Effect of Trifluralin and Dinitramine on Aphanomyces Root Rot of Pea

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ABSTRACT

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The herbicides trifluralin and dinitramine reduced root rot of pea caused by *Aphanomyces euteiches* in the field and in controlled environments. Yield of fresh, shelled peas was higher for plants grown in trifluralin- or dinitramine-treated soils than in nontreated soils at three of four locations.

Additional key words: soil-borne plant pathogens.

Yield and quality of commercially-grown pea (*Pisum sativum* L.) in Minnesota are reduced annually by root-infecting fungi, the most common of which, in decreasing economic importance, are: *Aphanomyces euteiches* Drechs., *Fusarium solani* (Mart.) Appel & Wr. f. sp. pisi (Linf.) emend. Synd. & Hans., *Pythium ultimum* Trow, *Hhizoctonia solani* Kuhn, and *Ascochyta pinodella* L. K. Jones (10, 15). Although *A. euteiches* is the most destructive of these pathogens, it usually is part of a root disease complex.

The effect of soil-incorporated herbicides on the root disease complex of pea or on individual pathogens of the complex has received little attention. Atrazine increases root and epicotyl rot caused by *F. solani* f. sp. *pisi* (11), and DMPA reduces damping-off caused by *P. debaryanum* (3). Harvey et al. (5) reported higher yields when peas were grown in soils treated with trifluralin. They concluded that yields were higher because root disease was decreased by herbicides and also that trifluralin lowered root disease severity of peas grown in naturally infested soils in the greenhouse. A more recent report indicates that dinoseb also effectively lowers root disease caused by *A. euteiches* (6). Research on the effects of herbicides on the agro-ecosystem and more specifically, the effect of herbicides on plant disease, has increased recently (2, 7, 8, 9, 14).

Dinitroaniline herbicides commonly are studied in association with plant pathogens and plant disease. These herbicides are incorporated into soil, have low solubility in water, are absorbed readily onto soil colloids, generally do not leach in soil, and are volatile (1). Trifluralin is a dinitroaniline herbicide that has been used extensively for weed control in commercial pea production in Minnesota. However, in field trials, dinitramine consistently has resulted in even greater yields of peas than trifluralin or other dinitroaniline herbicides tested (B. Yahnke, Green Giant Co., Le Sueur, Minnesota, *personal communication*). Little is known on the effect of trifluralin and other related herbicides on root diseases and their pathogens on pea.

The purpose of this study was to evaluate the effect of trifluralin and dinitramine on root disease severity of pea in naturally infested soils, both in the field and in controlled environments.

MATERIALS AND METHODS

Herbicides.—Commercial grades of the herbicidesα, α, α-trifluoro-2, 6-dinitro-N, N-dipropyl-*p*-toluidine (trifluralin) (Eli Lilly & Co., Greenfield, IN 46140) and N^3, N^3-diethyl-2, 4-dinitro-6-trifluoromethyl-*m*-phenylene diamine (dinitramine) (U. S. Borax & Chemical Corp,Anaheim, CA 92803) were used to determine their effect on root disease of pea grown in naturally infested soils in the field and in controlled environments.

Commercial grades of herbicides were dissolved in 95% ethanol. Stock solutions of herbicides were stored at 10 C. The herbicides used in controlled environment studies were dissolved in 95% ethanol and appropriate quantities of that solution, in turn, were mixed in water before being applied to soils.Manufacturer's recommended rates for given soil types were used in field investigations and simulated rates were used in growth chamber studies; the weight of the top 10- cm of the soils was used to convert kilograms per hectare to micrograms per gram of soil. Herbicides were suspended in water for field applications and agitated to maintain the suspension.

Pea cultivars.—Green Giant (GG) pea cultivars 359 (early maturity type) and 549 (late maturity type) of pea were used. Seed of all cultivars were treated with N-(trichloromethylthio)-4-cyclohexene-1, 2-dicarboximide (captan).

Field experiments in Minnesota.—Field plots were established at Rosemount (4% organic matter) and St. Paul (3% organic matter) (Waukegan silt loam soils) in 1974 in soils in which peas had been monocultured for 13 and 45 years, respectively, and in two commercial fields (Wadena sandy loam, 4% organic matter) at Le Sueur. Fields at Le Sueur will be designated Le Sueur 1 and Le Sueur 2. Moderate-to-severe root disease had been observed in previous pea crops on all fields. Soils at all locations were plowed the previous fall and tilled once in the spring before applications of herbicides and before planting.

Dinitramine and trifluralin were sprayed onto the soil surface at the following active ingredient rates: 0.56 kg dinitramine/hectare (ha) at Le Sueur 2, St. Paul, and Rosemount; 0.74 kg dinitramine/ha at Le Sueur 1; and 0.56, 0.74, 0.84, and 0.84 kg trifluralin/ha, at Le Sueur 2, Le Sueur 1, St. Paul, and Rosemount, respectively. The herbicide-treated plots were rototilled to a depth of 10 cm immediately after the material was applied.

Green Giant pea cultivars 359 and 549 were planted on 26 April at Le Sueur 1 and 24 May at Le Sueur 2, 29 April at St. Paul, and on 4 May at Rosemount, all on the day following herbicide application. Plots were 1.0×8.0 m at Le Sueur and 1.5×2.0 m at St. Paul and Rosemount. Weeds were removed by hand in plots not treated with herbicides.

A randomized block design was used with three blocks and each treatment replicated three times per block at the first Le Sueur location and once at St. Paul and Rosemount. A three-block design with each treatment replicated four times per block was set up at the Le Sueur 2 location, but two blocks were washed out by rain. Two samples were taken from each replicate to give eight replicates per herbicide treatment.

Effect of herbicides on root disease in controlled environments.—A Clarion Webster clay loam (6% organic matter content) soil from a commercial pea field where severe root disease had been observed in previous crops was used to determine the effects of trifluralin and dinitramine on root disease, and shoot and root growth of pea under controlled conditions. Soil was sieved through a 1.25-cm screen and mixed to improve uniformity. Commercial grades of trifluralin and dinitramine were suspended in distilled water and applied to the surface of the soil with an atomizer. Soil was treated with trifluralin or dinitramine at 0, 0.50, and 0.75 μg/g of soil. Herbicides were incorporated by mixing them into the soil in a metal container. Fifty seeds of the pea cultivar GG 549 were planted in 20×25-cm plastic pots. These were incubated in a growth chamber at 25 C with fluorescent illumination for 16 hours per day. Treatments were replicated twice. Each pot was watered daily with 500 ml of tap water for the 1st and 4th week of incubation and 750 ml of tap water the 2nd and 3rd week of incubation. Pots were randomized initially and then rotated in the growth chamber every 3rd day.

Estimation of root disease severity.—Root disease severity was estimated at initial anthesis approximately 6 weeks after planting for cultivar GG 359 and 8 weeks after planting for cultivar GG 549 by the method of Sherwood and Hagedorn (12) at all field locations by evaluating 50 random plants selected from 75-100 plants dug per replicate per treatment from the outside rows of treatment plots. Plants grown in a controlled environment were evaluated 30 days after planting.

Statistical significance of differences between treatment means was determined by analysis of variance and Tukey's test for the comparison of treatment means at $P = 0.05$ and 0.10 (13).

RESULTS

Effect of herbicides on root disease severity.—Root disease was reduced ($P = 0.05$) for pea cultivar GG 549 by trifluralin at Le Sueur 1 and Rosemount and also cultivar GG 359 at St. Paul. The differences observed for cultivar GG 359 at Le Sueur and GG 549 at St. Paul for trifluralin versus nontreated soil were not significant at $P = 0.05$ (Fig. 1). Dinitramine also reduced root disease ($P = 0.05$) for cultivar GG 359 at St. Paul and Le Sueur 1 and for cultivar GG 549 at Le Sueur 1 and Rosemount (Fig. 1). Root disease of cultivar GG 549 was not reduced by dinitramine at St. Paul. In four of the five cultivar-location combinations, root disease was less for plants grown in dinitramine-treated soils than in trifluralin-treated soils (Fig. 1). Total rainfall was 24.5, 21.4, and 20.1 cm at Rosemount, St. Paul, and Le Sueur, respectively, which resulted in soils becoming water-saturated several times between the time of planting and the time disease evaluations were made. This amount of rainfall favored root infection by *Aphanomyces*

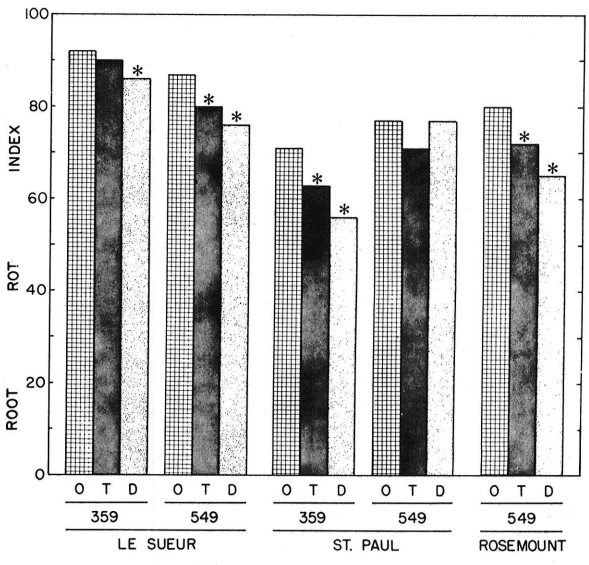

Fig. 1. The effect of trifluralin (T) and dinitramine (D) on the root disease severity (scale: 0 = healthy and 100 = rotted roots and epicotyls) on two pea cultivars (GG 359 and 549) at three locations in Minnesota. Asterisks designate values statistically different ($P = 0.05$) according to Tukey's test. Rates of trifluralin were 0.74 kg/hectare (ha) at Le Sueur and 0.84 kg/ha at St. Paul and Rosemount, and of dinitramine were 0.74 kg/ha at Le Sueur and 0.56 kg/ha at St. Paul and Rosemount.

euteiches, which was the primary root disease pathogen at all locations.

Trifluralin and dinitramine reduced root disease of plants grown in a naturally infested soil in a controlled environment ($P = 0.05$) compared to plants grown in nontreated soils (Table 1). Differences in root disease between herbicide and nonherbicide treatments were greater in a controlled environment compared to the field study. More dead plants were observed in nontreated soil compared to trifluralin or dinitramine-treated soil ($P = 0.05$). The number of dead plants decreased with higher rates of the herbicides (Table 1).

Effect of herbicides on plant dry weight.— Dry weight of shoots and roots was used to estimate the pathogenic effects of *A. euteiches* in the presence or absence of trifluralin and dinitramine. Shoots and roots from plants grown in naturally infested soil in a growth chamber were dried in paper bags in a convection drying oven at 100 C for 24 hours. All plants were allowed to cool to room temperature (about 24 C) before being weighed.

The lower root disease values for plants grown in herbicide-treated soils described above were reflected in higher shoot weights for these same plants ($P = 0.05$) (Table 1). Dry weights of roots were higher for plants grown in trifluralin- and dinitramine-treated soil; however, the trifluralin treatment was not statistically significant from plants grown in nontreated soils ($P = 0.10$).

Effect of trifluralin and dinitramine on pea vine weight, yield, and pea maturity.—Measurement of vine weight, yield, and maturity of pea were made by harvesting 1.5 square meters from the center of each treatment plot at both Le Sueur locations, and 0.75 square meters from the centers of those at St. Paul and Rosemount. Plants were hand-pulled and then processed through a stationary viner to obtain fresh, shelled peas, which were washed, weighed, and processed through a tenderometer for maturity estimates. Tenderometer values of 95-100 are desirable for best quality peas. Yield estimates for each treatment were adjusted to a tenderometer value of 100

TABLE 1. Effect of trifluralin and dinitramine on root disease severity, death of plants, shoot dry weight, and root dry weight of pea cultivar GG 549 grown in pots in soil naturally infested with *Aphanomyces euteiches*

Herbicide	Rate of application (μg/g)	Root disease severity[a]	No. dead plants	Shoot wt (mg/plant)[b]	Root wt (mg/plant)[b]
None		88	27	116	18
Trifluralin	0.50	61	12	149	31
	0.75	45	2	146	28
Dinitramine	0.50	68	12	166	38
	0.75	37	3	189	38
Tukey's test $w_{.05}$ =		31	3	30	24
Tukey's test $w_{.10}$ =		25	2	25	20

[a]Root disease severity (0 = healthy and 100 = rotted roots and epicotyls) of 30-day-old pea plants.
[b]Each value is the mean of 30-50 plants per replicate and replicated twice.

TABLE 2. The effect of trifluralin and dinitramine on vine weight, yield, and quality of peas as measured by tenderometer readings on two cultivars at three locations

	Cultivar and location				
	St. Paul		Le Sueur 1	Rosemount	Le Sueur 2
Herbicide[a]	359	549	359	549	549
	Vine weight (q/ha)				
None	252	246	168	257	114
Trifluralin	272	381	200*[b]	272	156*[b]
Dinitramine	204	312	175	310	172*[b]
	Pea yield (q/ha)				
None	39	49	24	47	18
Trifluralin	45	68*[b]	30*[b]	45	26*[b]
Dinitramine	30*[b]	65*[b]	29	52	29*[b]
	Tenderometer[c] reading				
None	97	114	117	150	116
Trifluralin	95	106	108	148	105
Dinitramine	107	127	112	140*[b]	110

[a]Trifluralin was applied at 0.74 kg/hectare (ha) at Le Sueur 1 and 0.56 kg/ha at Le Sueur 2, and 0.84 kg/ at all other locations. Dinitramine was applied at 0.74 kg/ha at Le Sueur 1 and 0.56 kg/ha at all other locations.
[b]Asterisk indicates a statistically significant difference from the control using analysis of variance and Tukey's test for comparison of means at $P = 0.10$.
[c]Yield was adjusted to a tenderometer value of 100 by the method of Hagedorn et al. (6).

according to the method of Hagedorn et al. (4).

Trifluralin.—Mean values for fresh weight of pea vines for the trifluralin treatment generally were higher than for the control (no herbicide), but were statistically significantly higher (P=0.10) only for cultivar GG 359 at LeSueur 1 and GG 549 at Le Sueur 2 (Table 2). Yield estimates of peas grown in the presence of trifluralin were higher than in the control for cultivar GG 549 at St. Paul and Le Sueur 2 (Table 2). Yield estimates of GG 359 were statistically higher only at the first Le Sueur location. Fresh peas from plants grown in trifluralin-treated soil had lower tenderometer values than those from the controls, but none of the differences were statistically significant (P = 0.10) (Table 2).

Dinitramine.—Fresh vine weights were higher for cultivar GG 549 grown in dinitramine-treated soils at Le Sueur 2 (Table 2). Yield of fresh, shelled peas was higher in cultivar GG 549 when grown in dinitramine-treated soil than in controls at St. Paul and Le Sueur 2. Yield was lower for cultiver GG 359 for the dinitramine treatment at St. Paul, but this reduction was considered to reflect the phytotoxicity of dinitramine and not root disease. A lower tenderometer value was recorded for cultivar GG 549 grown in dinitramine-treated soil at Rosemount (P = 0.10). All other differences between tenderometer values for peas from the dinitramine treatments and those from the controls were not statistically significant.

DISCUSSION

The reduced severity of pea root rot caused by *Aphanomyces euteiches* in trifluralin- or dinitramine treated soils obtained in our field and controlled environment trials agrees with previous reports (6, 7). In no case did trifluralin or dinitramine treatments favor higher root disease. However, the rates applied should be regulated to avoid phytotoxicity such as that observed for dinitramine applied on cultivar GG 359 at St. Paul (Table 2). Root rot severity was reduced, but so was yield.

Dinitroaniline herbicides generally are incorporated into the upper 5-10 cm of the soil. The action of trifluralin and dinitramine might retard root infection by *A. euteiches*. This would delay the onset of severe root disease, thus resulting in less apparent root disease at any point in time and thus higher yields. Any delay in root infection would enhance seedling vigor over seedlings under immediate disease stress; increased seedling vigor may make roots more tolerant to *A. euteiches* when they grow out of the herbicide zone.

Although differences in root disease between control plants and those that received herbicide treatments were statistically significant, the biological significance of these difference is unknown. Based on previous reports, a difference of 20 units or more might be needed for biological significance (14). Larger differences between controls and herbicide treatments were observed for plants grown in a controlled environment compared to field-grown plants. However, plants grown in the controlled environment were evaluated for root rot sooner after planting than for plants in the field study. If field-grown plants had been evaluated at an earlier date, larger differences may have been observed. Natural senescence of pea roots may have started at anthesis and altered root disease evaluations.

Commercial pea growers can use trifluralin or dinitramine without risk of increasing root disease incidence when *A. euteiches* is the primary cause of root rot. It is important to select chemicals that have multiple pest control attributes to realize their total benefit to agriculture.

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