Population Fluctuations of *Rotylenchulus reniformis* in Pineapple Fields and the Effect of the Nematode on Fruit Yield

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ABSTRACT

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Population fluctuations of *Rotylenchulus reniformis* were studied in three pineapple fields on the island of Oahu, Hawaii, in nematicide-treated and untreated plots. Soil population densities of the nematode remained low (<200/250 cm^3 of soil) for 6–9 mo after planting in all fields regardless of treatment. Nematode populations reached the carrying capacity in each pineapple field within 12 mo after planting. Numbers of *R. reniformis* decreased after flower induction but quickly resurged. Nematodes negatively affected yield. A single preplant application of 1,3-dichloropropene (337 L/ha) increased fruit yield in the first harvest over the untreated controls in all three fields. Postplant application of fenamiphos (1.1 kg a.i./ha) resulted in highest yields by the second harvest (8% more in one field and 25% more in another field). Nematode control remains imperative for economical pineapple production in Hawaii, yet the long lag phase in nematode population development that follows a new planting of pineapple perhaps could be exploited to enhance long-term control.

Additional keywords: *Ananas comosus*, reniform nematode

Several genera of nematodes are economically important plant pathogens of pineapple (*Ananas comosus* (L.) Merr.). *Meloidogyne*, *Pratylenchus*, and *Rotylenchulus* are the most damaging genera worldwide (4,5,7). *Meloidogyne javanica* (Treub) Chitwood is a significant problem on only a limited hectarage in Hawaii today, although it was the major nematode problem prior to 1950 (3). The reniform nematode, *Rotylenchulus reniformis* Linford & Oliveira, causes the greatest amount of crop loss in Hawaii. It infests nearly all of the 10,000 ha of pineapple grown in this state (1).

Current plantation practices in Hawaii are designed for the production of three fruit harvests from one planting, at roughly 18, 30, and 42 mo after planting (8). Without nematode control, the first and second ratoon crops (the second and third harvests) produce small fruit that are not economical to harvest (1,9). Nematodes are controlled by fumigation before planting with either 1,3-dichloropropene (1,3-D) or methyl bromide, followed by trimonthly applications of nonfumigant nematicides such as fenamiphos and oxamyl. Historically, nematode research for Hawaiian pineapple has focused on chemical control and not on nematode biology or temporal patterns of population change.

The temporal fluctuations of nematode populations in pineapple and subsequent effects on plant growth need to be better understood to improve nematode control. The population dynamics of *Pratylenchus* in pineapple are dependent upon soil moisture, and numbers of this nematode remain low during the dry season (4). In Australia, *M. javanica* population densities remain at low levels in pineapple fields for 6–8 mo, regardless of preplant treatments (13). Population densities of *R. reniformis* in soil remain low up to 9 mo after fumigation and planting, but then increase to the carrying capacity of the crop within a year (10). Reniform nematode population densities are negatively correlated with fruit weight (11). The population dynamics of *R. reniformis* have not been adequately described for the entire 4-yr pineapple cropping cycle.

Our objectives were: 1) to elucidate the population fluctuations of *R. reniformis* in pineapple fields under standard plantation practices with and without nematicide treatment and 2) to determine the effect of this nematode on pineapple yield.

MATERIALS AND METHODS

R. reniformis population changes were evaluated in three fields on the Del Monte Produce (Hawaii), Inc., plantation at Kunia, Oahu, Hawaii. Field 5, a silty clay loam (fine oxidic, isothermic, Ustoxic Humitropept, Inceptisol), was prepared and planted in July 1990. Field 203, a silty clay (clayey, kaolinitic, isothermic, Tropeptic Eutrastox, Oxisol), was planted in September 1990. Field 66, a silty clay loam (fine oxidic, isothermic, Ustoxic Humitropept, Inceptisol and clayey, kaolinitic, isothermic, Tropeptic Eutrastox, Oxisol), was planted in November 1990. Field 66 had been abandoned and weeds allowed to grow for 7 yr, whereas the other two fields were under a normal sequence of a 3- to 6-mo fallow period between pineapple plantings.

Standard plantation practice consisted of plowing to 60 cm deep and smoothing the soil for planting. A planting bed was formed with a drip irrigation tube and a 1-mil thick, 80-cm wide black plastic film during the preplant fumigation operation. Two weeks after fumigation, pineapple crowns were planted 25 cm apart, two rows per bed, directly through the plastic film and set with 2.5 cm of water by overhead irrigation. Flowering was induced with an ethylene treatment 14 mo after planting, and fruit were harvested 6 mo later (plant crop). Flowering was induced again about 6 mo after the plant crop harvest to repeat the cycle for a second harvest (first ratoon crop).

Replications were established in each field in randomly selected field blocks. Plots were 6.6 m wide (six beds) × 10 m long. Treatments were: 1) a single preplant fumigation with 1,3-D at 337 L a.i./ha, 2) preplant fumigation with 1,3-D at 224 L a.i./ha followed by trimonthly fenamiphos (1.1 kg a.i./ha) applications (standard plantation practice), or 3) no nematicides. Field 5 did not receive treatment 2, the standard plantation practice. Treatments were replicated three times in field 5, six times in field 203, and four times in field 66.

Nematode population densities in the soil (all vermiform stages) were assayed monthly after planting until December 1990, and then bimonthly until the experiment was terminated at the first ratoon harvest. Six soil cores were collected from 20 cm deep along the plant lines of the center two beds of each plot and composited. A 250-cm^3 soil subsample was sifted through a 1.0-cm-mesh screen, elutriated (2), and centrifuged (6) to extract nematodes.

Pineapple yield was recorded for the plant crop and first ratoon. Fruit were harvested from 200 plants from the four inside beds of each plot, graded on a fresh fruit basis, and weighed. Percentage of packable and discard fruit (underweight, overweight, multiple crown, and deformed) was calculated. Packable fruit is based upon the number of fruit required to fill an 88-kg box.

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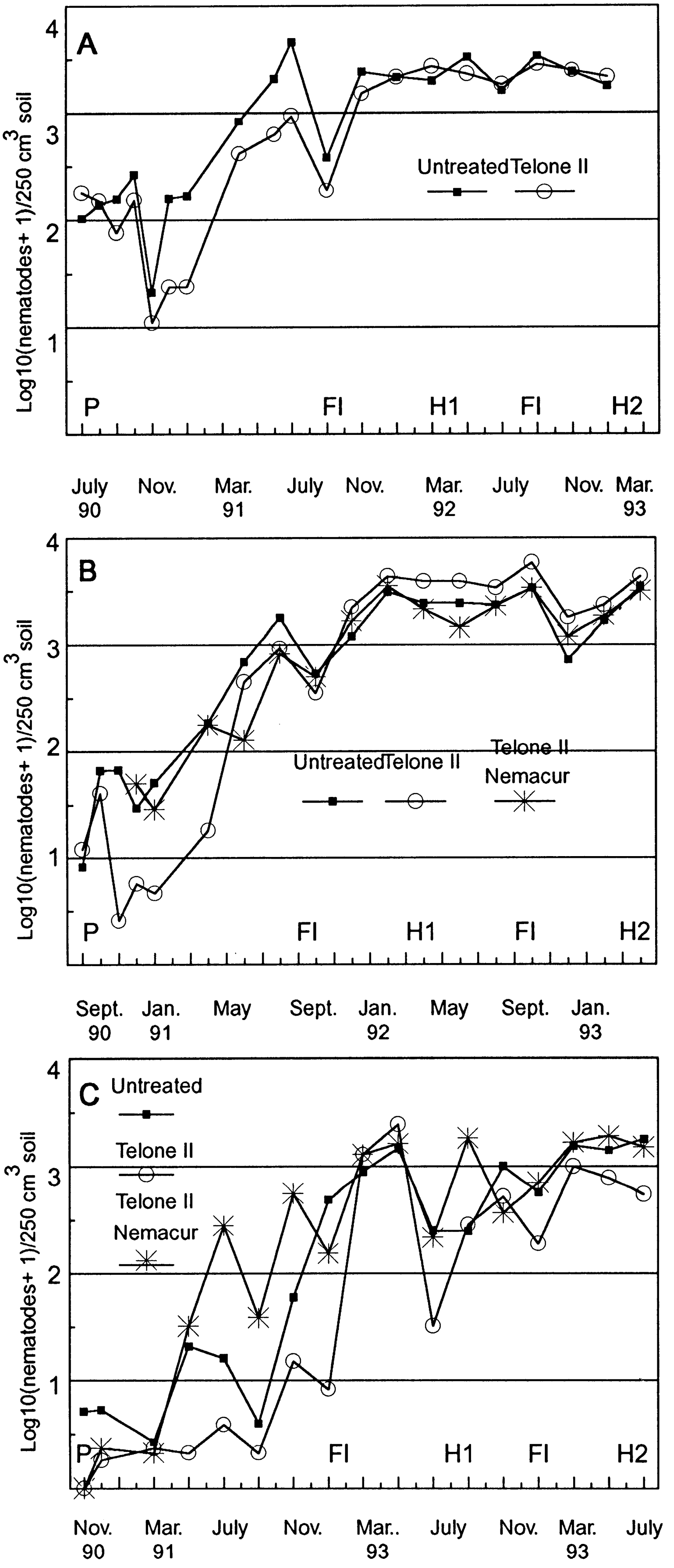

Fig. 1. Population densities of *Rotylenchulus reniformis* in pineapple from planting (P) to first ratoon harvest (H2) in **(A)** field 5, **(B)** field 203, and **(C)** field 66. Fl = flower induction, H1 = plant crop harvest.

The nematode count data (n) were $\log_{10}(n + 1)$ transformed to stabilize variance. Pearson correlation coefficients were calculated between sampling date and both plant crop and first ratoon yield. Differences in yield among treatments were tested by an analysis of variance and means separated using the Waller-Duncan k-ratio t test. Nematode population density data were plotted for each treatment. Population growth for the first 12 mo were fitted to logistic, Gompertz, and monomolecular regression models. The best fitting model was selected for each treatment in a field.

RESULTS AND DISCUSSION

Population densities of *R. reniformis* were low during the first 6–8 mo after planting, regardless of preplant fumigation or postplant nematicide application (Fig. 1). The initial population (P_i) of reniform nematode differed among the three fields. P_i was 171 nematodes per 250 cm^3 of soil in field 5, 32 nematodes per 250 cm^3 in field 203, and six nematodes per 250 cm^3 in field 66. The nematode population increased rapidly between 6 and 12 mo after planting and then changed little thereafter. It decreased following flower induction by ethylene application and resurged within 2 mo to a level considered to be the crop carrying capacity for the field (Fig. 1). Final mean nematode population densities were 2,165, 1,644, and 5,017 per 250 cm^3 of soil in fields 5, 66, and 203, respectively. The maximum number of nematodes in a plot varied among fields, ranging from >14,000 nematodes per 250 cm^3 of soil in fields 5 and 66 to nearly 25,000 per 250 cm^3 in field 203.

Because the rate of reniform nematode population increase differed only slightly between treatments in any field, data were combined. The overall population development for a field is given by the following Gompertz model equations: field 5, $\log_{10}(n + 1) = \exp[1.599 \exp(-0.112t)]$, $r^2 = 0.98$; field 66, $\log_{10}(n + 1) = \exp[1.612 \exp(-0.118t)]$, $r^2 = 0.98$; and field 203, $\log_{10}(n + 1) = \exp[1.588 \exp(-0.108t)]$, $r^2 = 0.98$, where exp = 2.178 and t = months after planting. Rates of population growth were similar among fields based upon slope values, ranging from 1.588 to 1.612.

The long lag phase (6–8 mo) associated with *R. reniformis* population increase in pineapple is similar to *M. javanica* population behavior in Australia (13) and *Pratylenchus* population increase in Africa on this crop (4). A food source does not appear to be a limiting factor, because pineapple is well rooted within a month after planting (7). Thus, an adequate food base would appear to be available for the nematodes. Still, the nematode soil population does not increase as would be expected. For *Pratylenchus*, the lag phase in nematode population development is attributed to

Table 1. Pineapple fruit weight, size, and quality data from Del Monte field 5 as influenced by *Rotylenchulus reniformis* and 1,3-dichloropropene (1,3-D)[z]

Yield parameter	Plant crop Untreated	Plant crop 1,3-D	First ratoon crop Untreated	First ratoon crop 1,3-D
Average fruit weight (kg)	1.8	2.0	1.5	1.5
Metric tons/ha	135.5	147.4	123.3	120.1
Percent packable	76.0	76.6	46.7	47.5
Marketable tons/ha	110.5	115.1	62.9	62.7

[z] Values within a crop harvest are not significant between untreated and 1,3-D treatment.

Table 2. Pineapple fruit weight, size, and quality data from Del Monte field 203 as influenced by *Rotylenchulus reniformis*, 1,3-dichloropropene (1,3-D), and fenamiphos

Yield parameter	Plant crop Untreated	Plant crop 1,3-D	Plant crop Plantation practice[y]	First ratoon crop Untreated	First ratoon crop 1,3-D	First ratoon crop Plantation practice
Average fruit weight (kg)	1.5 b[z]	1.7 a	1.8 ab	1.4 a	1.3 a	1.4 a
Metric tons/ha	103.1 b	122.0 a	121.4 ab	103.6 a	104.6 a	112.0 a
Percent packable (size 7–14)	69.8 b	81.7 a	77.3 ab	62.0 a	56.4 a	63.2 a
Marketable tons/ha	78.2 b	106.9 a	95.9 ab	70.4 a	65.8 a	76.1 a

[y] Standard plantation practice = preplant 224 L a.i. 1,3-D/ha followed by trimonthly 1.1 kg a.i. fenamiphos/ha commencing 3 mo after planting.

[z] Numbers followed by the same letter within rows of a crop harvest are not different according to the Waller-Duncan k-ratio t test ($k = 100$).

Table 3. Pineapple fruit weight, size, and quality data from Del Monte field 66 as influenced by *Rotylenchulus reniformis*, 1,3-dichloropropene (1,3-D), and fenamiphos[y]

Yield parameter	Plant crop Untreated	Plant crop 1,3-D	Plant crop Plantation practice[z]	First ratoon crop Untreated	First ratoon crop 1,3-D	First ratoon crop Plantation practice
Average fruit weight (kg)	1.6	1.6	1.7	1.5	1.4	1.6
Metric tons/ha	111.2	113.1	120.8	120.5	120.5	136.1
Percent packable (size 7–14)	69.8	67.2	71.0	64.2	68.3	71.4
Marketable tons/ha	86.0	85.1	93.0	79.0	85.4	98.7

[y] All values within a crop harvest are not different according to the Waller-Duncan k-ratio t test ($k = 100$).

[z] Standard plantation practice = preplant 224 L a.i. 1,3-D/ha followed by trimonthly 1.1 kg a.i. fenamiphos/ha commencing 3 mo after planting.

low soil moisture (4). The cause of the lag phase is unknown for *M. javanica* and *R. reniformis* but may be from a lack of penetration or poor nematode development in young pineapple roots. Further research is required to definitively answer these questions.

Although the soil population increase and fluctuations of *R. reniformis* were similar in nematicide-treated and untreated plots, pineapple yields differed numerically among treatments. Only vermiform stages from soil samples were measured, thus ignoring eggs and those reniform nematodes in the roots. A large portion of the nematode population may be eggs in the soil or sedentary females in pineapple roots. These components of the nematode population may be affected by the postplant nematicide treatments even though they are not reflected in the soil population density data. The nematicide treatments appear to protect the pineapple roots sufficiently to allow continued plant growth and greater yield. In annual crops, it is common to find nematicide-treated plants supporting greater nematode population levels late in the season (12). A similar response may occur in pineapple. Research is needed to determine the partitioning of *R. reniformis* life stages between the soil and pineapple roots and between vermiform and egg stages of the nematode. A more accurate measure of the nematode population may explain the relationships observed between plant growth parameters and nematode population levels.

Even though the general configurations of the nematode population growth curves were similar for all treatments, control affected the average yield from each plot (Tables 1–3). Pineapple yield (t/ha) was negatively correlated to nematode numbers at 10 and 12 mo after planting in field 203 ($P < 0.05$), $r = -0.42$ and -0.48, respectively. No other significant correlations were detected. Differences between replications were unusually great and affected the significance of treatment differences in most fields. The trends were clearly evident, however. Untreated plots contained smaller fruit than nematicide-treated plots in the plant crop harvest (Tables 1–3), i.e., there was a greater percentage of fruit in the 12–16 range (undersized) in the untreated plots than in the treated plots. More undersized fruit occurred in the first ratoon harvest than in the plant crop. Except for the first ratoon crop in field 203 (Table 2), marketable tons per hectare were greater from plots receiving some nematicide. Yield (marketable tons/ha) of the ratoon crop was higher in plots receiving the standard plantation practice than in the untreated plots or those that received only preplant 1,3-D (Tables 2 and 3).

Nematode control remains important for profitable pineapple production in Hawaii. Profitable fresh pineapple fruit production is dependent upon an interrelation between market demand, world supply, and general economic conditions (fresh pineapple is considered a luxury item). Market demands dictate the amount of any size fruit that can be sold. Differences in fruit size result in reduced marketability and therefore profit. Fresh pineapple that is too large or too small may not have a market niche, limiting profitability to a relatively narrow range of fruit sizes. Preplant fumigation is effective in protecting the plant crop from nematode damage but provides insufficient protection for the subsequent ratoon crops. Currently, a combination of pre- and postplant nematicides is required as a management tool in Hawaii to maintain acceptable fruit sizes in economically acceptable ranges. Future management of nematodes in pineapple must consider and attempt to exploit the long lag phase in nematode population development for long-term control.

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