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Comparison of Single- and Double-chisel Injection Methods for the Control of *Rotylenchulus reniformis* in Pineapple

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Abstract: The efficacy of 1,3-dichloropropene (1,3-D) applied with one or two chisels was determined for control of *Rotylenchulus reniformis* on pineapple. The soil was fumigated with 1,3-D at 157 liters/ha with either a single chisel 46 cm deep or two chisels 41 cm deep in replicated experiments conducted in four commercial fields. Soil samples were collected before fumigation and 45 days afterward from three depths and three positions. The three depths were 0–15, 16–30, and 31–45 cm; and the three positions were the center of the bed, plant line, and interbed area. The single-chisel injection was comparable to the two chisels in percentage control of *R. reniformis.* Satisfactory control was achieved in three fields (percentage reduction from untreated = 79, 81, and 83) but not in the fourth field. The highest level of control was at the lowest soil depth (31–45 cm) nearest the points of injection. Among the sampling positions, control in the interbed area was generally the lowest. A single-chisel injection may be recommended because of the slightly enhanced control.
Key words: Ananas comosus, 1,3-dichloropropene, fumigation, nematicide, nematode, pineapple, reniform nematode, *Rotylenchulus reniformis.*

Pineapple is a perennial crop cultivated on about 12,000 ha in Hawaii (1). Most of this land is infested with *Rotylenchulus reniformis* Linford and Oliveira or *Meloidogyne javanica* (Treub) Chitwood. Without adequate nematode control, the first pineapple harvest, about 18 months after planting, will usually have small fruit (3). The greatest economic impact from nematode infection occurs during the first ratoon, 12 months after the first harvest, because the fruit fails to develop (3). Consequently, adequate nematode control is important for the duration of the cropping cycle.

Two tactics are employed for nematode control in Hawaiian pineapple fields: cultural and chemical. The first tactic involves destruction of the crop followed by a fallow period of 6–12 months. The crop residue is usually left on the field and burned prior to soil preparation for the next crop. In addition to fallowing, each field is fumigated with either 1,3-dichloropropene (1,3-D) or methyl bromide. Currently, the standard practice is to deliver 1,3-D into the planting bed with two chisels set 41 cm deep and offset 20 cm from the center of the planting bed and simultaneously seal the bed with a 1 mil × 86 cm plastic film.

Detection of unacceptable levels of 1,3-D in the air in California (Noffsinger, pers. comm.) generated concerns regarding the use of this chemical in Hawaii. Loss of 1,3-D at this time would be devastating to the Hawaiian pineapple industry because alternative control measures are not fully developed. It is imperative that 1,3-D application methods and rates minimize the potential for groundwater and air pollution. Because application methods can influence fumigant emission into the air (8), injection of the fumigant with a single chisel centered in the planting bed and sealed with a plastic mulch may help to contain the fumigant in the soil, thereby reducing air contamination (6). An added benefit of this application method might be to increase the efficacy of the fumigant compared with the current two-chisel application method. The objective of this research was to compare the efficacy of soil fumigation with 1,3-D injected either 46 or 41 cm deep with a single chisel or two chisels spaced 20 cm off bed center, respectively.

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Materials and Methods

An experiment was conducted in four Del Monte fields (fields 1, 4, 8, and 32) located within 5 km of Kunia, Hawaii. The soil in fields 4, 8, and 32 was a fine kaolinitic, isothermic, Ustoxic Humitropept, Inceptisol. In field 1, the soil was a clayey kaolinitic, isothermic, Tropeptic Eutrustox, Oxisol. Two blocks of 0.5–1.2 hectares were selected in each field. The blocks, except for a 600 m^2 area in each, were treated with 157 liters of 1,3-D/ha with commercial plantation equipment. The untreated areas served as controls. Each block was randomly assigned to either the one- or two-chisel injection treatment. The planting bed was sealed with a 1 mil × 86 cm plastic film as the chemical was injected. Field 1 was treated 5 December 1990, field 4 on 6 July 1991, field 8 on 5 August 1991, and field 32 on 30 June 1991. Four plots, 17 m long × 6 beds wide, were arbitrarily established in each block (three plots in the treated area and one in the untreated area).

Soil samples were collected before fumigation and 45 days after treatment with soil-bucket augers from three depths (0–15, 16–30, and 31–45 cm) and three positions relative to the row: the drip line down the center (C), the plant line (P), and the midpoint between two beds (M) (Fig. 1). A third set of samples, similar to the 45-day sampling, was taken 18 weeks posttreatment in field 1. Samples were collected from the four center beds in each of the treated plots and from all six beds in the untreated control plots. Each sample was processed individually by sifting it through a 0.5-cm-pore sieve and processing a 250-cm^3 subsample by elutriation (4) and centrifugation (5).

The numbers of *R. reniformis* in the soil from treated plots were compared with those in untreated plots to measure efficacy. Percentage control of *R. reniformis* was derived by the following formula:

$$(1 - (X_{Tij}/X_{Cij}) \times 100$$

where X_{Tij} is the mean number of *R. reniformis* from the treated plots at depth i and position j, and X_{Cij} is the mean number of *R. reniformis* from the untreated plots at depth i and position j. Data from all four fields were combined for analysis. Fields and application method served as independent variables in the experiment. Percentage control was analyzed for variance using the field × application method mean square as the error term. A Waller-Duncan

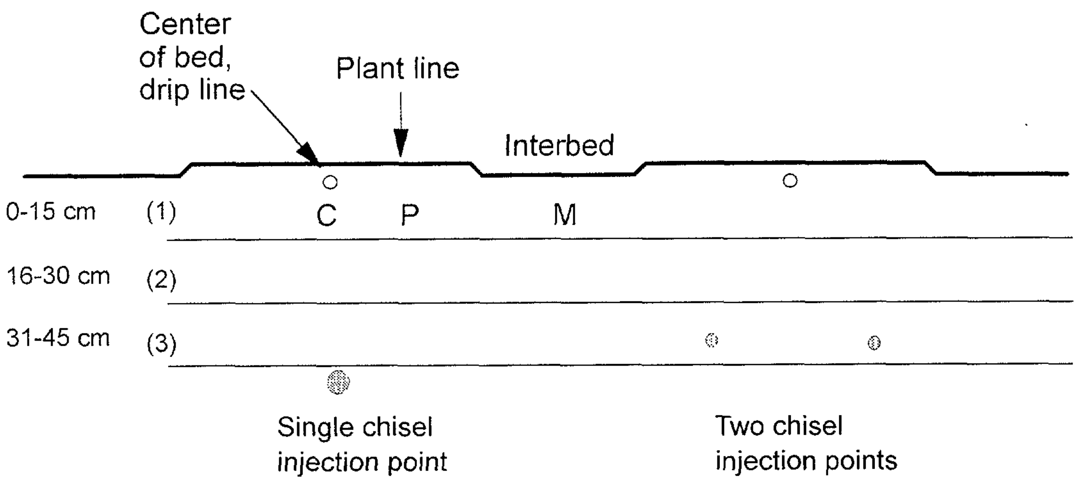

FIG. 1. Sampling scheme used in determining percentage *Rotylenchulus reniformis* control in pineapple beds, showing the center of the bed where the irrigation tubing is positioned (position C), plant line (position P), and interbed area (position M). Samples were taken with a soil-bucket auger from depths of 0–15 cm (depth 1), 16–30 cm (depth 2), and 31–45 cm (depth 3).

means separation was calculated to assess treatment differences. Linear contrasts between position and depths in the two treatments were also calculated.

Results

Numbers of *R. reniformis* differed among fields ($P = 0.01$) before treatment with 1,3-D (Table 1). Field 1 had the highest levels of infestation, whereas the other three fields had similar infestation levels (Table 1). Control of *R. reniformis* (comparing pre- and postfumigation) was deemed good in fields 1, 4, and 32, but poor in field 8 (Table 1).

Percentage control of *R. reniformis* was similar ($P = 0.06$) with injection of 1,3-D with one or two chisels, but control differed among sampling positions and depths. Average control in the C position (82%) was higher ($P = 0.001$) than in either position P (70%) or M (48%), and higher in position P than in position M ($P = 0.001$). Control at the lowest soil depth (31–45 cm) was higher ($P = 0.001$) than in the other soil zones (73, 66, and 61% at 31–45, 16–30, and 0–15 cm, respectively). The single-chisel treatment gave the best control at C3 and C2 (position C at the 31–45 and 16–30 cm depths) 45 days postfumigation (Fig. 2). Control with the two chisels was similar among positions C1, C2, C3, and P3 (Fig. 2).

Eighteen weeks after fumigation, control of *R. reniformis* was more evident than at 45 days in field 1 (Table 2). The two-chisel application of 1,3-D resulted in 97–100% control at both the C and P positions. The single-chisel delivery gave 96–100% control in the C position, but only 60–76% and 22–34% control in the P and M positions, respectively (Table 2). Overall, the areas nearest the point of injection showed the highest level of nematode control at 45 days or 18 weeks after treatment (Table 2, Fig. 2).

Discussion

Injection of 1,3-D with a single chisel gave control of *R. reniformis* equivalent to that achieved with two chisels. Consequently, the single-chisel application may be preferable due to environmental concerns. The fumigant is delivered deeper with the single chisel than with the two chisels, and only a single chisel trace is left. The single chisel trace in the center of the bed covered with an 82-cm-wide plastic film resulted in reduced air emission of 1,3-D as compared to the two chisels each leaving a trace near the edge of the plastic film. The air concentration of 1,3-D was reduced 2.5-fold in a field treated using a single chisel compared with a field treated using the two-chisel method (C. H. Oda, unpubl.). Based on percentage control of *R. reniformis*, our results demonstrated that outward and upward diffusion of 1,3-D in the soil is restricted. This apparently limited movement could be manipulated to minimize environmental impacts such as groundwater contamination and air emis-

Table 1. Mean numbers of *Rotylenchulus reniformis*/250 cm^3 soil sampled before fumigation with 1,3-dichloropropene (prefumigation) and 45 days later (postfumigation) in treated plots from four commercial pineapple fields near Kunia, Oahu, Hawaii.

Field	Sampling date: Prefumigation		Sampling date: Postfumigation		Percentage control
1	754	a x	162	ab y	79
4	298	b x	52	b y	83
8	332	b x	303	b x	9
32	235	b x	45	b y	81

Mean nematode numbers were derived from all plots at prefumigation and only from treated plots at postfumigation. Numbers with the same letters (x, y) within a field (row) are not different according to a Waller-Duncan k-ratio *t*-test (k = 100). Numbers across fields (columns) with the same letters (a, b) are not different according to a Waller-Duncan k-ratio *t*-test (k = 100).

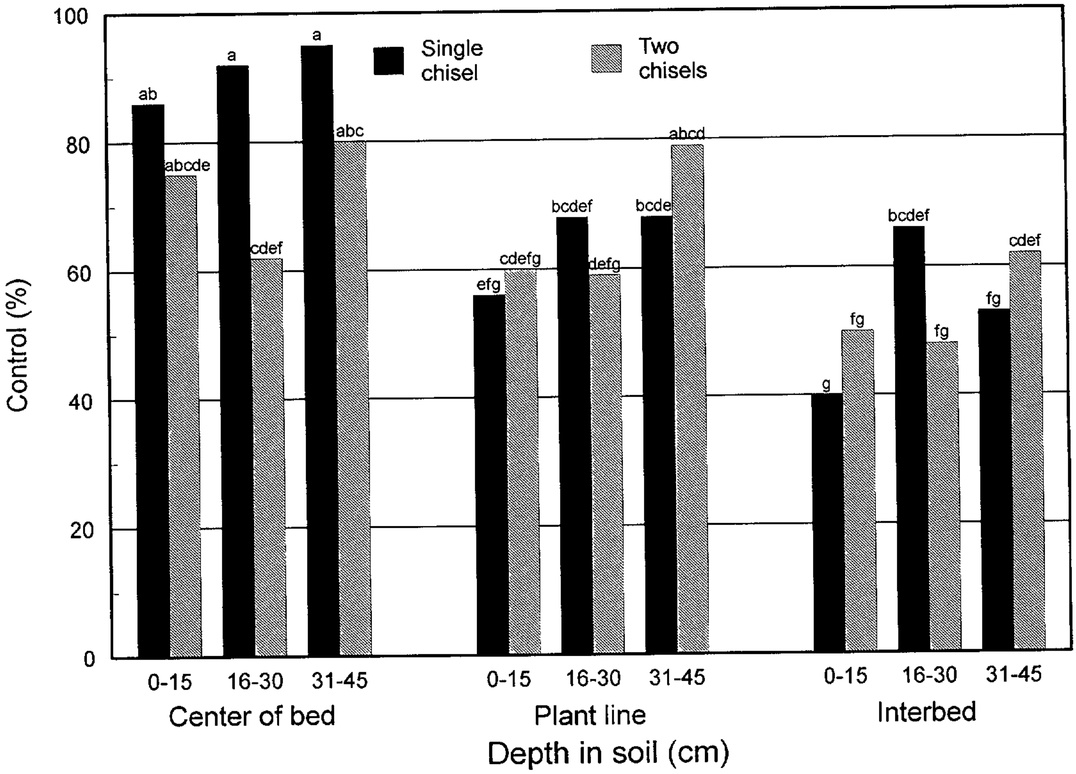

FIG. 2. Percentage *Rotylenchulus reniformis* control at 45 days after 1,3-dichloropropene (1,3-D) treatment. Delivery of 157 liters 1,3-D/ha was either 46 cm deep with a single chisel down the center of the plant bed or 41 cm deep with two chisels placed 20 cm on each side of the bed center. Values followed by the same letter are not different (k = 100) according to a Waller-Duncan k-ratio *t*-test. Means are from four fields.

sion and to increase the efficacy of 1,3-D in pineapple nematode control.

The unsatisfactory level of nematode control in one of the four fields may have been due to environmental conditions (soil moisture and temperature), soil preparation, plant debris, or application methods (2). There were no observable differences in soil preparation between the four fields. We were unable to separate field effects from other environmental effects. However, the best control was achieved in fields treated during the winter and early summer when soil and air temperatures were below 27 C. The least control was realized in a field treated in late summer when the soil was warmer than 27 C and drier (based upon observation). Cool, moist conditions maintain 1,3-D in the soil water phase longer than do hot, dry soils (7). Warm temperatures hasten volatilization (7), and lethal concentrations are less likely to be maintained for a sufficiently long period to kill nematodes. The dry conditions observed in the field with unsatisfactory control may have hastened the volatilization or hydrolysis of the 1,3-D. Improper application of the fumigant either by having the

TABLE 2. Percentage *Rotylenchulus reniformis* control 18 weeks after treatment with 157 liters/ha 1,3-dichloropropene in a pineapple field.

Application method†	Soil depth (cm)	Position of sample‡		
		C	P	M
Double chisel	0–15	99	97	47
	16–30	99	100	39
	31–45	96	99	17
Single chisel	0–15	96	60	34
	16–30	99	76	22
	31–45	100	62	24

† Delivery of 1,3-D was either 46 cm deep with a single chisel down the center of the bed or 41 cm deep with two chisels each 20 cm from the center of the bed.

‡ C = center of bed, P = plant line 20 cm from the bed center, M = middle of interbed area.

chisel set at an improper depth or insufficient sealing of the chisel trace, may have also contributed to the inadequate control in field 8.

A simple change in the application of 1,3-D to a single chisel set to deliver the fumigant 46 cm deep has proven effective in controlling *R. reniformis.* Research is currently in progress to investigate the efficacy and environmental fate of 1,3-D in pineapple fields as application methods are altered. Improved application technology should help to maintain 1,3-D as a safe, effective nematicide in pineapple until alternative control measures are refined and ready to be deployed.

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