Preplant Fumigation for Citrus Nematode Control in Florida[1]

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Abstract: Preplant soil fumigation experiments were conducted to control the citrus nematode, *Tylenchulus semipenetrans*. Generally, D-D (1,3-dichloropropene, 1,2-dichloropropane and related chlorinated C_3-hydrocarbons), Telone (1,3-dichloropropene and related chlorinated C_3-hydrocarbons), Telone PBC (80% 1,3-dichloropropene, 15% chloropicrin, 5% propargyl bromide), and EDB (ethylene dibromide) controlled *T. semipenetrans* effectively for 4 years. The trials involved four scion varieties, two rootstock varieties and three soil types. Tree growth and yield were increased with application of D-D at 374 or 561 liters/ha (40 or 60 gal/acre) or Telone at 299 or 449 liters/ha (32 or 48 gal/acre) in broadcast and strip treatments. *Key Words:* Nematicides, chemical control, *Tylenchulus semipenetrans*.

The citrus nematode, *Tylenchulus semipenetrans* Cobb was reported to be an important problem in Florida citrus (6) and was found in approximately 53% of citrus groves in Florida (10). *T. semipenetrans* also causes considerable damage to citrus in California and Arizona (1, 8, 11). Preplant soil fumigation in California (2, 3, 4) and in other citrus-growing areas (5, 7, 9, 12) controlled the citrus nematode effectively and increased growth of trees.

The parasite feeds on citrus roots, causes reduced growth rate of young trees, tree debilitation, lowers fruit yield, and reduces fruit quality. *T. semipenetrans* is not endemic in soils but is distributed primarily by infected nursery stock. When infected trees are removed from a grove, infective stages of the parasite remain in the soil for several years and may infect replant trees.

This paper reports the results of several field experiments in Florida on control of *T. semipenetrans* and tree response following preplant application of soil fumigants.

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[2] Nematologists, Agricultural Research Service, U.S. Department of Agriculture, Orlando, Florida 32803, and University of Florida A.R.E.C., Lake Alfred 33850, respectively. We wish to acknowledge that the first three experiments were planned and applied by C. I. Hannon who terminated his position with the Lake Alfred A.R.E.C. shortly thereafter and to express our thanks to F. W. Bistline for his cooperation. Mention of trademark name or a proprietary product does not constitute a guarantee or warranty of the product by the USDA, and does not imply its approval to the exclusion of other products that may be suitable.

MATERIALS AND METHODS

Experiments were established in fields formerly planted to citrus trees and infested naturally with the citrus nematode. Soil fumigants, 1,3-dichloropropene, 1,2-dichloropropane mixture (D-D®), 1,3-dichloropropene and related chlorinated C_3-hydrocarbons (Telone®), dichloropropenes 80%, chloropicrin 15%, and propargyl bromide 5% (Telone PBC®), or ethylene dibromide (EDB) (Dowfume W-85®) were used as indicated in each experiment. Fumigants were injected 25.4 cm (10 inches) deep into the soil. After chemical application, the soil was leveled and compressed with a cultipacker. Yield data are expressed as boxes of fruit per tree (10.9 kg or 90 lb. of fruit per box).

Experiment 1: This experiment was conducted in a Florida east coast Felda fine sand (1.7% clay, 2.4% silt, 95.9% sand, 1.8% organic matter). D-D was applied at rates of 187, 374 and 561 liters/ha (20, 40 and 60 gal/acre) in plots 5.5 m (18 ft) wide and 28.7 m (94 ft) long. Injection chisels were spaced 30.5, 45.7 or 60.9 cm (12, 18 or 24 inches) apart. Each treatment, including the nontreated control, was replicated three times.

In March 1964, 10 months after chemical application, seven 'Queen' orange [*Citrus sinensis* (L.) Osb.] trees on 'Cleopatra' (*C. reticulata* Blanco) rootstock were planted 3.9 m (12.5 ft) apart in single-row plots 9.1 m (30 ft) apart. Tree height, trunk diameter [measured 15.2 cm (6 inches) above the bud union], number of citrus nematodes per gram of root [determined by an incubation method (13)] and yield of fruit was recorded annually for 3 years.

Experiment 2: This part of the study was conducted in a central Florida Lakeland fine sand (1.8% clay, 1.9% silt, 96.3% sand, 1.0%

organic matter). The old infected trees were removed 1 year prior to application of chemicals. D-D was applied at rates of 561, 842 and 1123 liters/ha (60, 90 and 120 gal/acre), and Telone at 449, 674 and 898 liters/ha (48, 72 and 96 gal/acre) respectively, in plots that were 8.8 m (29 ft) wide and 30.5 m (100 ft) long. Chisels were spaced 30.5 cm (12 inches) apart. Each treatment, including a nontreated control, was replicated four times.

In February 1964, 21 months after treatment, four 'Temple' orange trees on 'Cleopatra' rootstock were planted 7.6 m (25 ft) apart in single-row plots 7.6 m (25 ft) apart. Data were recorded, as in Experiment 1, annually for 4 years.

Experiment 3: This experiment was conducted in a Felda fine sand similar to Experiment 1. D-D was applied at rates of 187, 374 and 561 liters/ha (20, 40 and 60 gal/acre), Telone at 150, 299 and 449 liters/ha (16, 32 and 48 gal/acre) and EDB at 47, 94 and 140 liters/ha (5, 10 and 15 gal/acre) respectively, in plots 5.5 m (18 ft) wide and 28.7 m (94 ft) long. Chisels were spaced 45.7 cm (18 inches) apart. Scion/rootstock combination, plot design and data collected were the same as in Experiment 1.

Experiment 4: This part of the investigation was conducted in another central Florida Lakeland fine sand (1.9% clay, 2.0% silt, 96.1% sand, 1.5% organic matter). D-D was applied at rates of 374 and 561 liters/ha (40 and 60 gal/acre) and Telone PBC at 299 and 449 liters/ha (32 and 48 gal/acre), respectively. Chisels were spaced 40.6 cm (16 inches) apart. Two methods of chemical application were used: (i) broadcast, entire area of two rows 15.2 X 38.1 m (50 X 125 ft) treated, and (ii) a strip, 3.8 m (12.5 ft) wide centered on each of the two rows within plots 7.6 X 38.1 m (25 X 125 ft) was treated. All treatments were replicated three times.

In July 1966, 6 weeks after treatment, eight 'Orlando' tangelo (*C. paradisi* Macf. X *C. reticulata* Blanco) trees on 'Cleopatra' rootstock were planted, four in each row, in two-row plots with 7.6 X 7.6 m (25 X 25 ft) spacing between trees and rows. Trunk circumference, foliar volume [determined by multiplying the tree height (H) by the tree canopy width squared (W^2) and dividing the product by four $\left(\frac{H \times W^2}{4}\right)$], and number of nematodes per gram root were recorded annually for 5 years.

Experiment 5: This experiment was conducted on the east coast of Florida. The soil was a shallow, poorly drained Leon loamy sand that contained 7.5% clay, 6.2% silt, 86.3% sand and 2.3% organic matter. Because of seasonal high water tables, raised beds with drainage ditches on each side were prepared before planting. Each bed was 18.3 m (60 ft) wide and accommodated two rows of trees. Beds were divided into plots 30.5 m (100 ft) long with five plots per bed. D-D was applied at rates of 187 and 374 liters/ha (20 and 40 gal/acre), and Telone PBC at rates of 150 and 299 liters/ha (16 and 32 gal/acre) respectively. Chisels were spaced 40.6 cm (16 inches) apart. Chemicals were applied as follows: (i) broadcast, the entire plot 18.3 X 30.5 m (60 X 100 ft) treated, and (ii) strip, 4.6-m (15-ft) wide strip centered on each of the two rows within the plots 9.1 X 30.5 m (30 X 100 ft) was treated with only the high rate of each chemical. All treatments were replicated three times.

In December 1966, 8 weeks after chemical soil treatment, 10 'Marsh' grapefruit trees (*C. paradisi* Macf.) on sour orange (*C. aurantium* L.) rootstock were planted in each two-row plot with five trees per row. Trees were spaced 6.1 m (20 ft) apart and rows were 9.1 m (30 ft) apart. Trunk circumference, foliar volume and number of nematodes per gram of root were recorded annually for 5 years.

RESULTS AND DISCUSSION

Experiment 1: Figure 1 shows that D-D suppressed the number of *T. semipenetrans* per gram of root for 4 years after chemical application. Roots of trees in control plots had approximately 820 larvae and males/g compared with a mean of 87/g of root from trees in treated soil. This represents an 89% reduction by application of D-D. Trunk diameter of trees 4 years after chemical treatment were 2 - 18% greater than for trees on nontreated plots. Heights of trees from treated plots were 2 - 13% greater (one exception) than height of trees from control plots. The first fruit yield, recorded 3 years after planting, from five of nine fumigated plots were 15 - 165% greater than yield from control plots. Application of D-D at 561 liters/ha (60 gal/acre) rate on a 60.9-cm (24-inch) spacing resulted in the highest yield, tree height and trunk diameter.

Experiment 2: For 4 years after application of chemicals and replanting, nematode

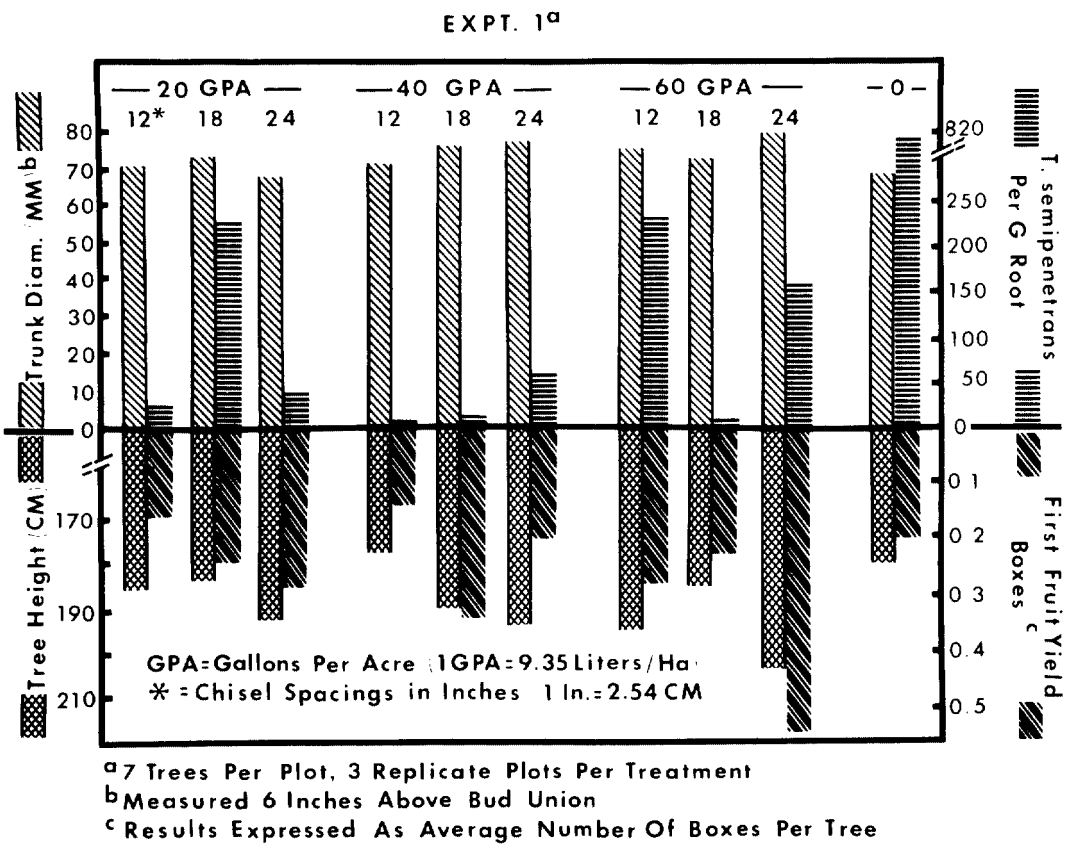

FIG. 1. Trunk diameter, tree height, fruit yield and number of *Tylenchulus semipenetrans* per gram of root in 'Queen' oranges as influenced by application of D-D at different rates and chisel spacings.

populations on roots of trees in nonfumigated plots increased at a greater rate than in fumigated plots; the mean numbers are shown in Fig. 2. Based on the number of *T. semipenetrans* per gram of root, both D-D and Telone controlled the nematode effectively at all dosage levels. Trees in all plots showed increases of 102-122% in trunk diameter the first year after planting. During the second year, the diameter of trees on fumigated plots increased 74-91% while the diameter of trees on control plots increased 73%. Tree height measurements followed this general pattern. First fruit yields were recorded 3 years after planting, but the yield was sparse and not considered normal; even so, trees on plots treated with D-D at 561 liters/ha (60 gal/acre) and Telone at 449 liters/ha (48 gal/acre) yielded 29 and 10% more fruit, respectively, than trees on nontreated plots. Second year yields (Fig. 2), harvested 4 years after planting, were considered normal and ranged from 5 - 26% more from fumigated plots than from nonfumigated plots. The highest yield came from trees on plots treated with the highest rate of D-D and Telone.

Experiment 3: Based on the number of *T. semipenetrans* per gram of root, all soil fumigants except D-D at 18.7 liters/ha (20 gal/acre) drastically reduced the nematode population 4 years after chemical application (Fig. 3). Trees on nonfumigated plots contained approximately 967 nematodes/g of root while trees on treated plots contained a mean of 48/g roots, which indicates a 95% reduction in infestation. Diameter of trees on fumigated plots were 9 - 25% greater than for trees on nonfumigated plots, while tree heights were 6 - 21% greater. Fruit yields, recorded 3 years after planting, in eight out of nine fumigant treatments were 50 - 520% greater than from trees on nonfumigated plots. Trees growing on D-D-treated plots gave the highest yields, compared with other treatments. Yield also

increased as dosage level of EDB increased. The different rates of Telone had little influence on yields in this experiment.

Experiment 4: Nematode population levels varied from year to year, but generally all fumigants controlled *T. semipenetrans* for 4 years (Fig. 4). Prevention of early infection by nematodes resulted in increased root growth and tree development. Figure 5 illustrates how trees in this experiment (kept relatively free of early nematode infection when grown in fumigated soils) reacted to drought conditions, compared to infected trees grown in nonfumigated plots under the same conditions.

Foliar volume of trees in plots that received high rates of D-D or Telone PBC broadcast were significantly larger at the 1% and 5% level of significance than nonfumigated trees during 1970 and 1971 (Fig. 4). During 1971, foliar volume of trees on treated plots increased 77 and 45% over nontreated control. Significant (P = .05) foliar increases were also obtained with the low rate of D-D compared with controls. Tree-row strip treatments with D-D or Telone PBC at the high rates resulted in significant growth increases (P = .05) of trees (Fig. 4).

Experiment 5: Control of citrus nematode persisted for 4 years in the fumigated plots. Broadcast treatments with high rates of D-D or Telone PBC resulted in highly significant (P = .01) foliar volume increases compared with tree response in the nonfumigated plots in 1970 (Fig. 6). Growth increases of these trees were 29 and 19% greater than trees in nonfumigated plots. Tree-row strip treatments resulted in significant growth increases (P = .05) of trees in these plots in 1970. In 1971, all treatments resulted in highly significant (P = .01) growth increases (Fig. 6).

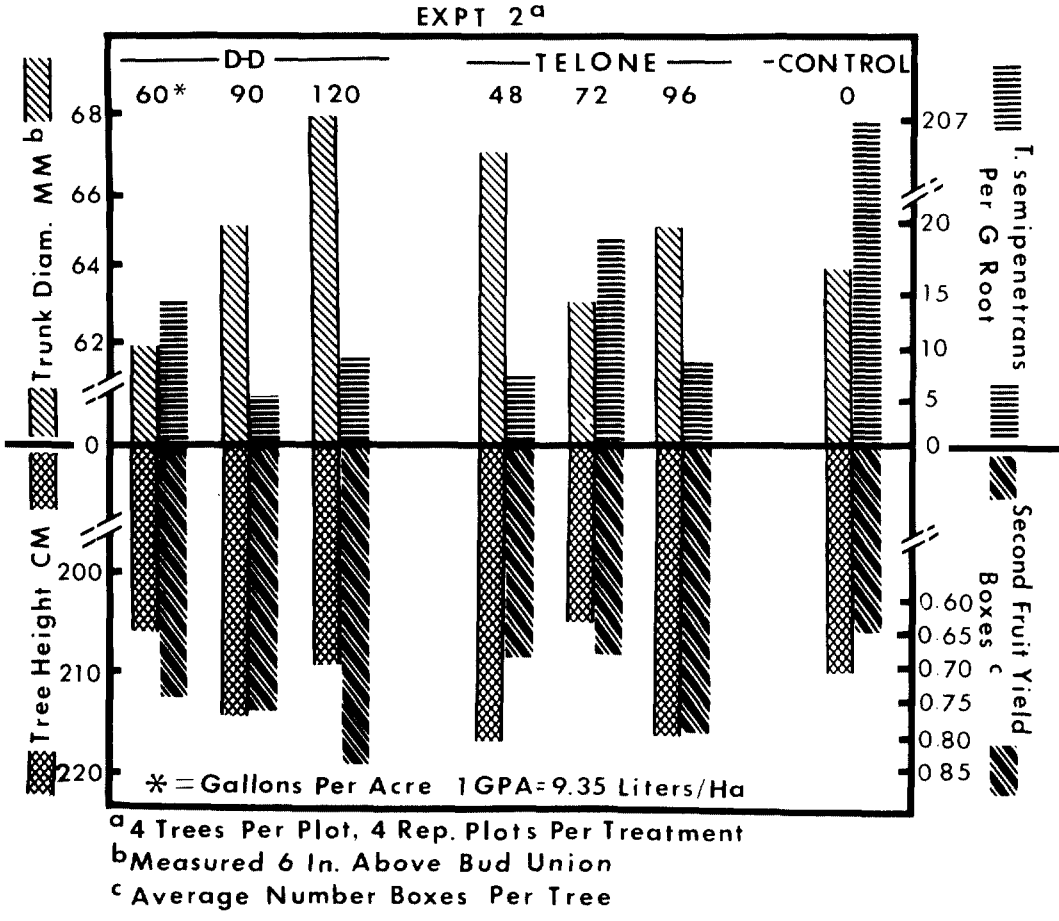

FIG. 2. Trunk diameter, tree height, fruit yield and number of *Tylenchulus semipenetrans* per gram of root in 'Temple' oranges as influenced by application of D-D and Telone at different rates.

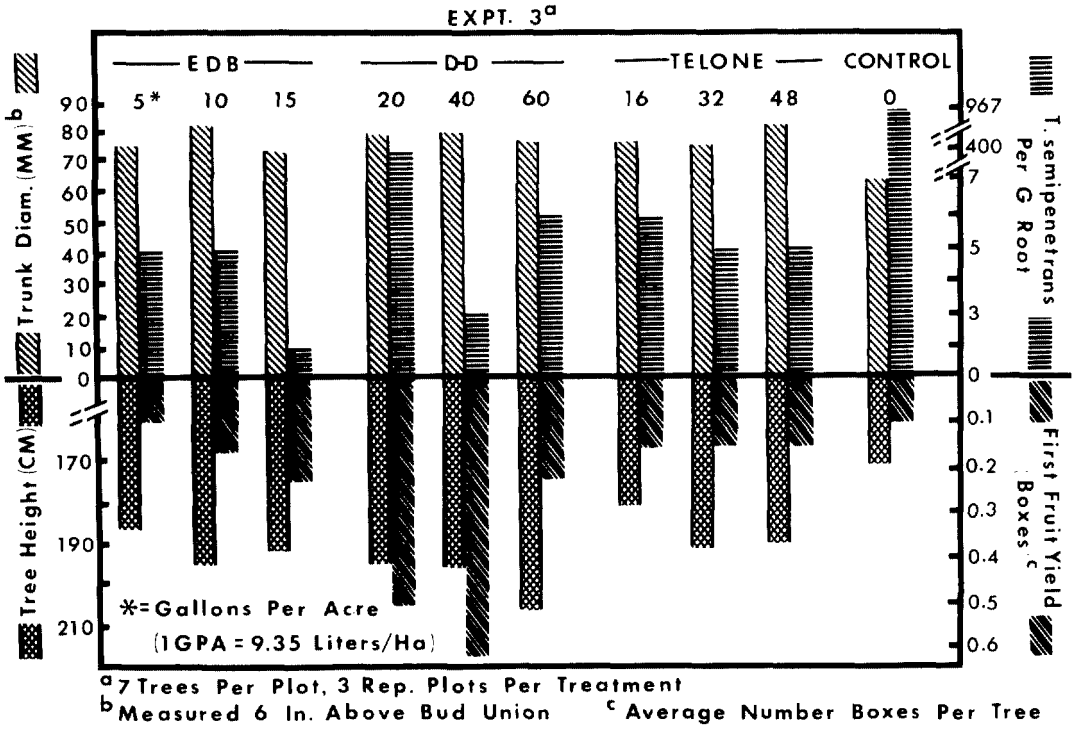

FIG. 3. Trunk diameter, tree height, fruit yield and number of *Tylenchulus semipenetrans* per gram of root in 'Queen' oranges as influenced by application of EDB, D-D and Telone at different rates.

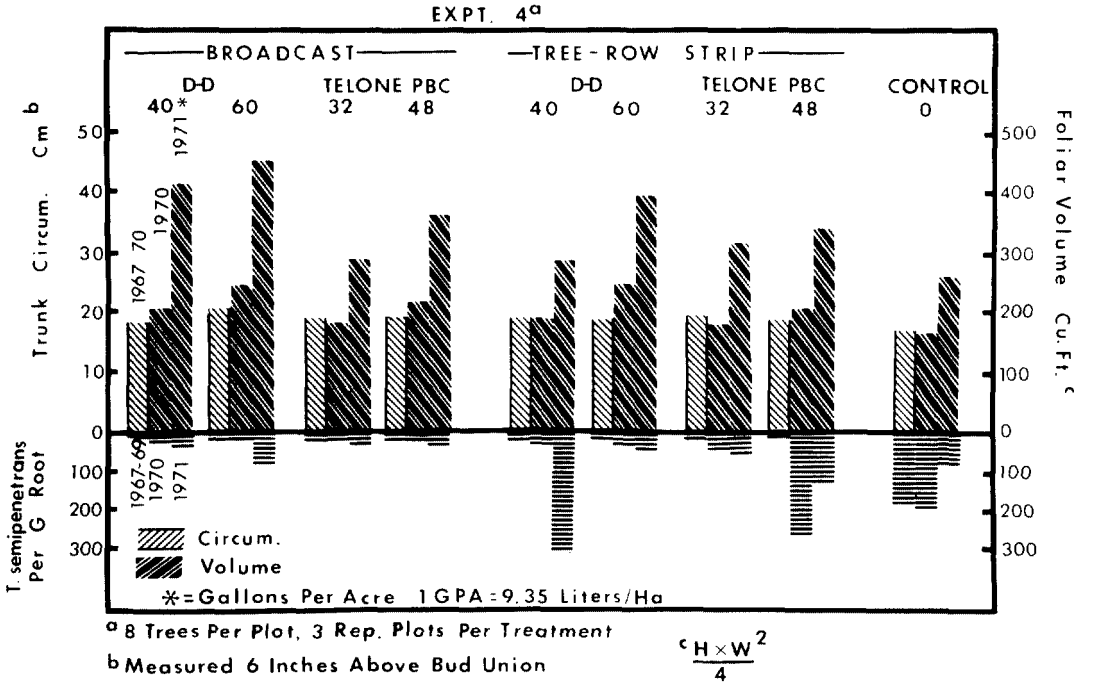

FIG. 4. Trunk circumference, foliar volume and number of *Tylenchulus semipenetrans* per gram of root in 'Orlando' tangelo as influenced by broadcast and tree-row strip application of D-D and Telone PBC.

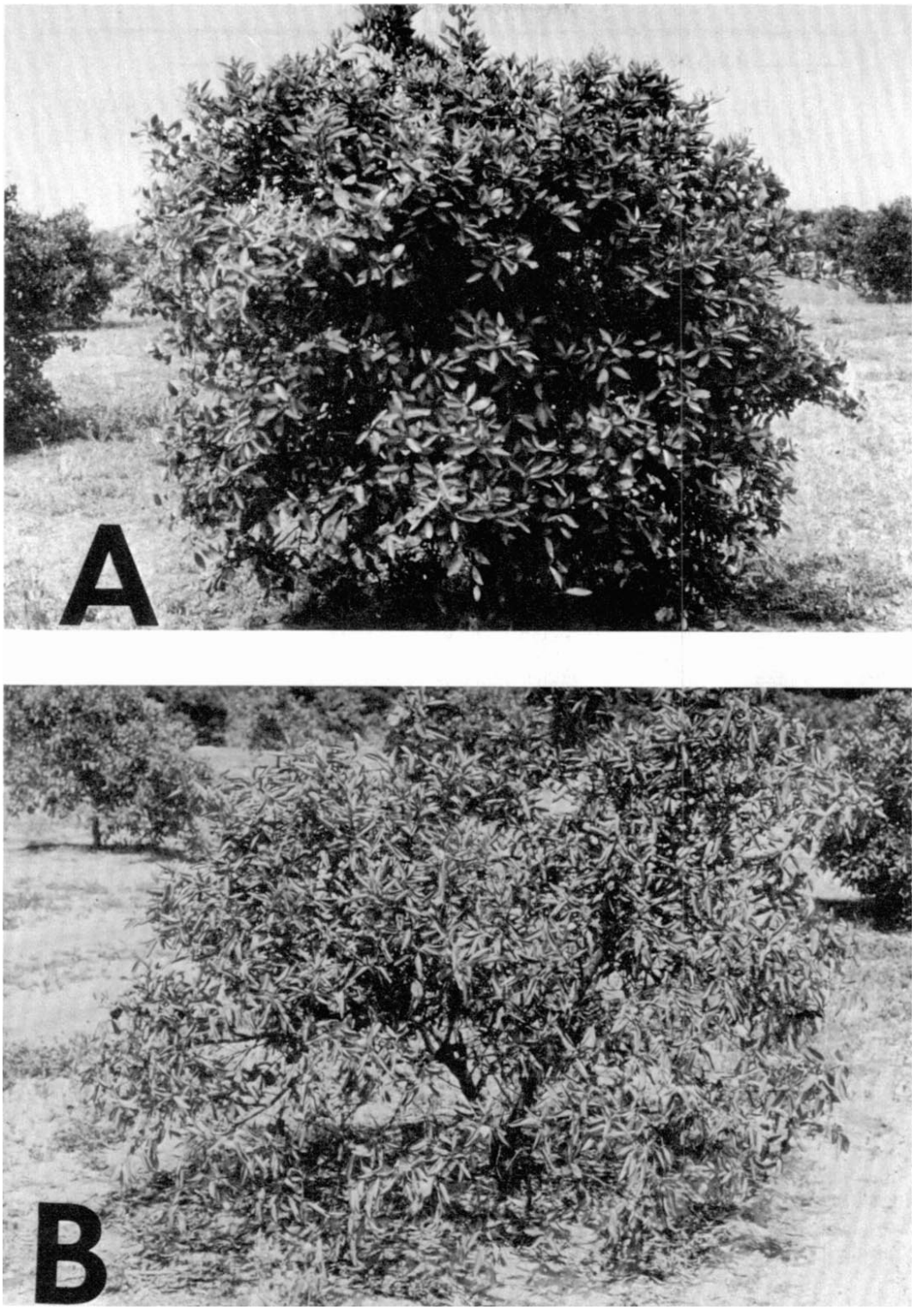

FIG. 5 (A, B). Five-year-old paired tangelo trees on 'Cleopatra' rootstock growing in fumigated and nonfumigated soil originally infested with *Tylenchulus semipenetrans.* **A.** in fumigated soil, **B.** in nonfumigated soil. (Note: Typical wilt symptoms during drought exhibited by infected tree in nonfumigated plot.)

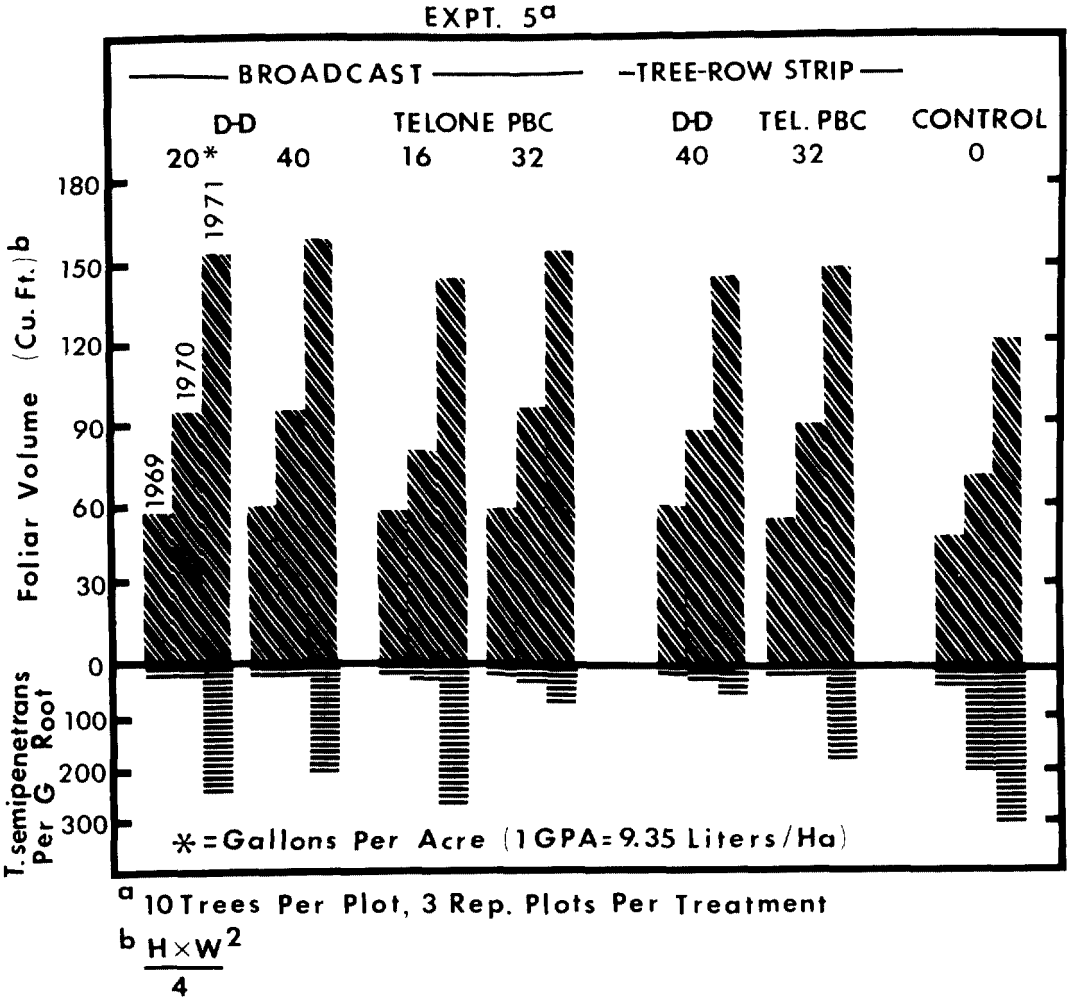

FIG. 6. Foliar volume and number of *Tylenchulus semipenetrans* per gram of root in 'Marsh' grapefruit as influenced by broadcast and tree-row strip application of D-D and Telone PBC.

These tests have proven conclusively the value of preplant fumigation in Florida for citrus nematode control. Fumigation of infested soils suppressed nematode populations for at least 4 years after treatment and resulted in significant growth increases and higher yields. In general, D-D at 374 or 561 liters/ha (40 or 60 gal/acre), or Telone at 299 or 449 liters/ha (32 or 48 gal/acre) resulted in the most favorable tree response. Strip treatment at equivalent rates showed similar responses.

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