematode control, P

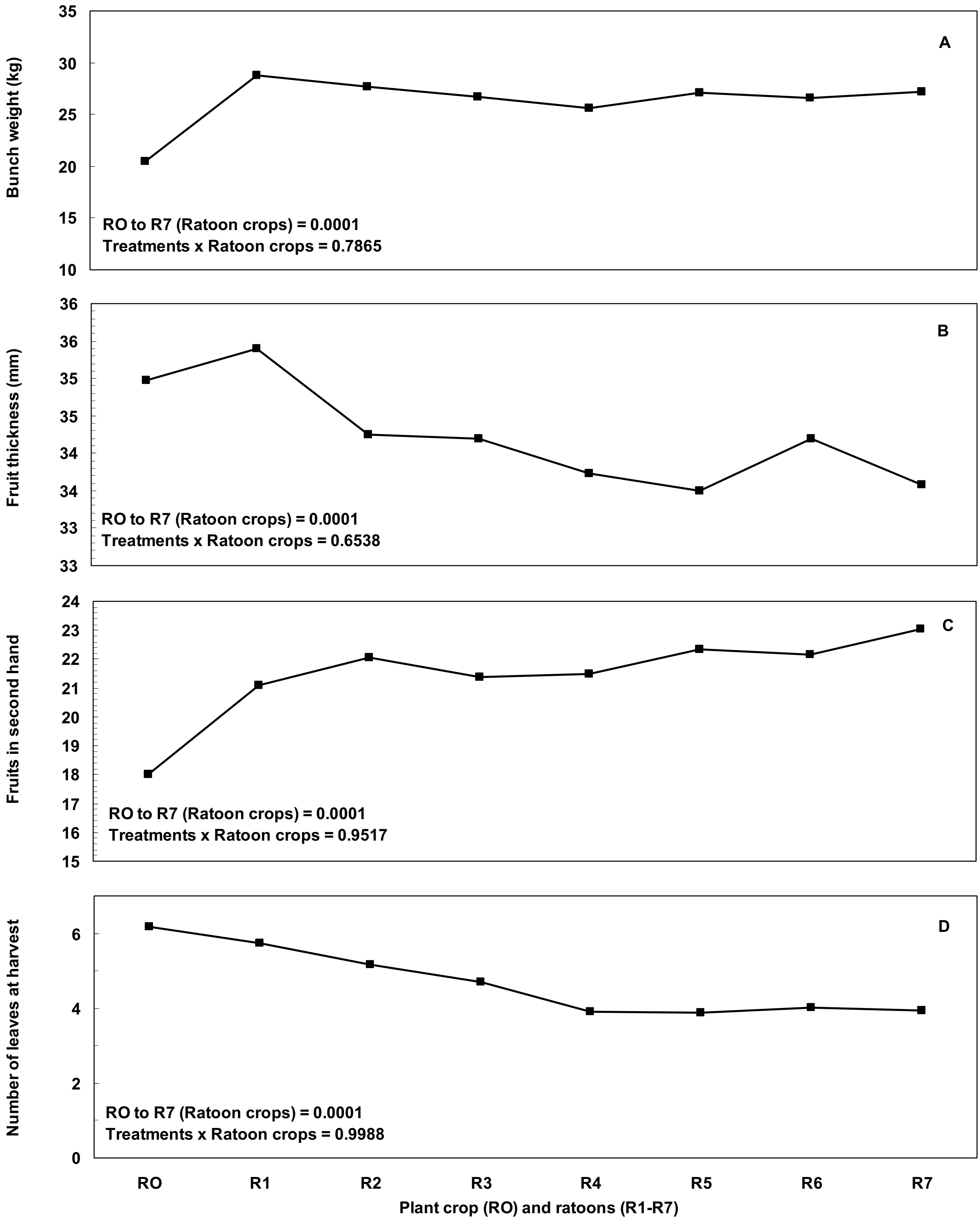

Fig. 2 Average of whole water suckers (WWS) and tissue culture (TC) plants with or without nematicide application of bunch weight, fruit tick, number of fruits and number of leaves at harvest of banana (*Musa* AAA cv. 'Williams') mother plants over eight crop cycles.

= 0.0067). The interaction was induced because TC plants had lower *R. similis* than WWS, without differing between nematode control methods, and in the WWS the nematicide application resulted in 53% less nematode ($P < 0.0001$) compared to the untreated control (**Table 5**). In total nematodes per 100 g of fresh roots, WWS had three times more nematodes ($P < 0.0001$) than TC plants. The nematicide application did not reduce the total nematode population of TC plants, but it reduced ($P = 0.0038$) in 49% the population of the WWS plants. Total root and functional root weight were similar between propagative materials and nematode control methods (**Table 5**).

Differences among planting materials, averaging over nematicide treatments, appeared after the third crop cycle (R3) for *R. similis* ($P < 0.0040$) and for total nematodes ($P < 0.0064$) after the R4 (**Table 6**). In *R. similis* and total nematodes the WWS plants had from 3 to 14 and from 3 to 6 times more nematodes than TC plants, respectively. In total ($P = 0.0058$) and functional ($P = 0.0002$) root weight only in the R7, higher (25 and 39%) root content was ob-

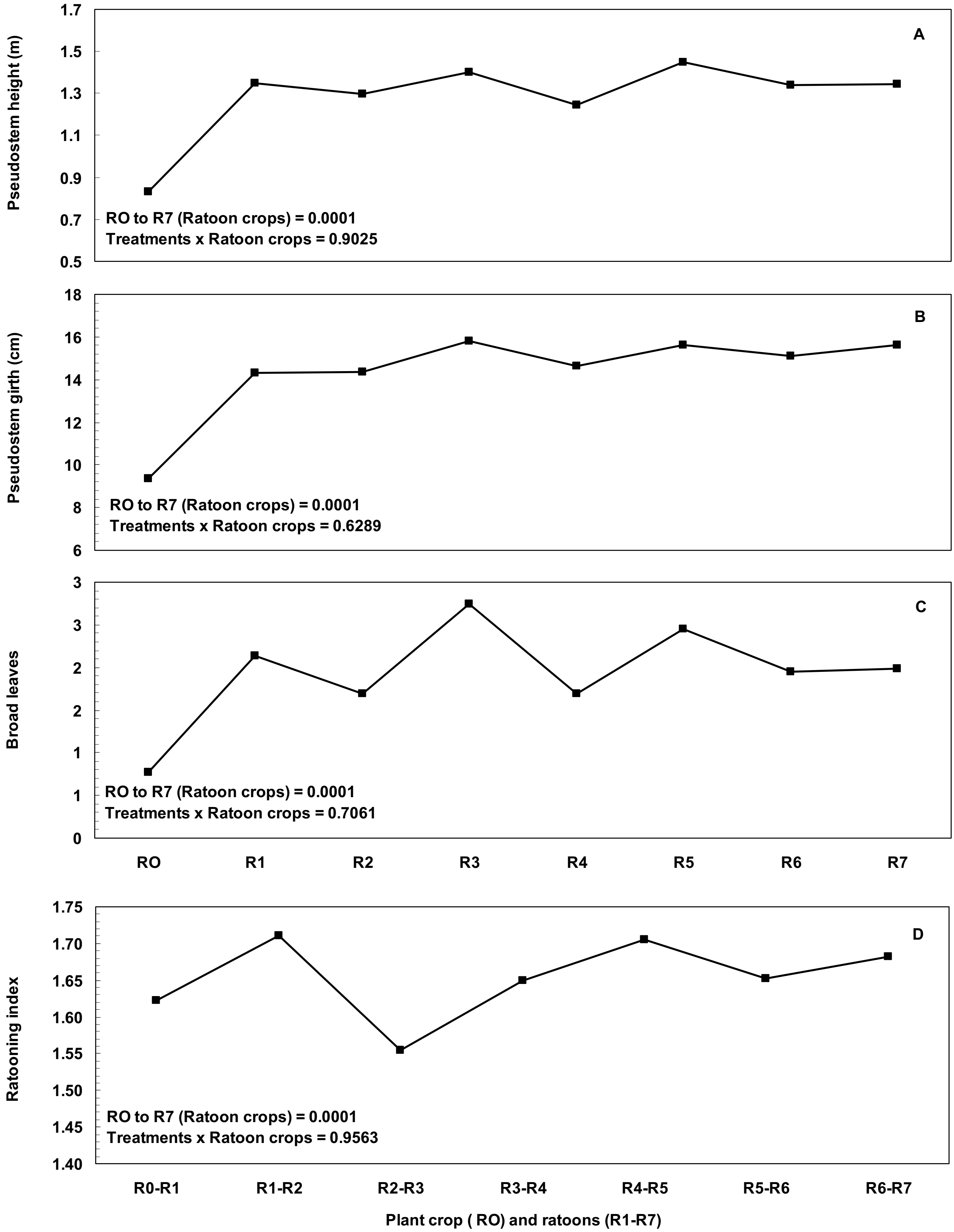

Fig. 3 Average of follower sucker from whole water suckers (WWS) and tissue culture (TC) plants with or without nematicide application of pseudostem height and girth, and number of broad leaves at flower emergence of its mother banana (*Musa* AAA cv. 'Williams') plants and rationing index over eight crop cycles.

tained in the TC propagated plants.

Considering the effect of the nematicide application, averaging over planting materials, on total and functional root weight the response was erratic (**Table 7**). In the R2 ($P < 0.0476$) ratoon crop lower root content was observed with the nematicide application, while in the R7 ($P < 0.0049$) the application increased the root content. In *R. similis* numbers, small reductions were observed in all the ratoon crops with the use of nematicide, but none was significant ($P > 0.0551$). In total nematodes, reductions were observed also in all the ratoon crops, but it was significantly only in the R1 ($P = 0.0031$), R4 ($P = 0.0162$) and R5 ($P = 0.0396$), varying from 52-83%.

Table 4 Percentage (%) of banana (*Musa* AAA cv. 'Williams') missing plants coming from whole water suckers (WWS[1]) or tissue culture (TC) treated or un-treated with nematicide.

Treatments	**Crop cycles**							
	RO	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
WWS plants with nematicide	11	2	1	0	3	0	1	3
WWS plants without nematicide	21	2	5	2	1	2	4	1
Average	16.0	2.0	3.0	1.0	2.0	1.0	2.5	2.0
TC plants with nematicide	2	0	0	0	0	0	0	0
TC plants without nematicide	2	0	1	2	2	1	1	0
Average	2.0	0	0.5	1.0	1.0	0.5	0.5	0
	Probabilities of contrasts							
WWS vs TC plants	0.0001	0.0181	0.0820	1.0000	0.2062	1.0000	0.1021	0.0331
With and without nematicide	0.5172	1.0000	0.0820	0.0181	0.3419	0.5000	0.1021	1.0000
	Probabilities of interaction							
Planting materials × nematicide	0.5172	1.0000	0.5687	1.0000	0.0494	1.0000	0.5300	1.0000

1 = without leaf and root pruning. Each value is the mean of 96 observations (16 experimental units by plot × 6 replications)

Table 5 Means (average of eight crop cycles) of fresh root (g) and nematode numbers per 100 g of fresh roots in plants propagated by whole water sucker (WWS[1]) or tissue culture (TC) treated or un-treated with nematicide.

Plant material	**Nematicide**	**Total root weight**	**Functional root weight**	***Radopholus similis***	**Total nematodes**
WWS	No	79.3	67.5	12913	14181
	Yes	74.0	66.0	6046	7223
TC	No	80.6	71.7	1709	3478
	Yes	79.0	70.6	2055	3421
Estimated standard error		± 2.4	± 2.2	± 1123	± 1122

1 = without leaf and root pruning. Each value is the mean of 48 observations (6 repetitions × 8 ratoon crops).

Table 6 Means (average of plants treated and untreated with nematicide) of fresh root (g) and nematode numbers per 100 g of fresh roots per crop cycle.

Crop cycle	**Planting material**	**Total root weight**	**Functional root weight**	***Radopholus similis***	**Total nematodes**
R0	WWS	107.5	96.3	249	899
	TC	101.1	90.6	454	2039
R1	WWS	100.5	92.3	2312	3404
	TC	113.3	103.4	33	1158
R2	WWS	71.4	64.3	3108	5717
	TC	68.8	60.9	103	3706
R3	WWS	61.4	51.7	6403	7726
	TC	56.1	49.3	461	2086
R4	WWS	60.6	54.3	5267	6796
	TC	60.4	53.6	455	1385
R5	WWS	66.9	56.9	15292	16069
	TC	67.6	59.5	4054	5922
R6	WWS	71.8	57.5	20685	21770
	TC	79.5	67.4	6134	7471
R7	WWS	73.2	60.7	22519	23235
	TC	91.8	84.3	3363	3825
Estimated standard error		± 4.7	± 4.4	± 2213	± 2210

TC = tissue culture plants, WWS = whole water sucker without leaf and root pruning obtained from a ratoon crop. Each value is the mean of 96 observations (6 repetitions, in each 3-4 plants were samples × 8 ratoon crops × 2 nematode control (with and without nematicide).

Table 7 Means (average of tissue culture and whole water sucker plants) of fresh root (g) and nematode numbers per 100 g fresh roots per crop cycle.

Crop cycle	**Nematicide**	**Total root weight**	**Functional root weight**	***Radopholus similis***	**Total nematodes**
R0	No	110.3	97.9	546	1469
	Yes	98.2	88.9	157	1470
R1	No	116.0	104.4	2254	3925
	Yes	97.8	91.3	29	637
R2	No	77.8	68.8	2501	5684
	Yes	62.4	56.4	709	3740
R3	No	57.6	48.3	3721	4673
	Yes	59.8	52.8	3143	5140
R4	No	61.8	54.4	4129	5514
	Yes	59.2	53.5	1593	2667
R5	No	66.3	56.6	15101	16743
	Yes	68.3	59.7	4246	5248
R6	No	77.6	62.4	14647	16374
	Yes	73.6	62.5	12173	12867
R7	No	72.2	63.7	15591	16255
	Yes	92.8	81.3	10292	10806
Estimated standard error		± 4.7	± 4.4	± 2213	± 2210

Each value is the mean of 96 observations (6 repetitions, in each 3-4 plants were sampled x 8 ratoon crops x 2 planting materials.

DISCUSSION

The lower bunch weight and number of hands per bunch observed in the whole water sucker (WWS) without leaf and root pruning compared to tissue culture (TC) plants are consistent with those results found by Espino *et al.* (1992), Robinson *et al.* (1993), Reddy and Kumar (2000), Zamora *et al*. (1989), Ekstein and Robinson (1995), and Fonsah *et* *al*. (2007) when they compared other type of traditional planting materials with TC plants. No difference in fruit thickness was observed which agrees with Reddy and Kumar (2000) who found the same results comparing sucker corms with TC of cv. 'Williams'. The number of fruits in the second hand was similar between WWS and TC plants which corroborates with the results of Zamora *et al*. (1989) when they evaluated sword leaf sucker established in plastic bags with TC plants, but disagrees with Reddy and Kumar (2000) who found more fruits with TC plants.

TC plants were taller and thicker than WWS overall the eight crop cycles which is on line with Fonsah *et al*. (2007) who found the same results comparing other type of traditional planting materials with TC plants over six crop cycles. Those results also agree with Espino *et al*. (1992), Robinson *et al*. (1993), Eckstein and Robinson (1995), Reddy and Kumar (2000), who compared other type of traditional planting materials with TC plants during the plant crop or one, two or three crop cycles.

Both planting materials (WWS and TC) had similar number of leaves at flower emergence and harvest, which should mean that they have potentially similar photosynthetic rate at this stage. However the differences in bunch weight and number of hands may come from different dry-matter assimilation rate and root growth rate, due to the physiological efficiency of TC, since it is known that these plants have more root mass (Robinson *et al*. 1993, Eckstein and Robinson 1995). The similarity in the number of leaves at flower emergence and harvest for WWS and TC plants is reasonable since the WWS was planted keeping all the leaves present. On the contrary, Espino *et al*. (1992), Robinson *et al*. (1993), Eckstein and Robinson (1995), Reddy and Kumar (2000) found that TC plants reached harvest earlier and with more leaves than traditional planting material, which is also reasonable because they planted suckers or corms free of roots and leaves, which means that they need to renew root and leaf production.

According to Zamora *et al*. (1989), Espino *et al*. (1992), Robinson *et al*. (1993), Reddy and Kumar (2000) that earlier harvest of the plant crop results also in an earlier harvest of the follower crop. In this trial, no difference in ratooning index was obtained between WWS and TC plants which was expected because the WWS were sowed with roots and leaves. For the same reason no differences in the follower sucker growth variables were observed between WWS and TC plants in the overall of the eight crop cycles.

In the WWS tested in this trial, roots and leaves were kept while in the traditional planting materials roots and leaves are pruned. Although all of these planting materials are rich in stored carbohydrates, our WWS keep the root system for early nutrient uptake and leaf area for assimilation. This consideration is important only for the plant crop, because number of fruits and fruit thickness in the second hand, follower sucker growth variables and ratooning index was similar between both planting materials which disagreed with Espino *et al*. (1992), who found an earlier harvest of the follower crop with TC plants compared to sucker-derived plants.

The higher percentage of missing plants found with WWS, mainly in the plant crop (16%), agrees with Hazarika *et al*. (2000) who found 52% in that type of material when comparing with other traditional planting materials. WWS plants were lost because in some of them the upper portion (above ground surface) dried out and died. Although at planting of both materials, soil humidity should be at field capacity, WWS may suffer more stress from transplanting, since it does not have substrate. The WWS survivability may be improved using taller and thicker material, an aspect that needs to be further evaluated.

Through the eight crop cycles yield and growth variables trend of WWS and TC plants was similar which was supported by the absence of interaction between planting material × crop cycle. From the studied variables only number of leaves at flower emergence and harvest were reduced from the plant crop up to R3 and R4, respectively, which is congruent with Villalobos *et al*. (2002) who working with several Cavendish cultivars, 'Williams' included, reported a reduction in the number of leaves at both stages as crop cycle increased from R0 to R2.

Bunch weight, number of hands and number of fruits in the second hand was no reduced as crop cycle increased which disagrees with Fonsah *et al*. (2007) who found a decline in those variables after the third crop cycle using other type of traditional planting material. In this trial, the reduction observed in fruit thickness with crop cycle more likely was related with the small increase in the number of fruits in the second hand.

As was expected, nematodes were detected when sowed plants were sampled at flower emergence of the plant crop and ratoon crops. That area was cultivated with *Musa* AAAB cv. FHIA-01 and FHIA-02 which are known as a host of banana root nematodes (Moens *et al*. 2005). *Radopholus similis* and total nematodes were recorded in both planting materials which probably means that the soil was infested with nematodes. Higher number of nematodes in WWS plants should be due to the infection of the planting material sowed, since those plants comes from a plant crop of a commercial banana plantation were nematodes have been detected. The nematicide application reduced the number of nematodes in the WWS plants, but not in TC plants mainly because the nematode populations were very low in both treated and untreated plants. High populations of *R. similis* and total nematodes were registered after the R4, but did not affect the bunch weight, since it was very stable after the first ratoon crop. TC plants showed a higher root content than WWS plants in the plant crop (R0) and first ratoon crop (R1) which agrees with Robinson *et al*. (1993), Eckstein and Robinson (1995), Robinson (1996), but thereafter were erratic.

The results encourage continuing with the use of tissue culture plants in areas new to bananas or replanting areas where the fruit is for export markets. However, for domestic consumption or even in plantations where the fruit is advocated to export markets, but are limited by restrictions of TC plants by cost or availability, the results obtained with WWS show potential for their use in frequently replanting areas, especially those areas sowing at high plant densities, where the demand of planting material is high. The WWS health should be improved by taking them from plantations free of nematodes in order to reduce the nematode potential infection.

REFERENCES

Araya M (2002) Metodología utilizada en el laboratorio de nematología de CORBANA S.A. para la extracción de nematodos de las raíces de banano (*Musa* AAA) y plátano (*Musa* AAB). *CORBANA* **28**, 97-110

Belalcázar S (1991) *El cultivo del plátano en el trópico*. Manual de Asistencia Técnica No. 50. Instituto Colombiano de Investigación (ICA), Centro Internacional de Investigaciones para el desarrollo CIID (IDCR), Comité Departamental de Cafeteros del Quindío, Red para el Mejoramiento del Banano y el Plátano (INIBAP-LAC), 375 pp

Eckstein K, Robinson J (1995) Physiological response of banana (*Musa* AAA; Cavendish sub-group) in the subtropics. IV. Comparison between tissue culture and conventional planting material during the first month of development. *Journal of Horticultural Science* **70**, 549-559

Espino RRC, Pascua OC, Magnaye LV, Loguias L (1992) Perfomance of tissue culture and sucker-derived planting materials of banana cv. Cardaba, Latundan and Lakatan. *Acta Horticulturae (ISHS)* **321**, 226-248

Figueroa A, Molina M, Pérez L (1990) Cultivos alternos para controlar nematodos en renovación de plantaciones bananeras. *ASBANA* **14**, 19-26

Fonsah EG, Adamu CH, Okole B, Mullinix B (2007) Field evaluation of Cavendish banana cultivars propagated either by suckers or by tissue culture over six crop years in the tropics. *Fruits* **62**, 205-212

Fonsah EG, Chidebelu SN (1995) *Economics of Banana Production and Marketing in the Tropics*, Minerva Press, London, UK, 230 pp

González M (2007) Evaluación de un programa de producción anual de banano (*Musa* AA) en altas densidades de siembra en la vertiente Atlántica del Caribe de Costa Rica. In: J. Sandoval (Ed) *Informe Anual 2007*, Corporación Bananera Nacional, San José, Costa Rica, 2008, 129 pp

Grisales F (1999) Comparación agronómica entre tipos de semilla en el plátano Dominico Hartón (*Musa* sp. Grupo AAB). *InfoMusa* **8**, 29-29

Hazarika DN, Singh RKD, Mohan NK (2000) Establishment and growth on banana suckers after planting. In: Sing HP, Chadha KL (Eds) *Proceedings of the Conference on 'Challenges for Banana Production and Utilization in 21st Century'*, AIPUB/NHB/INIBAP, Trichy, India, 1996, pp 314-316

Moens T, Araya M, Swennen R, De Waele D (2005) Screening of *Musa* cultivars for resistance to *Helicotylenchus multicinctus*, *Meloidogyne incognita*, *Pratylenchus coffeae* and *Radopholus similis*. *Australasian Plant Pathology* **34**, 299-309

Perez L (1999) Renovación de plantaciones de banano y su relación con la presencia de raíces sanas y producciones altas. *CORBANA* **25**, 211-216

Pérez L, Acuña P, Ruiz E, Escalant JV (1992) Posición taxonómica, clasificación y mejoramiento genético de los clones de banano. In: Soto M (Ed) *Bananos. Cultivo y Comercialización* (2nd Edn), Litografía e Imprenta Lil, S.A, Costa Rica, pp 139-210

Patel CB, Patel DB, Patel AN (2000) High-density plantation in relation to growth, yield and quality of banana cv. Basrai under south Gujarat conditions. In: Sing HP, Chadha KL (Eds) *Proceedings of the Conference on 'Challenges for Banana Production and Utilization in 21st Century'*, AIPUB/NHB/INIBAP, Trichy, India, 1996, pp 310-313

Premalatha T, Menon R, Pillai J (2000) Effect of plant densities on growth and yield in banana var. Palayankodan (*Musa* AAB). In: Sing HP, Chadha KL (Eds) *Proceedings of the Conference on 'Challenges for Banana Production and Utilization in 21st Century'*, AIPUB/NHB/INIBAP, Trichy, India, 1996, pp 275-278

Reddy BMC, Kumar V (2000) A field comparation of conventional suckers with *in vitro* derived planting material on banana cultivars Dwarf Cavendish and Robusta. In: Sing HP, Chadha KL (Eds) *Proceedings of the Conference on 'Challenges for Banana Production and Utilization in 21st Century'*, AIPUB/NHB/INIBAP, Trichy, India, 1996, pp 242-246

Robinson JC (1996) *Bananas and Plantains*, CAB International, Wallingford, UK, 238 pp

Robinson J, Frasier C, Eckstein K (1993) A field comparison of conventional suckers with tissue culture banana planting material over three crop cycles. *Journal of Horticultural Science* **69**, 831-836

Rojas S, Vargas A (2002) Rebrotes enteros: nueva opción de semilla en el cultivo de plátano de alto rendimiento. In: Rosales F, Pocasangre L (Eds) *Oferta Tecnológica de Banano y Plátano para América Latina y el Caribe*, INIBAP, MUSALAC, CEDAF, San José, Costa Rica, pp 27-28

Soto M, Soto E, Solís P, López A (1992) Siembra y operaciones de cultivo. In: Soto M (Ed) *Bananos. Cultivo y Comercialización* (2nd Edn), Litografía e Imprenta Lil, S.A, Costa Rica, pp 211-365

Stover RH (1987) Somaclonal variation in Gran Naine and Saba bananas in the nursery and field. In: Persley G, De Langhe E (Eds) *Bananas and Plantain Breeding Strategies*, Proceedings of an International Workshop, Cairns, Australia, 1986, ACIAR Proceedings 21, pp 136-137

Taylor LQ, Loegering WQ (1953) Nematodes associated with root lesions in abaca. *Turrialba* **3 (1-2)**, 8-13

Vargas A (1994) Validación de tecnología de producción para alto rendimiento del plátano Curraré o Falso Cuerno (*Musa* AAB), en el Atántico de Costa Rica. *CORBANA* **19**, 17-24

Villalobos C, Pérez L, Sandoval J (1992) Caracterización vegetativa y productiva de ocho cultivares de banano del subgrupo Cavendish (*Musa* AAA). *CORBANA* **28**, 13-26

Zamora AB, Damasco OP, Estaño ES, Barba RC, Pateña LF (1989) Growth and yield of micropropagated and sucker-derived banana plants (*Musa* spp., cvs. Lakatan, Bungulan and Saba). *The Philippine Agriculturist* **72**, 458-465