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Influence of Aphanomyces Root Rot on Alfalfa Health and Forage Yields

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Introduction

Maximum alfalfa performance is achieved when grown on deep, well drained soils, while severe stand and yield losses can occur on soils that are imperfectly drained (Wing, 1909; Alva et al., 1985). In Wisconsin, nearly half of all forage production is on soils that are classified as somewhat poorly drained.

Phytophthora root rot (Phytophthora megasperma (Drechs) f. sp. medicaginis) is often considered to be the major cause for alfalfa failure in wet soils (Kuan and Erwin, 1980; Erwin, 1966). More recently, Delwiche et al. (1987) reported seedling and root rot of alfalfa caused by Aphanomyces euteiches (Drechs) leading to reduced field productivity (Holub and Grau, 1990).

Disease resistance offers the most effective, long term means of reducing losses due to Phytophthora and Aphanomyces root rot and improving productivity of alfalfa in wet soil environments. The first reports of developing Phytophthora root rot resistant germplasms were by Frosheiser and Barnes (1973) and Hine et al. (1975). Today, many newly released alfalfa varieties have high levels of resistance. Alfalfa populations have been improved for resistance to Aphanomyces root rot by phenotypic recurrent selection methods (Holub and Grau, 1990). Most private breeding programs incorporate some level of Aphanomyces root rot resistance into newly developed varieties.

Although Phytophthora and Aphanomyces root rot can be independently screened for in alfalfa breeding and selection programs, dual resistance has the potential for significantly improving the performance of alfalfa varieties (Holub and Grau, 1990), especially in poorly drained soil conditions. In addition, while seedling assays are useful for characterizing resistance to either Phytophthora or Aphanomyces root rot, it will not always predict field performance of alfalfa. Therefore, field studies were conducted to determine the effect of various levels of resistance to Phytophthora and Aphanomyces root rot on alfalfa seedling survival and plant productivity when exposed to naturally infested soils. Ultimately, we wanted to compare forage yields of varieties with differing levels of resistance to Phytophthora.
and Aphanomyces root rot in state variety performance trials to determine what level of disease resistance is required to adequately protect the crop in Wisconsin.

Materials and Methods

Seedling Establishment Trial - Marshfield
Alfalfa varieties were evaluated in field trials during 1990-1992. Plots were established at the University of Wisconsin, Marshfield Agricultural Research Station, Marshfield, Wisconsin, on a somewhat poorly drained Withee silt loam. Planting dates were 17 July, 1990; 28 May, 1991; and 4 June, 1992. Alfalfa was seeded at a rate of 0.035 oz per 10 feet of row (9.6 lbs/acre equivalent) and rows were spaced 12" apart. When plants reached the third to fourth trifoliate stage of growth, the plot area was irrigated to maintain a saturated soil condition for two to three weeks. Plots were hand weeded during the growing season.

During late August or September of each year a visual stand (0 to 100%) and vigor (1 = poor vigor to 5 = excellent vigor) rating of each plot was recorded. During 1990, plants were dug from the check variety plots. Plant roots were visually scored for root size and health (1 = excellent, large root to 3 = poor root) and counted by category.

The experimental design was a randomized complete block design with five replicates. Because each trial tested a different number of varieties, data were analyzed separately for each year using AOV. Mean separations were determined using a protected Fisher’s LSD (P > 0.10).

Wisconsin Alfalfa Variety Performance Trials
Annual alfalfa variety forage yield data are collected from multiple locations in Wisconsin (Table 1) and published for grower information (Undersander et al. 1990, 1991, 1992). Each variety is classified for the National Alfalfa Variety Review Board for level of resistance to various diseases as follows:

- S (Susceptible)  < 5% resistant plants
- LR (Low Resistance)  5 - 15 % resistant plants
- MR (Moderately Resistant)  16 - 30 % resistant plants
- R (Resistant)  31 - 50% resistant plants
- HR (Highly resistant)  > 50% resistant plants

Alfalfa forage yield is collected from each trial using a 3 or 4 cut harvest schedule for 1 to 3 years. Yield is averaged across cuts and years and expressed as a percentage of the variety Vernal. This set of data includes 179 individual alfalfa varieties for which yield and disease resistance information was available.

Statistical analysis was performed using nonorthogonal analysis with a model appropriate for a completely random design. Polynomial contrasts were calculated to determine linear and quadratic response to resistance level. Linear or curvilinear regressions were calculated on disease level means to characterize yield response to disease resistance level.
<table>
<thead>
<tr>
<th>Environment/Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Soil Type</th>
<th>Year of Seeding</th>
<th>Number of Harvest Years</th>
<th>Yield (ton DM/a)</th>
</tr>
</thead>
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<tr>
<td>1 Arlington</td>
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<td>89/21'</td>
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<td>90/58'</td>
<td>Ontonagon silty clay loam</td>
<td>1987</td>
<td>3</td>
<td>2.58</td>
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<tr>
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<td>88/51'</td>
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<td>11 Hancock</td>
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<td>90/47'</td>
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<td>3</td>
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<td>3.14</td>
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<tr>
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<td>90/08'</td>
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<td>88/32'</td>
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<td>92/31'</td>
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<td>4.69</td>
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<tr>
<td>23 River Falls</td>
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<td>92/31'</td>
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<td>2</td>
<td>4.27</td>
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<td>87/39'</td>
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<td>25 Sheboygan</td>
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<td>26 Spooner</td>
<td>45/49'</td>
<td>91/53'</td>
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On 21 July, 1993 an alfalfa variety evaluation trial was seeded with 117 varieties at Marshfield, WI. Above normal precipitation fell in August and September, leading to very intense Phytophthora and Aphanomyces root rot symptom development in the trial. A visual rating of plant health and vigor was taken on 24 September, 1993 using a 1 = poor to 5 = excellent scale. Forage yield was measured on 14 October, 1993 and expressed as a percentage of Vernal. Linear or curvilinear regressions were calculated using disease resistance level for each variety versus forage yield.

**Results and Discussion**

**Seedling Establishment Trial - Marshfield**

Stand percentage and vigor score differences were found among alfalfa varieties in all years of the study (Table 2). Stand percentage of Saranac and all commercial entries were lowest in 1990 and similar but higher in 1991 and 1992. In each year, the resistant checks had higher plant stand percentages than the susceptible varieties. This increase in alfalfa plant survival is due to the higher levels of resistance to Phytophthora and Aphanomyces root rot found in the resistant varieties. In 1990 and 1992 the stand percentage of the top ten commercial entries was not significantly different from WAPH-1, and in 1991, stands were higher, indicating resistance to both Phytophthora and Aphanomyces root rot in the material submitted for testing. Vigor scores followed the same pattern as stand percentage where plant vigor was markedly improved when varieties had dual resistance to Phytophthora and Aphanomyces root rot.

In the 1990 trial, six varieties were dug and roots were scored for size and health (Figure 1). WAPH-1 and Aph 103 had the most plants per square foot, while Saranac had the least. Based on the varying levels of resistance to Phytophthora and Aphanomyces root rot in the varieties tested, it is evident that both the presence and level of Phytophthora and Aphanomyces root rot resistance influenced total plant stand and root health. Apollo II and Agate have high levels of
resistance to Phytophthora root rot, but are susceptible to Aphanomyces root rot and performed intermediate to varieties with high levels of resistance to both Phytophthora and Aphanomyces root rot and the susceptible variety Saranac. The varieties with the best stands also had a greater proportion of plants with root scores of 1s and the lowest proportion of 3s. Several researchers have shown that level of resistance to Phytophthora root rot greatly influences severity and agronomic impact of root disease (Alva et al., 1985; Barta and Schmittenner, 1986; Leuschen et al., 1976). In addition, Holub and Grau (1990) reported increased plant stand for plants which were resistant to both Phytophthora and Aphanomyces root rot in a dual-infested nursery.

![Figure 1. Alfalfa plant stand for six varieties by root score in 1990 at Marshfield, WI.](image)

**Wisconsin Alfalfa Performance Trials**

Alfalfa forage yields averaged across varieties and years of harvest were largely influenced by environment (Table 1). Average yields ranged from 1.82 tons DM per acre in environment 6 to 6.46 tons DM per acre in environment 24. This wide yield variation represents the diversity of growing conditions found in Wisconsin and included drought environments (1988) and very high yield environments.

Averaged across years, locations, and varieties, forage yield increased as the level of resistance to Phytophthora root rot increased from 0 to 40% resistance (Figure 2). Further increases in level of Phytophthora root rot resistance did not result in additional yield benefit. Lack of additional yield increase beyond 40% Phytophthora root rot resistance indicates the presence of other yield limiting factors. Yields of varieties increased linearly with increasing levels of resistance to Aphanomyces root rot from 0 to 75% resistance (Figure 2). These data show that across a wide range of environments, forage yield is maximized by having dual resistance to Phytophthora and Aphanomyces root rot. This confirms what was seen in the seedling
establishment trials, where Phytophthora root rot resistance improved stand, root health, and vigor above the susceptible variety Saranac, but dual resistance to Phytophthora and Aphanomyces root rot was required to achieve the highest stands and best plant health. Differences in forage yield level between the Phytophthora and Aphanomyces root rot regression lines are due to the confounding effect of having R or HR levels of Phytophthora root rot resistance at all levels of Aphanomyces root rot resistance, leading to higher overall performance.

![Graph](image)

**Figure 2.** Alfalfa forage yield (as a % of Vernal) averaged across environments, varieties, and years for varying levels of resistance to Phytophthora and Aphanomyces root rot.

While the environment x disease level interaction could not be examined statistically in this data analysis, several trends are evident. In all 26 environments, forage yields are higher when the level of Phytophthora root rot is MR, R, or HR when compared with S and LR levels. There was no environment in which there was a forage yield penalty for having a MR or higher level of Phytophthora root rot resistance. Likewise, having an MR level of Aphanomyces root rot resistance or higher resulted in the same or higher forage yields than having a S or LR level in all environments tested. It was evident that in environments where Phytophthora and Aphanomyces root rot were severely suppressing yields, the penalty for low resistance to these pathogens was very great.

The 1993 alfalfa variety evaluation at Marshfield demonstrates the dramatic reductions in yield and plant vigor of susceptible varieties under extreme Phytophthora and Aphanomyces root rot stress. Alfalfa forage yield was positively correlated with level of Phytophthora and
Aphanomyces root rot resistance (Figure 3). The large difference in level of yield between the Phytophthora and Aphanomyces root rot regression lines is because varieties at all levels of Aphanomyces root rot resistance have a R or HR level of resistance to Phytophthora root rot. Having dual resistance resulted in superior performance with the best varieties yielding over 325% better than Vernal.

Figure 3. Alfalfa forage yield (as a % of Vernal) averaged across varieties for varying levels of resistance to Phytophthora and Aphanomyces root rot at Marshfield, WI in 1993.

Vigor scores (Figure 4), representing above ground plant health, also show significant increases in vigor with increasing levels of Phytophthora and Aphanomyces root rot resistance. Varieties with vigor scores of 1 or 2 had severely stunted above ground and root growth. In this trial, only plants with high levels of resistance to Phytophthora root rot and moderate to high levels of resistance to Aphanomyces root rot will likely survive a winter.
Figure 4. Alfalfa vigor score averaged across varieties for varying levels of resistance to Phytophthora and Aphanomyces root rot at Marshfield, WI in 1993.

Summary

Alfalfa varieties with resistance to Phytophthora and Aphanomyces root rot are required to maximize stand establishment, plant vigor, and forage yield in Wisconsin. The improved stand survival and long term root health gained through resistance to Phytophthora and Aphanomyces root rot results in increased yield potential in a broad range of environments. These studies demonstrate both the lethal (stand mortality) effects of Phytophthora and Aphanomyces root rot frequently seen in the seedling phase of plant growth as well as an apparent sublethal (yield reduction) effect of these pathogens in Wisconsin. Nelson (1973) suggests that significant reductions in yield of most crops is brought about in nonspectacular fashion by diseases that occur in less epidemic proportions. Incorporation of both Phytophthora and Aphanomyces root rot resistance in modern varieties has expanded the acreage on which alfalfa can be grown to include those regions where "wet-soil syndrome" is a limiting factor to establishment and growth. Availability of highly resistant varieties may be useful in finding other microorganisms or abiotic factors which may be limiting yield potential in poorly drained soils. These studies also confirm that there is a yield advantage for growing resistant varieties in many environments, including those environments which are not apparently prone to wet-soil conditions. We would recommend that farmers select varieties with R or HR levels of resistance to both Phytophthora and Aphanomyces root rot to adequately protect their crop and to maximize forage productivity in Wisconsin.

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