Soil Conditions and Distribution of Pathogens in Relation to Pea Root Rot in Wisconsin Soils

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ABSTRACT

Aphanomyces euteiches was prevalent throughout the plowed layer in 9 of 12 pea "root rot" fields and in 2 of 12 "nonroot rot" fields in southern Wisconsin. *Fusarium solani* f. sp. *pisi* was prevalent throughout the plowed layer in all 24 fields, averaging 275 to 6,175 propagules/g of soil, with no definite relationship between population and disease history. In contrast, populations of both pathogens were generally sparse immediately below the plowed layer. Neither disease histories nor pathogen numbers were correlated with recent cropping histories or with wide variations in soil pH. However, four fields in which peas had been grown repeatedly without a root rot problem, including two with a high incidence of both pathogens, had softer, less dense soil throughout the profile than the root rot fields. Soils in all fields were less compact in plowed layers than in subsoils. Phytopathology 60:403-406.

Aphanomyces euteiches Drechs. is considered the principal pathogen of the pea (*Pisum sativum* L.) root rot complex in Wisconsin and other midwestern states. *Fusarium solani* (Mart.) Appel & Wr. f. sp. *pisi* (F. R. Jones) Snyd. & Hans. and other pathogens are of lesser importance (7, 8). Variation in disease severity among fields (16, 17) was reported by Temp & Hagedorn (16) to be related to soil type, but not to specific cropping sequence between pea crops. However, no one has studied the distribution of the principal pathogens in Wisconsin pea fields or soil hardness and soil pH as they relate to variations in disease severity. Burke (1) found that hard subsoils increased *Fusarium* root rot of beans by obstructing root growth, and that the pathogen is confined principally to plowed soil layers (2).

This study compares fields with a high root rot index (13) and/or a history of severe root rot with fields having a low root rot index and/or a history of healthy pea crops with regard to numbers and vertical distribution of the principal pathogens, soil hardness, and pH. A preliminary report of this work has been made (4).

MATERIALS AND METHODS.—Soil samples were collected from eight fields in three pea-growing districts in the vicinities of Janesville, Green Bay, and Fox Lake, Wisconsin. These districts vary in soil types and cropping practices. On the basis of previous indexing (13) or disease histories maintained by canning companies, half the fields selected for these studies in each district were considered "root rot fields", and half "nonroot fields".

Soil samples were collected at four locations in each field from five consecutive 7.6-cm layers from the soil surface to a depth of 38 cm. Samples were collected and stored in closed polyethylene bags at 5 C. Later, the samples were screened and homogenized. Subsamples from each collection were air-dried and stored in paper bags in the laboratory for use in *Fusarium* assays and pH determinations. Soils used in assays for *Aphanomyces* and for soil moisture determinations were refrigerated at 5 C in polyethylene bags.

At each sampling site in the Janesville and Green Bay districts, soil hardness was measured at intervals of 2.54 cm from the soil surface to a depth of 40 cm with a force-gauge penetrometer (15). The depth of the plowed layer varied among fields from about 18 to 27 cm. Because all fields in the Fox Lake district had been plowed shortly before sampling and soil moisture was high, soil hardness was not measured in those fields.

Aphanomyces populations were estimated by growing pea seedlings in the soil samples to determine disease indexes (6). Soil (15 g dry wt) from each sample was placed in each of five 5.7-cm square peat pots. The pots were then filled with vermiculite, and three Perfection 47 pea seeds were planted 2 cm deep in each. Thirty ml of tap water was added to each pot, and groups of 40 pots were placed in large, rectangular pans about 5 cm deep. Each pan was placed in a large polyethylene bag and transferred to a 16 C chamber. When seedlings emerged, polyethylene bags were removed; the pans were transferred to a 28 C growth room, and tap water was placed in the bottom of each pan to a depth of 2 cm to saturate the soil in each pot. During a 7-day incubation at 28 C, water in the bottom of each pan was maintained at about a 1-cm depth. Plants were then removed from the pots and *Aphanomyces* disease ratings recorded. Disease indexes were based on the number of pots containing one or more *Aphanomyces*-infected plants, as follows: no plants infected, 0; 1 pot, 20; 2 pots, 40; 3 pots, 60; 4 pots, 80; and 5 pots, 100. Plants having no *Aphanomyces* symptoms when they were removed from the pots were placed in moist paper rag dolls (6) and incubated 3-5 days before final disease readings. Attempts to obtain quantitative data by using the most probable

number technique (9) were unsuccessful because dilution of *Aphanomyces*-infested soils more than 1:1 with noninfested soil or vermiculite prevented infection.

Fusarium counts were made on modified PCNB agar (11), because the original medium (10) did not adequately suppress bacterial growth. Top soil samples were plated at a dilution of 1:1,000, and subsoil samples at a dilution of 1:200 in five replicate dishes. Dishes were incubated in diffuse daylight at 20-22 C. Samples from five fields were assayed twice with comparable results. Colonies of *F. solani* f. sp. *pisi* on PCNB agar differ in appearance from those of *F. solani* f. sp. *phaseoli* (10), and they are less easily distinguished from some saprophytic *F. solani* types (Fig. 1). Nevertheless, we were able to recognize the pea *Fusarium* with 80-90% accuracy, as confirmed by numerous identifications of transfers on potato-dextrose agar and pathogenicity tests on pea seedlings. Furthermore, several representative isolates from each field were routinely tested for pathogenicity. Total numbers of *Fusarium*like colonies and those of other fungi appearing on dilution plates were also recorded.

RESULTS.—All subsoils were more compacted than the plowed layers. Part of the greater firmness of subsoils was due to their generally lower moisture content, but there were no significant differences in soil moisture levels in corresponding layers of soil from root rot and nonroot rot fields. Soil hardness was about the same in nonroot rot and root rot fields in the Janesville district. However, all four fields in the Green Bay area in which root rot was not considered a problem had more easily penetrable subsoils than three of the root rot fields (Fig. 2). In the Fox Lake district, three root rot fields were rocky and the nonroot rot fields were not.

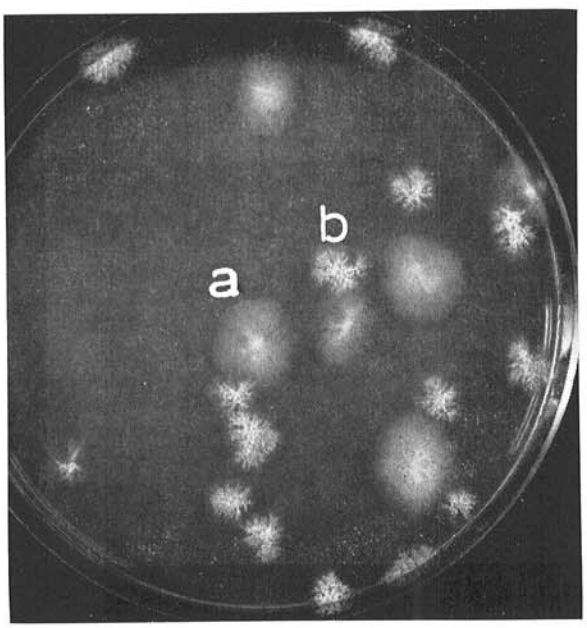

Fig. 1. Five-day-old colonies of *Fusarium solani* f. sp. *pisi* (a) and *F. solani* f. sp. *phaseoli* (b) on modified PCNB agar.

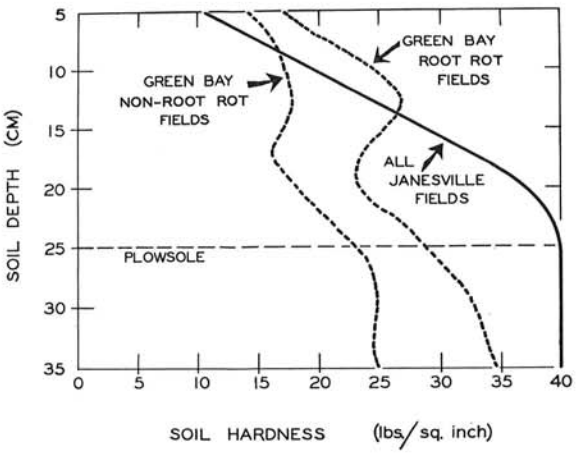

Fig. 2. Soil hardness in relation to soil depth in nonroot rot and root rot fields of two Wisconsin pea-growing districts as measured by a force-gauge penetrometer.

Soil pH among the various fields varied in the plowed layers from 5.6 to 7.5, and in subsoils from 5.0 to 7.8. However, these variations could not be correlated with disease history nor with populations of pathogens.

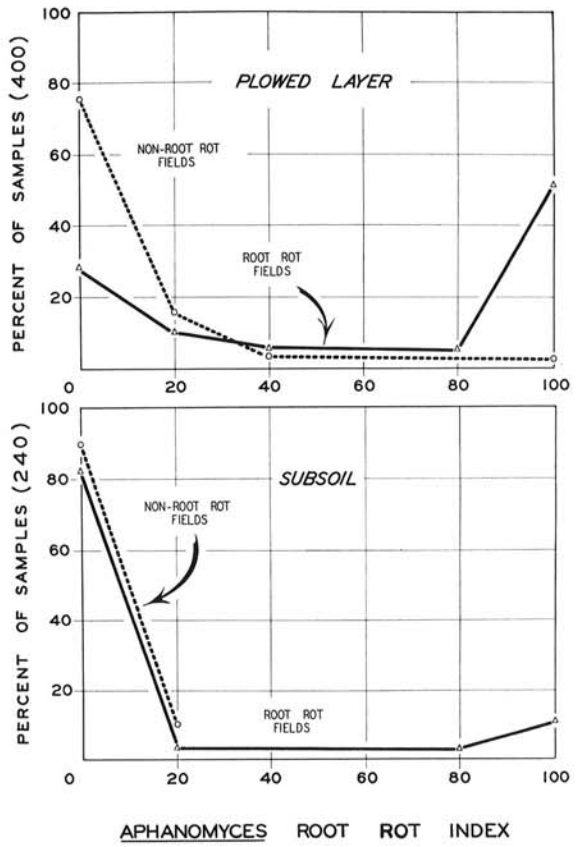

Fig. 3. Incidence of *Aphanomyces euteiches* in the plowed layer and the subsoil of Wisconsin nonroot rot and root rot pea fields.

Aphanomyces indexes were generally higher in root rot fields than in nonroot rot fields, and in plowed layers than in subsoils (Fig. 3). However, there were exceptions. Fields "O" and "S" (Table 1), for instance, had high indexes for *A. euteiches* and large populations of *F. solani* f. sp. *pisi*, but had a history of good pea crops. In contrast, field "P", with a history of root rot, appeared to have no *A. euteiches*.

Populations of *F. solani* f. sp. *pisi* were generally high, and the range was nearly the same among nonroot rot and root rot fields. Like *Aphanomyces*, this pathogen also was concentrated largely in the plowed layers, with relatively few propagules detectable in most subsoils (Table 2, Fig. 4).

Among other fungi appearing on PCNB plates, *Fusarium* spp., *Mortierella* spp., and *Penicillium* spp. were the most common from all locations and soil layers. *Fusarium* spp. were 15 times as numerous in the plowed layer as in the layer immediately below. The ratio for all other species was about 4:1 when comparing plowed layer to subsoil.

Conclusions and Discussion.—The general correlation of *Aphanomyces* indexes with root rot indexes and/or field disease histories, and the lack of such correlation with occurrence of *F. solani* f. sp. *pisi*, would appear to support the conclusions of previous workers (8, 16) that *Aphanomyces* is principally responsible for root rot in most problem fields in southern Wisconsin. However, the low *Aphanomyces* indexes in some root rot fields such as J, K, and P suggest that other pathogens may be more important in those fields.

The general occurrence of *F. solani* f. sp. *pisi*, a widely reputed pea root pathogen, in nonroot rot and root rot fields indicates that it is less important than *Aphanomyces* as a primary cause of crop damage in peas harvested for fresh processing in Wisconsin. Possibly, like the *Fusarium* causing bean root rot, it is prone to greater activity and multiplication on pre-

TABLE 1. Distribution of *Aphanomyces euteiches* in the surface and subsoils of "root rot" and "nonroot rot" pea fields in three Wisconsin pea production districts as indicated by disease indexes[a]

Root rot fields				Nonroot rot fields	
Field	Plowed layer	Subsoil	District	Field	Plowed layer	Subsoil
			Janesville			
A	93	25		D	0	0
B	53	0		E	13	5
C	72	5		F	8	5
G	20	0		H	0	0
			Green Bay			
J	35	0		I	25	0
K	28	0		M	0	0
L	30	20		N	0	0
P	0	0		O	90	25
			Fox Lake			
Q	100	50		R	5	5
T	90	20		S	65	10
U	100	15		W	0	0
V	35	20		X	0	0

[a] Each figure for plowed layers represents average data from 60 pots, and for subsoils, 20 pots.

TABLE 2. Distribution of *Fusarium solani* f. sp. *pisi* in soil from "root rot" and "nonroot rot" pea fields in three Wisconsin pea production districts[a]

Root rot fields				Nonroot rot fields	
Field	Plowed layer	Subsoil	District	Field	Plowed layer	Subsoil
			Janesville			
A	4,500	50		D	800	0
B	3,600	0		E	1,400	0
C	1,600	0		F	800	0
G	1,300	50		H	2,000	0
			Green Bay			
J	900	50		I	2,600	900
K	600	50		M	800	0
L	850	125		N	300	0
P	850	650		O	3,000	500
			Fox Lake			
Q	300	50		R	300	250
T	2,500	900		S	1,500	50
U	1,200	100		W	600	150
V	400	50		X	5,400	650

[a] Each figure for plowed layers represents the average propagules/g dry soil from 40 platings on PCNB agar and for subsoils, 20 platings.

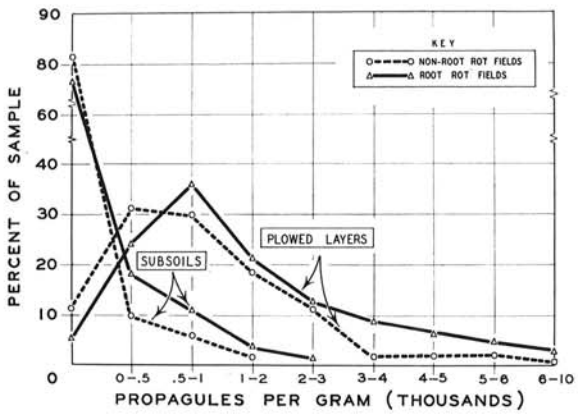

Fig. 4. Incidence of *Fusarium solani* f. sp. *pisi* in plowed layers and subsoils of Wisconsin nonroot rot and root rot pea fields.

viously diseased, retarded, or senescent roots than on vigorously growing ones (3). It also may be capable of multiplying in the rhizospheres of many kinds of plants and on decomposing crop debris as does the bean *Fusarium* (12). Its populations may be maintained in these ways in both root rot and nonroot rot fields (14).

The virtual confinement of these root pathogens to the plowed layer may be significant in understanding the effect of cultural practices on the disease problem, and may influence eventual control (1). The concentration of pathogens in the plowed layer suggests that pea roots in infested fields, like bean roots (2), may be confined largely in the plowed layers by the hard subsoils. Some fields have soils more easily penetrated by roots than others, and this may account for their not having a disease problem in spite of high populations of pathogens. We previously (5) found that root obstructions, in the form of clay saucers buried in a pea field, increased severity of *Aphanomyces* root rot. Also, hard soil promotes *Fusarium* root rot of beans (1). Hard soils and rocks increase pea root rot by delaying root extension out of the pathogen-infested plowed layer into the sparsely infested subsoil.

LITERATURE CITED

1. Burke, D. W. 1968. Root growth obstruction and *Fusarium* root rot of beans. Phytopathology 58:1575-1576.
2. Burke, D. W. 1969. Significance of the plowed soil layer in *Fusarium* root rot of beans. Phytopathology 59:1020 (Abstr.).
3. Burke, D. W., & A. W. Barker. 1966. Importance of lateral roots in *Fusarium* root rot of beans. Phytopathology 56:292-294.
4. Burke, D. W., & D. J. Hagedorn. 1968. Numbers and distribution of pathogens in relation to pea root rot in Wisconsin soils. Phytopathology 58:1045 (Abstr.).
5. Burke, D. W., D. J. Hagedorn, & J. E. Mitchell. 1969. *Aphanomyces* and *Fusarium* root rot of peas with partial vs. total exposure of roots to infested soil. Phytopathology 59:1261-1266.
6. Burke, D. W., J. E. Mitchell, & D. J. Hagedorn. 1969. Selective conditions for infection of pea seedlings by *Aphanomyces euteiches* in soil. Phytopathology 59:1670-1674.
7. Jones, F. R. 1923. Stem and root rot of peas in the United States caused by a species of *Fusarium*. J. Agr. Res. 26:459-476.
8. Jones, F. R., & C. Drechsler. 1925. Root rot of peas in the United States caused by *Aphanomyces euteiches* (n. sp.). J. Agr. Res. 30:293-325.
9. Maloy, O. C., & M. Alexander. 1958. The "most probable number" method for estimating populations of plant pathogenic organisms in the soil. Phytopathology 48:126-128.
10. Nash, Shirley M., & W. C. Snyder. 1962. Quantitative estimations by plate counts of propagules of the bean root rot *Fusarium* in field soils. Phytopathology 52:567-572.
11. Papavizas, G. C. 1967. Evaluation of various media and antimicrobial agents for isolation of *Fusarium* from soil. Phytopathology 57:848-852.
12. Schroth, M. N., & F. F. Hendrix, Jr. 1962. Influence of nonsusceptible plants on survival of *Fusarium solani* f. *phaseoli* in soil. Phytopathology 52:906-909.
13. Sherwood, R. T., & D. J. Hagedorn. 1958. Determining common root rot potential of pea fields. Wis. Agr. Exp. Sta. Bull. 531. 12 p.
14. Sherwood, R. T., & D. J. Hagedorn. 1962. Studies on the biology of *Aphanomyces euteiches*. Phytopathology 52:150-154.
15. Taylor, H. M., G. M. Roberson, & J. J. Parker, Jr. 1965. Soil strength and root penetration relations for medium- to coarse-textured soil materials. Soil Sci. 102:18-22.
16. Temp, M. V., & D. J. Hagedorn. 1967. Influence of cropping practices on *Aphanomyces* root rot potential of Wisconsin pea fields. Phytopathology 57:667-670.
17. Walker, J. C., & W. W. Hare. 1943. Pea Diseases in Wisconsin in 1942. Wis. Agr. Exp. Sta. Res. Bull. 145. 32 p.