Take-All of Wheat as Influenced by Organic Amendments and Nitrogen Fertilizers

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ABSTRACT

Take-all of wheat, caused by *Ophiobolus graminis* was suppressed by maintaining a substantial proportion of rhizosphere N in the NH_4-N form. The result was the same regardless of whether NH_4-N was supplied by fertilizers or by mixing alfalfa meal with soil shortly before seeding wheat into *Ophiobolus*-infested soil. Disease suppression was highly correlated with the magnitude of reduction in rhizosphere pH and with the concn of NH_4-N in the rhizosphere. Take-all was not suppressed at low absolute concns of NH_4-N, or at any concn of NO_3-N.

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Take-all of wheat (*Triticum aestivum* L.), caused by *Ophiobolus graminis* Sacc. (=*Gaeumannomyces graminis* Sacc. v. Arx & Olivier var. *tritici* J. Walker), is generally most severe where wheat follows clover-grass pasture or alfalfa in the rotation (1). Cultural practices known to increase the nitrogen (N) fertility during the carryover phase of this pathogen tend to increase take-all severity on subsequent wheat crops. Saprophytic survival of the pathogen is increased when soil N concns are high (2). Where N is immobilized between wheat crops the disease is reduced (1, 5, 6, 7). Severe disease often occurs in wheat which follows an alfalfa crop. However, little disease occurs when the alfalfa residues are mixed into soil shortly before seeding. These contrasting effects of timing may relate to an influence on survival of the pathogen in the first instance, and on parasitism in the latter instance.

Ammonium-nitrogen (NH_4-N) suppresses take-all in infertile soils and nitrate-nitrogen NH_4-N enhances, suppresses slightly, or has no effect on the severity of this disease (3, 4, 8). The effect of NH_4-N) in the root zone during pathogenesis was to reduce the rhizosphere pH to values unfavorable to *Ophiobolus.* The magnitude of change in rhizosphere pH was often more highly correlated with disease severity than was either the initial or final pH, and this was thought to involve a role of antagonism toward *Ophiobolus* by microorganisms. Since the crop which precedes wheat influences both the severity of take-all and the N-fertility of soil, the fertilizer studies of Smiley and Cook (8) were extended to include soils amended with plant residues, which result in net mineralization (alfalfa hay) of N or net immobilization (wheat straw) of N. Results of this work are presented here.

MATERIALS AND METHODS.–The soils, fertilizers, and procedures used have been described (8). Soils used in these tests were a Puyallup fine sandy loam and a Ritzville silt loam with saturated paste pH (in 0.01M $CaCl_2$) values respectively, of 5.6 and 7.1. Both were deficient in native N. Fertilizers were of commercial grades of prilled $Ca(NO_3)_2$ and crystalline $(NH_4)_2SO_4$. They were applied at the rate of 0.1 g N/kg soil. Superphosphate and gypsum were also provided. Finely ground oat inoculum infested with *O. graminis* was blended with the soil at the rate of 0.25% (w/w). Wheat straw (0.6%N, C:N ratio = 67) and alfalfa hay (2.5%N, C:N ratio = 17) were milled to pass through a 2-mm screen and then were mixed with soil at the rate of 2% (w/w). The soils were moistened to about -1 bar potential and dispensed into 15-cm diam plastic pots (1.5 kg soil/pot). Spring wheat (cultivar Idaed) was planted and the soils were incubated in the greenhouse at alternating day-night temp of about 22-10 C, and at an approximate day-length of 13 h. The stand was thinned to four seedlings per pot. Each treatment was replicated three times and sufficient pots were prepared for sampling at 3 (seedling stage) and 9 (heading) wk after emergence. Determinations were made of the percentage of *O. graminis*-infected seminal and coronal roots at 3 and 9 wk, the NH_4-N and NO_3-N concns and pH in rhizosphere soil at 3 wk, and the plant height at 9 wk.

RESULTS. – Root infection was suppressed more by fertilizers which supply NH_4-N than those which supply NO_3-N, and more by soil amendment with alfalfa hay than with wheat straw (Table 1). Suppression of disease with alfalfa occurred regardless of fertilizer treatment, and the suppressive influence of NH_4-N was likewise exhibited in each of the six soil:amendment variables. Nitrate had a variable effect, but generally did not reduce infection percentages to any great extent. Compared to the controls, more NH_4-N and total N were measured in alfalfa-amended soils, and less in wheat straw-amended soils. The highest NH_4-N concn in the Puyallup soil was measured in the treatment soil with alfalfa and fertilized with NH_4-N. It was in this treatment that the greatest suppression of take-all also occurred. A considerable reduction in disease severity occurred in wheat-amended Puyallup soil where most of the N was immobilized. This pattern is typical of take-all in field soils deficient in N, but it did not occur in the Ritzville soil.

The severity of take-all was inversely correlated with the NH_4-N concn ($y = -0.619 X + 64.619$; $r = 0.61$; 16 dF). Although this relationship was highly significant ($P = 0.01$), its value is limited in that there was considerable variability in disease at intermediate to low NH_4-N concns (less than 20 μg N/g). Nevertheless, the level of root infection was least when the NH_4-N concn was highest, and most where the concn of NH_4-N was lowest. No relationship existed between root infection and NO_3-N or N concns. It therefore appears that the pathogen requires at least some N, but beyond this point no relationship exists between infection and total N.

Incorporation of alfalfa hay or wheat straw into soil resulted in higher rhizosphere pH values than in nonamended controls. For each soil:amendment combination, the addition of NH_4-N reduced the rhizosphere pH compared to the nonfertilized control, but no real changes occurred with NO_3-N additions. When data from all six of the soil:amendment combinations in Table 1 were grouped, the magnitude of change in rhizosphere pH, compared to nonfertilized controls, was highly correlated with the corresponding changes in infection percentages (Fig. 1-A). The percentage of infected roots was highly correlated with absolute values of rhizosphere pH within individual soils and/or amendment variables, but when all variables were grouped there was no apparent correlation (Fig. 1-B).

Mature plant height was a useful criterion for assessing the severity of take-all in the soils used in this greenhouse study. Plant height was always greater in alfalfa-amended soils (66-76 cm), least in soils amended with wheat straw (25-36 cm), and intermediate in nonamended soils (43-71 cm). The plant height was inversely correlated (P=0.01) with the percentage of infected roots ($y = -0.164 X + 28.666$; r

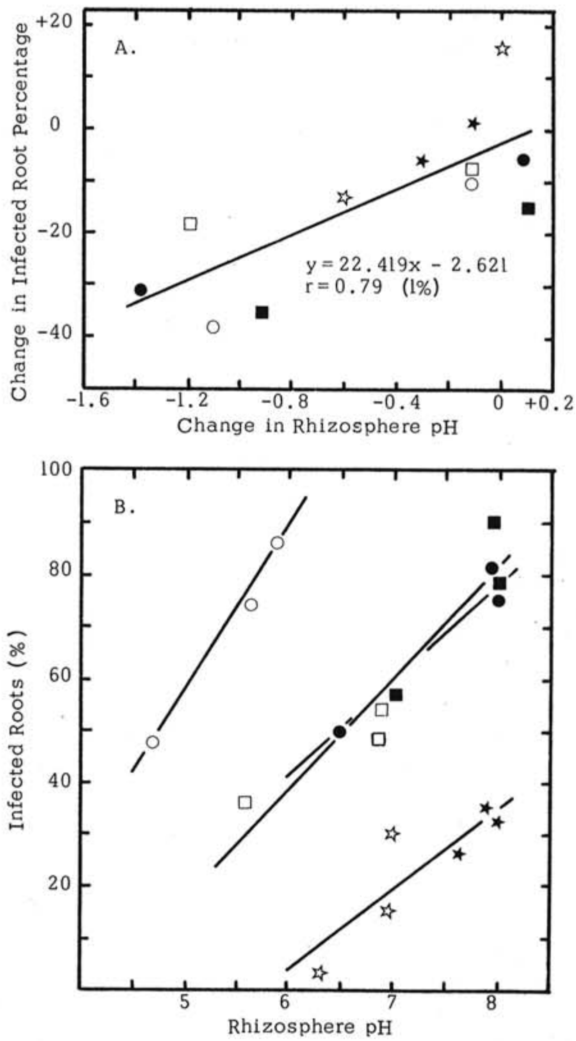

Fig. 1. Take-all severity and changes in rhizosphere pH in Puyallup (open symbols) and Ritzville (solid symbols) soils fertilized with NH_4 - vs NO_3 -N and amended with alfalfa hay (★), wheat straw (■), or nonamended (●).

TABLE 1. Take-all severity and the N concns and pH in the rhizosphere of wheat

Soils and measured parameters	Soil amendments								
	Wheat Straw[a]			Alfalfa Hay			None		
	no N	NO_3-N[b]	NH_4-N	no N	NO_3-N	NH_4-N	no N	NO_3-N	NH_4-N
Puyallup fine sandy loam[c]									
Infected Roots (%)	54	47	35	15	31	2	87	76	49
pH[d]	6.8	6.7	5.6	6.9	6.9	6.3	5.8	5.7	4.7
NH_4-N (μg N/g)	5	2	8	11	18	82	4	17	37
NO_3-N (μg N/g)	0	0	0	2	71	101	1	56	17
Ritzville silt loam[c]									
Infected Roots (%)	90	76	56	32	34	27	81	76	50
pH[d]	7.9	8.0	7.0	8.0	7.9	7.7	7.9	8.0	6.5
NH_4-N (μg N/g)	0	4	8	17	36	40	5	2	59
NO_3-N (μg N/g)	0	0	0	36	103	3	0	52	16

[a]Finely chopped wheat straw and alfalfa hay (2%, w/w) were mixed into soil.
[b]$Ca(NO_3)_2$ and $(NH_4)_2SO_4$ were mixed into soil at the rate of 0.1 g N/kg soil.
[c]Soils were inoculated with *Ophiobolus graminis* by additions of infested, finely ground oats (0.25%, w/w).
[d]Rhizosphere pH of 3-wk-old wheat plants was measured as 1:2 suspension of soil in 0.01 M $CaCl_2$.

= 0.60; 16 dF). The largest plants produced large heads and full kernels of grain, whereas the stunted plants produced small heads and shrivelled grain typical of that from "whiteheads". Grain yields were not measured. Root numbers and root mass were less in the NH_4-N fertilized soils than in nonfertilized or NO_3-N fertilized soils. Addition of wheat and alfalfa to soil uniformly reduced root numbers, but alfalfa increased the root mass in comparison to the other amendment variables.

DISCUSSION.—The severity of take-all was inversely correlated with the magnitude of change in rhizosphere pH. Although the absolute level of rhizosphere pH and the magnitude of change were both important in the previous study with fertilizers (8), the latter appeared most important where organic amendments had recently been added to soil. Disease was suppressed when the rhizosphere pH was reduced and when the NH_4-N concn in soil was maintained at high levels by addition of ammoniacal fertilizer or by mineralization of finely ground alfalfa hay.

A large part of the suppressive effect of alfalfa was not attributable to reduced rhizosphere pH or to the concentration of NH_4-N. Increased levels of antagonism and competition by microorganisms was probably involved as well. Even with an alfalfa amendment, however, NH_4-N gave a greater suppressive effect on disease severity than NO_3-N. Soils generally supply N to roots predominantly in the NO_3-N form. Under these conditions there is a clear tendency for the pH of rhizosphere soil to be nearer neutrality (low NO_3-N concn) or more alkaline (high NO_3-N concn) than the surrounding soil (8, 9). In contrast, absorption and assimilation of NH_4-N by roots in poorly- to moderately-buffered soils induces a sharp reduction in the rhizosphere pH. Microorganisms are more affected by changes in pH than by absolute values of pH in agricultural soils, and some rhizoplane-inhabiting microorganisms also serve to suppress the rate of ectotrophic growth of *O. graminis* (Smiley, *unpublished*). The reason that the magnitude of change in pH appeared to be most important in this study may be due to its effect on the rhizoplane-inhabiting microorganisms which antagonize *Ophiobolus*. Where the reduction in rhizosphere pH by NH_4-N is prevented by adding an excess of lime to soil, the suppressive influence of NH_4-N is also negated (8).

Amendment of soil with alfalfa hay effectively reduced the infection of roots by *O. graminis*. When alfalfa or other residues with a low C:N ratio are mixed with soil, NH_4-N is released by net mineralization of organic N. If wheat roots are growing in soil at this time, as they were here, much of the NH_4-N may be absorbed directly, thus reducing the rhizosphere pH and thereby reducing the inoculum potential of the pathogen and increasing its susceptibility to antagonism by the general rhizosphere microflora. The NH_4-N which is not absorbed by roots is largely nitrified. If wheat is planted when most of the inorganic N exists as NO_3-N, as generally occurs in the field, the roots will be highly susceptible to attack by *Ophiobolus*. The contrasting effects of incorporating alfalfa into soil well before or just prior to seeding serve to emphasize that the form of N, and not N per se, is important during pathogenesis.

Where wheat:legume rotations are practiced in *Ophiobolus*-infested fields, it remains to be determined whether the severity of take-all can be reduced by seeding wheat soon after the legumes have been turned into the soil. The results will depend largely upon the NO_3-N concn in soil, the rates of ammonification and nitrification of N released upon degradation of the freshly incorporated legume, and the presence of sufficient soil moisture for root growth in the upper soil profile. Suppression of nitrification could alleviate severe losses due to take-all.

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