Pinto Bean Yield Increased by Chemical Control of *Pratylenchus* spp.[1]

R. T. ROBBINS, O. J. DICKERSON, and J. H. KYLE[2]

Abstract: Pinto bean yields and *Pratylenchus* spp. (nematode) population densities are reported for field plots pre-plant treated with nematicides in 1966 and 1968. Vidden-D (1,3-dichloropropene, 1,2-dichloropropane and related chlorinated hydrocarbons), Vorlex (20% methyl isothiocyanate plus 80% chlorinated C_3-hydrocarbons), Telone PBC (80% dichloropropenes, 15% chloropicrin, and 5% propargyl bromide), Dasanit (0,0-Diethyl 0-[p-(methylsulfinyl)phenyl] phosphorothioate, and Dowfume MC-2 (98% methyl bromide plus 2% chloropicrin) were used in 1966. Vorlex, Dasanit, and D-D (1,3-dichloropropene, 1,2-dichloropropane and related chlorinated hydrocarbons) were each used at two rates in 1968.

Fumigated plot yields ranged 32-56% higher than control plots in 1966 and 11-80% higher in 1968. Significant yield increases were obtained for all fumigants except Telone PBC in 1966. In 1968 significant increases were obtained from use of the high rate (374 liters/ha) of Vorlex and low rate (8.4 liters/ha) of Dasanit. There was an inverse relationship between yield and numbers of *Pratylenchus* spp./g root on four sampling dates in 1968. A correlation coefficient of −.39 ($P \leq 0.05$) was obtained for samples taken 36 days after planting and −.52 ($P \leq 0.01$) for samples taken 30 days later. There was no significant correlation between yield and numbers of *Pratylenchus* spp. recovered from the soil. *Key Words:* Pathogenicity, Nematicides, Population dynamics, Fumigation.

Received for publication 25 June 1971.

[1] Contribution No. 536, Dept. of Plant Pathology, and Contribution No. 103, Garden City Branch, Kansas Agricultural Experiment Station, Manhattan, Kansas 66502.

[2] Graduate Research Assistant and Associate Professor, Department of Plant Pathology, Kansas State University, Manhattan 66502 and Assistant Professor, Garden City Branch Station, Kansas Agricultural Experiment Station, Garden City 67846. Present address of senior author: Department of Plant Pathology, North Carolina State University, Raleigh 27607.

High population densities of *Pratylenchus* spp. nematodes are often associated with reduced yield of pinto beans (*Phaseolus vulgaris* L.) in western Kansas. It is known that some species of plants are tolerant to these pests (9,10). The purposes of the experiments reported here were to determine pinto bean yield loss due to *Pratylenchus* spp. and to evaluate the efficacy of several nematicides against a field population of *Pratylenchus* spp.

MATERIALS AND METHODS

Plots were established in 1966 and 1968 at

the Kansas Agricultural Experiment Station, Garden City Branch on deep Keith silt loam with 0 to 1% slope (6). A randomized, complete-block design with either six or seven treatments and four replicates was used. All plots were 2.8-m wide and 15-m long with a 3-m alley between plots. Each plot contained four rows, two on each of two beds on 1.4-m centers. The two rows of each bed were spaced 0.6-m apart. Irrigation furrows were located on both sides of all beds.

At the time of nematicide application in 1966, the mean *Pratylenchus* spp. population was 117/473 cc of soil with no significant differences detected between plots. The species present were identified as *P. neglectus, P. hexincisus, P. scribneri,* and *P. alleni.* The proportion of the total population for each species was not determined. An average of 28 *Tylenchorhynchus acutus*/473 cc of soil was also present.

Treatments in 1966 included 1,3-dichloropropene, 1,2-dichloropropane and related chlorinated hydrocarbons (Vidden-D®); methyl isothiocyanate 20% plus chlorinated C_3-hydrocarbons 80% (Vorlex®); dichloropropenes 80%, chloropicrin 15%, and propargyl bromide 5% (Telone PBC®). The application rate of these liquid nematicides was 350 liters/ha on a broadcast basis. 0,0-Diethyl 0-[p-(methylsulfinyl)phenyl] phosphorothioate (Dasanit-10G®) was applied at 19.9 kg active ingredient/ha (ai/ha) on a broadcast basis. Other treatments were methyl bromide 98% plus chloropicrin 2% (Dowfume MC-2®) at 50g/m^2 and the control.

Liquid fumigants were applied 20-cm deep with three chisels on 30-cm centers/bed with a drag to seal the surface. Dasanit was broadcast on the bed surface with a fertilizer applicator and rototilled 10-cm deep. The actual treated area for the liquid fumigants and Dasanit was the 0.9-m strip between irrigation furrows. Dowfume MC-2 was applied to the entire plot under polyethylene tarp. Soil temperature was 18 C at 20-cm. Plots were planted on May 26 (21 days after treatment) to 'Idaho 111' pinto beans.

Representative soil and root samples were taken from the outer rows of each plot 62 and 104 days after seeding. Each sample contained four sets of roots and adjacent soil. Roots were removed, washed, weighed, and placed in a mist chamber. Nematodes were collected daily for 7 days, and the number of *Pratylenchus* spp./g root (fresh wt) calculated. One composite soil sample/replication was processed by the sieving-Baermann funnel method of extraction and the nematodes counted. The middle 9-m of the two middle rows of each plot were harvested 109 days after seeding. To minimize variation in numbers of nematodes recovered, data were transformed by the formula $N' = \sqrt{N} + 1$ in the statistical analysis (8).

In 1968 the plot design, host variety, sampling, nematode recovery and data processing were the same as in 1966. In 1968 the mean nematode numbers/473 cc of soil at the time of nematicide treatment were 89 *Pratylenchus* spp. and 15 *T. acutus* with no significant differences detected between plots. *Xiphinema americanum, Helicotylenchus* sp., and *Heterodera schachtii* were found sporadically in small numbers both in 1966 and 1968. Treatments were: 1,3-dichloropropene, 1,2-dichloropropane and related hydrocarbons (D-D®); and Vorlex applied at 187 and 384 liters/ha on a broadcast basis; Dasanit applied at 8.4 and 16.8 kg ai/ha on a broadcast basis; and the control. Application was the same as in 1966 except that liquids were applied through only two chisels, one 25-cm to the left and one 25-cm to the right of center of the beds. At time of application, soil temperature was 16 C at 20-cm deep; 25 days later, May 27, the pinto beans were planted. Samples were taken 7, 36, 66, and 93 days after seeding. At maturity, 107 days after seeding, the center 6-m of the two middle rows were harvested for yields.

RESULTS

In 1966 all nematicides tested except Telone PBC resulted in significantly greater pinto bean yields (Table 1). No significant yield differences among nematicide treatments and no differences in the number of pods or total dry wt were found. Population densities of *Pratylenchus* spp. in soil treated with Dowfume MC-2, Vorlex, and Telone PBC were significantly lower ($P \leq 0.05$) than for the control at both sampling dates (Table 1). Population densities in soil treated with Dasanit-10G and Vidden-D were not different from the controls at 62 days after seeding but were significantly lower ($P \leq 0.05$) at 104 days after seeding (5 days prior to harvest). On both sampling dates there were significant differences in the mean number of *Pratylenchus* spp. recovered/10 g fresh wt of pinto bean roots (Table 1); significantly fewer were

TABLE 1. Effect of nematicide treatments on population densities of *Pratylenchus* spp. and resulting yields of pinto beans.

Treatment† and dosage on a broadcast basis	*Pratylenchus* spp. per 10 g fresh roots		*Pratylenchus* spp. per 473 cc soil		Pinto Bean Yield (kg/ha)	Pinto Bean % yield increase
	July 27	Sept. 7	July 27	Sept. 7		
Vidden-D 350 liters/ha	9,775 ab‡§	24,888 a§	181 ab§	393 b§	2,310.9 a§	39.7
Dowfume MC-2, 50 g/m^2	10 c	15 b	0 b	0 d	2,574.6 a	55.7
Vorlex 350 liters/ha	2,997 abc	13,513 a	57 ab	95 cd	2,536.5 a	53.4
Dasanit 19.9 kg ai/ha	2,450 bc	16,350 a	81 ab	207 bc	2,541.0 a	53.7
Telone PBC 350 liters/ha	3,783 abc	13,163 ab	40 b	137 cd	2,180.0 ab	31.9
Control - untreated	10,191 a	21,687 a	288 a	636 a	1,653.2 b	
LSD .05	8,417	13,470	214	193	625.2	

† Each treatment was replicated four times. Entire plots were treated with MC-2. For the other nematicides a 0.9-m strip, containing two rows, between irrigation furrows on 1.4-m centers was treated.
‡ Significant differences indicated were calculated from data transformed by the formula $N' = \sqrt{N + 1}$.
§ Unlike letters within a column indicate significant differences at the 95% confidence level.

recovered from the Dowfume MC-2 treated plots than from all others. On both dates root population densities from Vorlex and Telone PBC treated plots were significantly ($P \leq 0.05$) lower than those from the Vidden-D and the control plots. Dasanit resulted in a population density significantly lower than that recorded for control and Vidden-D for the first sampling period; but for the second, the population density was significantly lower than that recorded for Vidden-D only.

In 1968, yields from plots treated with Dasanit at 8.4 kg ai/ha and Vorlex at 374 liters/ha were significantly higher ($P \leq 0.05$) than those from the control (Table 2). No significant yield differences were detected among Dasanit at 16.8 kg ai/ha, Vorlex at 187, D-D at 187 and 374 liters/ha, and the control.

All 1968 treatments had significantly fewer *Pratylenchus* spp./g dry wt of pinto bean roots than did the control 7 days after seeding (Table 2). The control had the highest nematode numbers/g dry wt of roots for the first three samplings; D-D at 187 liters/ha had a slightly larger number than the control on the last. There was a negative relationship between pinto bean yield and the number of *Pratylenchus* spp./g dry wt of roots for each of the sampling dates. This is shown by the correlation coefficients (r) between yield and nematode numbers in the roots at the different sampling dates. The four values obtained were -0.36, -0.39, -0.52, and -0.34 at 7, 36, 66, and 93 days after planting, respectively (for $r \leq -0.37$, $P \leq 0.05$).

Correlation coefficients of 0.44, 0.44 and 0.54 were found for nematode population densities in the roots at the first sampling compared with the second, third, and fourth, respectively (for $r \geq +0.37, P \leq 0.05$). Correlation coefficients of the nematode numbers of the second and third samplings compared to the final sampling were not significant at the above level.

Average numbers of *Pratylenchus* spp. recovered/473 cc of soil for all treatments were 30, 35, 151, and 2,000 at 7, 36, 66, and 93 days after treatment, respectively. Numbers recovered did not differ among treatments at any sampling date nor was there a significant correlation between pinto bean yield and numbers of *Pratylenchus* spp. recovered from the soil.

All treatments except Dasanit at 8.4 kg ai/ha resulted in significantly fewer *Tylenchorhynchus acutus* than in the controls at 7 days after seeding. Like *Pratylenchus* spp., fewer were recovered in the middle of the season than either at pre-treatment or near maturity. Average numbers recovered/473 cc of soil were 4, 5, 32, and 109 at 7, 36, 66, and 93 days after treatment, respectively. Yields did not have a negative relationship with the numbers of this nematode. No differences were found in the numbers of specimens among the other genera of plant-parasitic nematodes observed.

DISCUSSION

Dowfume MC-2 (9), Vorlex and other fumigants containing propargyl bromide (7), and 1-3 dichloropropene, 1-2 dichloropropane mixture (1) reportedly have fungicidal properties. Because the effects of these chemicals on yield were not significantly different from that of Dasanit (not reported to

TABLE 2. Effects of two rates of selected nematicides on population densities of *Pratylenchus* spp. and resulting yield of pinto bean.

Treatment† and dosage on a broadcast basis	*Pratylenchus* spp./g dry wt roots				Pinto Bean	
	June 3	July 2	Aug. 1	Aug. 28	Yield (kg/ha)	% yield increase
Dasanit 8.4 kg ai/ha	174 b‡§	3,544 a§	12,406 a§	9,383 bc§	1,311.9 ab§	72.7
Dasanit 16.8 kg ai/ha	187 b	3,432 a	13,590 a	3,950 d	909.5 bc	19.7
Vorlex 374 liters/ha	158 b	914 a	6,036 a	8,094 bc	1,364.5 a	79.6
Vorlex 187 liters/ha	327 b	968 a	10,104 a	7,822 bcd	1,171.7 abc	54.2
D-D 374 liters/ha	304 b	1,438 a	8,935 a	6,288 cd	937.9 bc	23.4
D-D 187 liters/ha	448 b	1,377 a	8,240 a	14,331 a	842.6 c	10.9
Control - untreated	1,088 a	4,562 a	15,201 a	12,521 ab	759.5 c	
LSD .05	442	4,016	10,313	4,853	419.3	

† Each treatment was replicated four times. Dasanit was applied to the bed surface (0.9-m width) between irrigation furrows that were on 1.4-m centers. There were two rows per bed. Liquid fumigants were applied in each row by a single chisel (four 30-cm strips treated in each 2.8-m plot).
‡ Significant differences indicated were calculated from data transformed by the formula $N' = \sqrt{N} + 1$.
§ Unlike letters within a column indicate significant differences at the 95% confidence level.

be fungicidal), it was assumed that soil pathogens other than nematodes were not a major factor in this test.

In 1966, no differences in *Pratylenchus* spp. populations were detected between Vidden-D and control plots, even though bean yield was greater on Vidden-D treated plots. That indicated that if differences in numbers did exist, samples were probably taken too long after planting (62 days) to detect the lowest population density/unit that would cause damage.

In both 1966 and 1968, the *Pratylenchus* spp. population densities/g of roots were higher at or near host maturity in some treatments than in control, even though yields from some treated plots were significantly higher. According to Steiner (11) that phenomenon is common. Presumably, the population density of *Pratylenchus* spp. in the soil drops in the middle of the growing season and then builds up rapidly at the end (3,4,5). Chang and Rohde (2) reported that the necrotic effect produced by *P. penetrans* repelled rather than attracted individual nematodes, and Young (12) reported that *Pratylenchus* spp. left decaying roots. Thus, a greater population density would be expected in the soil at or near the end of the growing season in those treatments with the earliest infection by relatively large numbers. That happened in the 1966 and 1968 pinto bean experiments.

The four sampling periods in 1968 revealed more about *Pratylenchus* spp. control on pinto beans than did the two periods in 1966. The first samples, taken 7 days after planting, showed a negative relationship between the resulting yields and the number of *Pratylenchus* spp./g root dry wt at that time for the three significantly different population levels. Control plots, with the highest nematode populations, gave the lowest yields. D-D at 187 liters/ha resulted in lower populations and higher yields than did the control. Vorlex at 374 liters/ha resulted in the lowest populations and the highest yields. No significant difference between numbers of nematodes recovered after 36 or 66 days was detected. This supports the hypothesis that nematode counts taken early in the growing season more reliably indicate nematicidal control effectiveness in increasing yield than those taken later in the season. The 16.8 kg ai/ha rate of Dasanit, which resulted in a lower yield than did the 8.4 kg ai/ha rate, seemed to be phytotoxic.

The positive r values between the number of nematodes in the roots at the first sampling compared to subsequent samplings suggests that roots with high nematode populations did not deteriorate sufficiently to cause nematode migration from the roots until near the end of the growing season.

Although *T. acutus* numbers were not shown to be associated with yield losses, their even distribution in the field would suggest that there could have been an additive effect on yield losses.

LITERATURE CITED

1. ANDERSON, E. J. 1966. 1-3 Dichloropropene, 1-2 dichloropropane mixture found active against *Pythium arrhenomanes* in field soil. Down to Earth 22(3):23.

2. CHANG, LIU-MEI, and R. A. ROHDE. 1969. The repellant effect of necrotic tissues on the nematode *Pratylenchus penetrans*. Phytopathology 59:398 (Abstr.).
3. FERRIS, J. M. 1967. Factors influencing the population fluctuation of *Pratylenchus penetrans* in soils of high organic content. I. Effect of soil fumigants and different crop plants. J. Econ. Entomol. 60:1708-1714.
4. FERRIS, V. R., and R. L. BERNARD. 1961. Seasonal variations of nematode populations in soybean field soil. Plant Dis. Rep. 45:789-793.
5. FERRIS, V. R., and R. L. BERNARD. 1967. Population dynamics of nematodes in fields planted to soybeans and crops grown in rotation with soybeans. I. The genus *Pratylenchus* (Nemata: Tylenchida). J. Econ. Entomol. 60:405-410.
6. HARNER, R. F., R. C. ANGELL, M. A. LOBMEYER, and D. R. JANTZ. 1965. Soil survey of Finney County, Kansas. Series 1961, No. 30, U. S. Government Printing Office, Washington. 91 p.; 108 figs.
7. HARRISON, R. P. 1966. Trizone soil fumigant. Down to Earth 22(2):16-18.
8. LE CLERG, E. L., W. H. LEONARD, and A. G. CLARK. 1962. Field plot technique. Burgess Publishing Co., Minneapolis 23, Minnesota. 373 p.
9. OOSTENBRINK, M. 1966. Major characteristics of the relation between nematodes and plants. Meded. Landbouwhogesch. Wageningen 66:3-46.
10. SEINHORST, J. W. 1966. The relationships between population increase and population density in plant parasitic nematodes. I. Introduction and migratory nematodes. Nematologica 12:157-169.
11. STEINER, G. 1949. Aims and problems of soil fumigation. Down to Earth 5(2):2.
12. YOUNG, P. A. 1953. Damage caused by meadow nematodes to corn in east Texas. Plant Dis. Rep. 37:599-600.