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# Differential Effects of *Pratylenchus neglectus* Populations on Single and Interplantings of Alfalfa and Crested Wheatgrass[1]

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*Abstract:* The invasion by three different Utah populations of *Pratylenchus neglectus* (UT1, UT2, UT3) was similar in single and interplantings of 'Lahontan' alfalfa and 'Fairway' crested wheatgrass at 24 ± 3 °C. Population UT3 was more pathogenic than UT1 and UT2 on both alfalfa and crested wheatgrass. Inoculum density was positively correlated with an invasion by *P. neglectus*. Invasions by UT3 at all initial populations (Pi) exceeded that of UT1 and UT2 for both single and interplanted treatments. The greatest reductions in shoot and root weights of alfalfa and crested wheatgrass were at a Pi of 8 *P. neglectus*/cm$^3$ soil. Pi was negatively correlated with alfalfa and crested wheatgrass shoot and root growth and nematode reproduction. The reproductive factor (Rf) for UT3 exceeded that of UT1 and UT2 in single and interplantings at all inoculum levels. There were no differences in Rf in the Utah populations in single or interplantings. A nematode invasion increased with temperature and was greatest at 30 °C. Population UT3 was more pathogenic than UT1 and UT2 and reduced shoot and root growth at all soil temperatures. Populations UT1 and UT2 reduced shoot and root growth at 20–30 °C. Soil temperature was negatively correlated with shoot and root growth and positively correlated with nematode reproduction. Reproduction of UT3 exceeded that of UT1 and UT2 at all soil temperatures.

*Key words:* alfalfa, crested wheatgrass, lesion nematode, *Medicago sativa, Pascopyrum smithii,* pathogenicity, *Pratylenchus neglectus,* reproductive factor, root weights, shoot weights, survival.

Rangelands in the western United States consist mainly of mixtures of grasses, forbs, and shrubs. Less than optimum usage of rangelands has resulted in an increase in shrubs associated with a loss of grasslands (Rumbaugh and Townsend, 1985). It is estimated that more than 86% of the rangelands are in poor condition, and productivity is less than 60% of their natural potential (Schmautz et al., 1980). The effort to upgrade rangeland quality includes the breeding of palatable grass cultivars and germplasm, including wheatgrasses that provide high-quality forage grasses in western North America during the spring and early summer (Asay and Knowles, 1985; Asay et al., 1985). Forage legumes such as alfalfa (*Medicago sativa* L.) may improve rangelands (Dubbs, 1971; Kilcher and Heinricks, 1965; Nyren et al., 1978; Pendry and Provenza, 1987; Rumbaugh et al., 1982). The root lesion nematode, *Pratylenchus neglectus* (Rensch) Filipjev & Schuurmans Stekhoven, an endemic species, is associated with alfalfa and rangeland grasses in the intermountain region of the western United States (Griffin, 1991, 1992, 1993; Thorne, 1961). *Pratylenchus neglectus* is pathogenic on both alfalfa and grasses, but its pathogenicity does not vary on single or mixed plantings of alfalfa and grasses (Griffin, 1994).

Genetic diversity and variability of races and pathotypes occur among nematode populations (Ladygika, 1985; Olthof, 1968; Sidhu and Webster, 1981; Wallace, 1973; Wilson, 1980), including pathotypic differences between *Meloidogyne hapla* and *P. neglectus* populations (Griffin, 1991; Griffin and McKenry, 1989). Similar differences may characterize geographically separated populations as well as other nematode species. These differences must be considered in screening and breeding programs to incorporate resistance to nematodes.

Alfalfa and grasses are both susceptible to *P. neglectus;* the persistence and growth of alfalfa and Hycrest crested wheatgrass (*Agropyron cristatum* (L.) Gaertner × *A. desertorum* (Fisch. ex Link) Schult), Fairway crested wheatgrass (*A. cristatum*), and Nordan crested wheatgrass (*A. desertorum*) inocu-

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lated with *P. neglectus* did not differ (Griffin, 1994). However, since difference in pathogenicity of *P. neglectus* populations occur (Griffin, 1991), the current study was initiated to determine the pathological differences of *P. neglectus* populations on alfalfa and alfalfa interplanted with crested wheatgrass, and how pathogenicity is affected by inoculum density and temperature.

## Materials and Methods

*Nematode inocula:* Three endemic *P. neglectus* populations were obtained from western wheatgrass (*Pascopyrum smithii* (Rydb.) Löve) from central Utah (UT1) and northern Utah (UT2, UT3) (Griffin, 1991). Nematodes were cultivated on wheat, *Triticum aestivum* L. cv. Nugaines, in a temperature-controlled-greenhouse. Nematode inocula were obtained from roots with a modified Baermann funnel and were surface-sterilized (Griffin, 1992).

*Greenhouse bench experiment:* Seedlings (3–5 mm radicle) of 'Lahontan' alfalfa and 'Fairway' crested wheatgrass were planted singly or interplanted into individual 6-cm-diam. plastic containers containing 540 $cm^3$ of steam-pasteurized Kidman fine sandy loam (coarse-loamy mixed mesic Calcic Haploxeroll; 86% sand, 7% silt, 7% clay; pH 7.2; 1.0% organic matter). *Rhizobium meliloti* Dang. was applied around the roots of alfalfa to ensure root nodulation. At 30 days after planting, soil in each container was inoculated with an initial density (Pi) of 0 (uninoculated control), 2, 4, or 8 *P. neglectus* (mixed life stages)/$cm^3$ soil of one of the nematode populations. Nematodes suspended in deionized water were poured into four holes 10 cm deep in the soil around the hypocotyl base of the plant. Uninoculated controls received deionized water alone. Containers were maintained in a greenhouse at 24 ± 3 °C.

The experiment consisted of three nematode populations and three plant combinations (four alfalfa plants, or four crested wheatgrass plants, or two alfalfas plus two crested wheatgrass plants per replicate or pot) in a randomized block design with 40 replications. Supplemental light (19-hour day length) was provided by high-output fluorescent lamps. Plants were watered daily and fertilized biweekly with a complete nutrient solution to offset any effect of nitrogen increase from *R. meliloti.* Twenty replicates of each treatment were harvested 20 days after inoculation, roots were washed free of soil and stained, and nematode invasion was determined with the use of a stereomicroscope. The remaining 20 replicates were harvested 130 days later, and plant persistence, shoot and root weights, and the nematode reproductive factor (Rf = final nematode population/initial nematode inoculum) were determined. Nematodes were extracted from the soil by elutriation (Byrd et al., 1976) followed by rapid centrifugal-flotation (Jenkins, 1964), and from alfalfa and grass roots with a Baermann funnel (Griffin, 1992). Each parameter was correlated with inoculum density. Data were analyzed with ANOVA. Percentage data on plant survival were transformed by arcsine ($\sqrt{x}$) before analysis, and differences among means were compared at $P \leq 0.05$ using LSD or Duncan's multiple-range test. Each parameter was regressed against inoculum density. The experiment was repeated, and the data presented are the combined means of two experiments.

*Growth chamber temperature experiment:* A study similar to the greenhouse experiment was conducted in temperature-controlled growth chambers with inoculum densities of 0 (uninoculated control) and 4 nematodes/$cm^3$ soil. Plants were grown in four chambers at constant temperatures of 15, 20, 25, and 30 °C. The experiment consisted of four temperatures, three plant combinations (four alfalfa plants, or four crested wheatgrass plants, or two alfalfas plus two crested wheatgrass plants per replicate or pot), and two nematode treatments. The experiment was a randomized block design with 12 replications. Six replicates of each treatment were harvested 20 days after inoculation, and nematode invasion was determined. The remaining six replicates were harvested 120 days later, and data were collected, recorded, and analyzed as described for the greenhouse bench study. The experiment was repeated, and the data presented are combined means of two experiments.

## Results

*Greenhouse bench experiment—alfalfa:* All Lahontan alfalfa plants in single and alfalfa-crested wheatgrass interplant treatments survived populations UT1 and UT2 at Pi of 0, 2, and 4 nematodes/$cm^3$ soil. Survival rates were 96% and 100% for UT1 and 95% and 100% for UT2 in single and interplanted treatments at Pi of 8 nematodes/$cm^3$ soil. The survival rates for UT3 in single and interplanted treatments were 100% and 100% (Pi = 2), 93% and 95% (Pi = 4), and 90% and 88% (Pi = 8).

Inoculum density was correlated positively with the invasion by *P. neglectus* of alfalfa ($r$ = 0.92) and crested wheatgrass ($r$ = 0.86). Invasion by UT3 at all Pi exceeded that of UT1 and UT2 in single and interplanted treatments ($P \leq 0.05$) (Table 1). At all Pi, invasion of both alfalfa and crested wheatgrass root tissue by *P. neglectus* was similar.

Population UT3 was more virulent than UT1 and UT2 at all inoculum levels. Populations UT1 and UT2 had similar effects on shoot and root growth. Virulence of the populations was similar in single and interplanted treatments (Table 1). The greatest reductions in shoot and root weights were at a Pi of 8 ($P \leq 0.05$) (Table 1). Pi was correlated negatively with alfalfa shoot and root growth for UT1 (shoot, $r$ = −0.88; root, $r$ = −0.83); UT2 (shoot, $r$ = −0.93; root, $r$ = −0.84) and UT3 (shoot, $r$ = −0.90; root, $r$ = −0.85). The Rf of UT3 exceeded that of UT1 and UT2 in single and interplantings at all inoculum levels. There were no differences in Rf for alfalfa in either single or interplantings. The Rf was positively correlated ($r$) with root growth in single (UT1 = 0.84; UT2 = 0.87; UT3 = 0.82) and interplantings (UT1 = 0.88; UT2 = 86; UT3 = 84).

*Crested wheatgrass:* All Fairway crested wheatgrass plants survived all UT1 and UT2

TABLE 1. Invasion, pathogenicity, and reproduction of different *Pratylenchus neglectus* populations from Utah (UT1, UT2, UT3)[a] on Lahontan alfalfa in single and interplant plantings of 'Lahontan' alfalfa and Fairway crested wheatgrass at a greenhouse temperature of 24 °C ± 3 °C.

| Inoculum level Nemas/$cm^3$ soil | UT1 Single | UT1 Interplant | UT2 Single | UT2 Interplant | UT3 Single | UT3 Interplant |
|---|---|---|---|---|---|---|
| | Nematodes/g root tissue[b] | | | | | |
| 2 | 29 cB | 31 cB | 25 cB | 27 cB | 38 cA | 42 cA |
| 4 | 46 bB | 44 bB | 48 bB | 45 bB | 68 bA | 73 bA |
| 8 | 69 aB | 72 aB | 71 aB | 66 aB | 97 aA | 93 aA |
| | Dry shoot weight (g) | | | | | |
| 0 | 3.45 aA | 3.39 aA | 3.45 aA | 3.39 aA | 3.45 aA | 3.39 aA |
| 2 | 3.38 aA | 3.31 aA | 3.36 aA | 3.32 aA | 2.89 bB | 2.94 bB |
| 4 | 3.20 aA | 3.17 aA | 3.24 aA | 3.21 aA | 2.39 cB | 2.44 cB |
| 8 | 2.78 bA | 2.83 bA | 2.73 bA | 2.80 bA | 1.88 dB | 1.93 dB |
| | Dry root weight (g) | | | | | |
| 0 | 1.74 aA | 1.69 aA | 1.74 aA | 1.69 aA | 1.74 aA | 1.69 aA |
| 2 | 1.69 aA | 1.62 aA | 1.72 aA | 1.64 aA | 1.51 bB | 1.45 bB |
| 4 | 1.57 aA | 1.53 aA | 1.65 aA | 1.57 aA | 1.11 cB | 1.19 cB |
| 8 | 1.12 bA | 1.09 bA | 1.17 aA | 1.16 aA | 0.80 dB | 0.86 dB |
| | Reproductive factor (Rf)[c] | | | | | |
| 2 | 7.3 aB | 6.8 aB | 7.7 aB | 7.3 aB | 15.8 aA | 14.9 aA |
| 4 | 4.8 bB | 4.2 bB | 4.1 bB | 4.4 bB | 10.3 bA | 9.8 bA |
| 8 | 3.7 bA | 3.9 bA | 3.7 bA | 3.6 bA | 4.3 cA | 4.7 cA |

Plants inoculated at 28 days and grown for 120 days.

Values are the means of 20 replicates (one plant per replicate). Means not followed by the same letter differ ($P \leq 0.05$) according to Duncan's multiple-range test (lowercase letters for columns, uppercase letters for rows).

[a] Nematode populations were obtained from western wheatgrass, *Pascopyrum smithii* (Rydb.) Lôve, from central Utah (UT1) and northern Utah (UT2, UT3).

[b] Nematode invasion determined 14 days after inoculation.

[c] (Rf) = final nematode population/initial nematode population.

Pi, and UT3 populations at Pi of 2. Survival rates in response to UT3 were 95% and 93% for single and 93% and 88% for interplanted treatments at Pi of 4 and 8, respectively. Invasion of crested wheatgrass increased with inoculum density for UT1 ($r$ = 0.81), UT2 ($r$ = 0.84), and UT3 ($r$ = 0.82) populations. Invasion by population UT3 at all Pi exceeded ($P \leq 0.05$) invasion by UT1 and UT2 in both single and interplanted treatments (Table 2). Invasion of crested wheatgrass by all nematode populations was similar in both single and interplanted treatments at all Pi.

Population UT3 was more virulent to alfalfa than UT1 and UT2 at all inoculum levels. Shoot and root growth were similarly affected by populations UT1 and UT2, and were pathogenic to crested wheatgrass only at a Pi of 8 ($P \leq 0.05$) (Table 2).

*Growth chamber experiment—Alfalfa:* All alfalfa plants (single and interplanted) survived inoculation with UT1 and UT2 at 15–25 °C, and 92% and 100% survived at 30 °C. In comparison, 92% and 88% of alfalfa plants survived inoculation with UT3 at 25 °C and 30 °C, respectively.

More UT3 invaded alfalfa than did UT1 and UT2 at all temperatures ($P \leq 0.05$) (Table 3). There were no differences in the invasion of alfalfa by populations UT1 and UT2 in single and interplanted treatments ($P \leq 0.05$). Nematode invasion increased with temperature ($r$ = 0.87) and was greatest at 30 °C.

UT3 reduced alfalfa shoot and root growth in single and interplanted treatments at all soil temperatures ($P \leq 0.05$). Populations UT1 and UT2 reduced shoot and root growth at 20–30 °C ($P \leq 0.05$) (Table 3). Population UT3 was more pathogenic than UT1 and UT2 at all soil temperatures. Soil temperature was correlated negatively with shoot and root growth for UT1 ($r$ = −0.84; $r$ = −0.78), UT2 ($r$ = −0.84; $r$ = −0.76), and UT3 ($r$ = −0.79; $r$ = −0.75). Soil temperature was positively correlated with reproduction of UT1 ($r$ = 0.86) UT2 ($r$ = 0.84), and

TABLE 2. Invasion, pathogenicity, and reproduction of different *Pratylenchus neglectus* populations from Utah (UT1, UT2, UT3)[a] on Fairway crested wheatgrass in single and interplant plantings of 'Lahontan' alfalfa and 'Fairway' crested wheatgrass at a greenhouse temperature of 24 °C ± 3 °C.

| Inoculum level Nemas/cm$^3$ soil | UT1 | | UT2 | | UT3 | |
|---|---|---|---|---|---|---|
| | Single | Interplant | Single | Interplant | Single | Interplant |
| | | | Nematodes/g root tissue[b] | | | |
| 2 | 19 cB | 21 cB | 16 cB | 19 cB | 28 cA | 32 cA |
| 4 | 33 bB | 32 bB | 34 bB | 33 bB | 57 bA | 64 bA |
| 8 | 57 aB | 61 aB | 58 aB | 55 aB | 88 aA | 83 aA |
| | | | Dry shoot weight (g) | | | |
| 0 | 1.95 aA | 1.87 aA | 1.95 aA | 1.87 aA | 1.95 aA | 1.87 aA |
| 2 | 1.90 aA | 1.90 aA | 1.85 aA | 1.91 aA | 1.68 bB | 1.71 bB |
| 4 | 1.86 aA | 1.81 aA | 1.90 aA | 1.85 aA | 1.12 cB | 1.20 cB |
| 8 | 1.45 bA | 1.40 bA | 1.38 bA | 1.34 bA | 0.96 dB | 1.02 dB |
| | | | Dry root weight (g) | | | |
| 0 | 1.04 aA | 1.12 aA | 1.04 aA | 1.12 aA | 1.04 aA | 1.12 aA |
| 2 | 0.99 aA | 1.05 aA | 1.01 aA | 1.00 aA | 0.97 bB | 1.08 bB |
| 4 | 1.02 aA | 1.05 aA | 1.05 aA | 1.02 aA | 0.75 cB | 0.79 cB |
| 8 | 0.87 bA | 0.82 bA | 0.90 bA | 0.89 bA | 0.55 dB | 0.51 dB |
| | | | Reproductive factor (Rf)[c] | | | |
| 2 | 7.2 aB | 7.3 aB | 6.9 aB | 6.6 aB | 10.3 aA | 11.1 aA |
| 4 | 5.2 bB | 4.8 bB | 5.0 bB | 4.8 bB | 10.3 bA | 9.8 bA |
| 8 | 4.0 bA | 4.1 bA | 3.9 bA | 4.2 bA | 4.3 cA | 4.7 cA |

Plants inoculated at 28 days and grown for 120 days.

Values are the means of 20 replicates (one plant per replicate). Means not followed by the same letter differ ($P \leq 0.05$) according to Duncan's multiple-range test (lowercase letters for columns, uppercase letters for rows).

[a] Nematode populations were obtained from western wheatgrass, *Pascopyrum smithii* (Rydb.) Löve, from central Utah (UT1) and northern Utah (UT2, UT3).

[b] Nematode invasion determined 14 days after inoculation.

[c] (Rf) = final nematode population/initial nematode population.

TABLE 3. Invasion, pathogenicity, and reproduction of different *Pratylenchus neglectus* populations from Utah (UT1, UT2, UT3)[a] on Lahontan alfalfa in single and interplant plantings of alfalfa and Fairway crested wheatgrass at four different temperatures.

| Soil temp. (°C) | UT1 | | UT2 | | UT3 | | Control | |
|---|---|---|---|---|---|---|---|---|
| | Single | Interplant | Single | Interplant | Single | Interplant | Single | Interplant |
| | | | | Nematodes/g root tissue[b] | | | | |
| 15 | 29 dB | 31 dB | 25 dB | 27 dB | 50 dA | 47 dA | — | — |
| 20 | 46 cB | 44 cB | 48 cB | 45 cB | 62 cA | 58 cA | — | — |
| 25 | 69 bB | 72 bB | 71 bB | 66 bB | 87 bA | 83 bA | — | — |
| 30 | 79 aB | 82 aB | 83 aB | 77 aB | 98 aA | 94 aA | — | — |
| | | | | Dry shoot weight (g) | | | | |
| 15 | 3.08 aA | 3.07 aA | 3.11 aA | 3.05 aA | 2.71 aB | 2.69 aB | 3.12 cA | 3.06 cA |
| 20 | 3.01 aB | 3.05 aB | 2.99 aB | 3.09 aB | 2.59 bC | 2.63 bC | 3.28 bA | 3.22 bA |
| 25 | 3.11 aB | 3.17 aB | 3.16 aB | 3.21 aB | 2.37 cC | 2.44 cC | 3.49 aA | 3.44 aA |
| 30 | 2.66 bB | 2.73 bB | 2.71 bB | 2.80 bB | 1.82 dC | 1.78 dC | 3.27 bA | 3.30 bA |
| | | | | Dry root weight (g) | | | | |
| 15 | 1.03 bA | 1.09 bA | 1.00 bA | 1.05 bA | 0.97 bA | 0.99 BA | 1.00 cA | 1.06 cA |
| 20 | 1.26 aB | 1.30 aB | 1.30 aB | 1.27 aB | 1.28 aB | 1.23 aB | 1.40 bA | 1.37 bA |
| 25 | 1.09 bB | 1.02 bB | 1.05 bB | 1.08 bB | 1.02 bB | 1.08 bB | 1.74 aA | 1.68 aA |
| 30 | 0.89 cB | 0.85 cB | 0.84 cB | 0.92 cB | 0.80 cB | 0.91 cB | 1.35 bA | 1.30 bA |
| | | | | Reproductive factor (Rf)[c] | | | | |
| 15 | 1.6 dA | 1.9 dA | 2.0 dA | 2.2 dA | 3.3 dA | 2.7 dA | — | — |
| 20 | 3.9 cB | 3.2 cB | 3.5 cB | 3.4 cB | 6.3 cA | 7.2 cA | — | — |
| 25 | 5.7 bB | 5.9 bB | 6.2 bB | 5.6 bB | 13.8 bA | 14.9 bA | — | — |
| 30 | 8.2 aB | 7.8 aB | 7.7 aB | 8.5 aB | 17.3 aA | 16.3 aA | — | — |

Plants inoculated with 4.0 nematodes/$cm^3$ soil at 28 days and grown for 120 days.

Values are the means of 20 replicates (one plant per replicate). Means not followed by the same letter differ ($P \leq 0.05$) according to Duncan's multiple-range test (lowercase letters for columns, uppercase letters for rows).

[a] Nematode populations were obtained from western wheatgrass, *Pascopyrum smithii* (Rydb.) Löve, from central Utah (UT1) and northern Utah (UT2, UT3).

[b] Nematode invasion determined 14 days after inoculation.

[c] (Rf) = final nematode population/initial nematode population.

UT3 ($r$ = 0.90). Reproduction of UT3 exceeded that of UT1 and UT2 at all soil temperatures ($P \leq 0.05$), and there were no differences in reproduction in single and interplanted treatments.

*Crested wheatgrass:* All crested wheatgrass plants survived exposure to UT1 and UT2 at all temperatures, and all survived exposure to UT3 at 15 °C and 20 °C. Survival rates of plants inoculated with UT3 were 88% and 88%, and 83% and 88% at 25 °C and 30 °C, respectively. Invasion of Fairway crested wheatgrass was similar, regardless of interplanting, temperature, or nematode populations (Table 4). More nematodes of population UT3 than populations UT1 and UT2 invaded crested wheatgrass ($P \leq 0.05$). Soil temperature was positively correlated (UT1 = 0.85; UT2 = 0.88; UT3 = 0.93) with nematode invasion.

Reduction of crested wheatgrass by population UT3 exceeded that of UT1 and UT2 at 15–30 °C ($P \leq 0.05$). Shoot growth was reduced at 15–30 °C and root growth 20–30 °C by UT3. Shoot and root growth was reduced at 20–30 °C by UT1 and UT2. There were no differences in shoot and root growth between a single and interplanted treatments at any temperature. Temperature was correlated negatively ($r$) with shoot growth (UT1 = –0.73; UT2 = –0.77; UT3 = –0.80) and root growth (UT1 = –0.73; UT2 = 0.77; UT3 = 0.75).

Nematode reproduction did not differ between single and interplanted treatments, but Rf of UT3 exceeds that of UT1 and UT2 ($P \leq 0.05$). There was a positive correlation ($r$) between nematode reproduction and soil temperature (UT1 = 0.84; UT2 = 0.82; UT3 = 0.90).

## DISCUSSION

This study confirmed that plant-parasitic nematodes can invade and parasitize resis-

TABLE 4. Invasion, pathogenicity, and reproduction of different *Pratylenchus neglectus* populations from Utah (UT1, UT2, UT3)[a] on Fairway crested wheatgrass in single and interplant plantings of 'Lahontan' alfalfa and 'Fairway' crested wheatgrass at four temperatures.

| Soil temp. (°C) | UT1 | | UT2 | | UT3 | | Control | |
|---|---|---|---|---|---|---|---|---|
| | Single | Interplant | Single | Interplant | Single | Interplant | Single | Interplant |
| | | | | Nematodes/g root tissue[b] | | | | |
| 15 | 18 dB | 22 dB | 17 dB | 19 dB | 38 dA | 37 dA | — | — |
| 20 | 33 cB | 31 cB | 29 cB | 30 cB | 55 cA | 58 cA | — | — |
| 25 | 44 bB | 42 bB | 44 bB | 47 bB | 62 bA | 63 bA | — | — |
| 30 | 53 aB | 55 aB | 58 aB | 57 aB | 76 aA | 74 aA | — | — |
| | | | | Dry shoot weight (g) | | | | |
| 15 | 1.64 aA | 1.60 aA | 1.58 aA | 1.63 aA | 1.58 aA | 1.56 A | 1.68 cA | 1.62 cA |
| 20 | 1.69 aB | 1.62 aB | 1.62 aB | 1.68 aB | 1.63 bC | 1.68 bC | 1.88 bA | 1.93 bA |
| 25 | 1.58 aB | 1.57 aB | 1.58 aB | 1.64 aB | 1.30 cC | 1.25 cC | 2.02 aA | 1.99 aA |
| 30 | 1.32 bB | 1.25 bB | 1.30 bB | 1.27 bB | 1.02 dC | 0.98 dC | 1.74 bA | 1.69 bA |
| | | | | Dry root weight (g) | | | | |
| 15 | 0.95 aA | 0.97 aA | 0.94 aA | 0.99 aA | 0.85 aA | 0.89 aA | 0.90 cA | 0.93 cA |
| 20 | 0.95 aB | 0.93 aB | 0.98 aB | 1.00 aB | 0.92 aB | 0.95 aB | 1.15 bA | 1.19 bA |
| 25 | 1.02 aB | 1.00 aB | 1.01 aB | 1.03 aB | 0.64 bC | 0.69 bC | 1.19 aA | 1.22 aA |
| 30 | 0.75 bB | 0.79 bB | 0.74 bB | 0.72 bB | 0.47 cC | 0.53 cC | 1.02 bA | 1.08 bA |
| | | | | Reproductive factor (Rf)[c] | | | | |
| 15 | 1.8 cA | 1.7 cA | 1.7 cA | 2.1 cA | 2.4 dA | 2.2 dA | — | — |
| 20 | 2.3 cB | 2.2 cB | 2.4 cB | 2.6 cB | 3.9 cA | 4.2 cA | — | — |
| 25 | 4.2 bB | 4.4 bB | 3.9 bB | 4.2 bB | 6.3 bA | 6.0 bA | — | — |
| 30 | 6.1 aB | 5.9 aB | 6.3 aB | 6.0 aB | 8.8 aA | 8.2 aA | — | — |

Plants inoculated with 4.0 nematodes/cm$^3$ soil at 28 days and grown for 120 days.

Values are the means of 20 replicates (one plant per replicate). Means not followed by the same letter differ ($P \leq 0.05$) according to Duncan's multiple-range test (lowercase letters for columns, uppercase letters for rows).

[a] Nematode populations were obtained from western wheatgrass from central Utah (UT1) and northern Utah (UT2, UT3).

[b] Nematode invasion determined 14 days after inoculation.

[c] (Rf) = final nematode population/initial nematode population.

tant cultivars. The alfalfa stem nematode, *Ditylenchus dipsaci* (Kühn) Filipjév, and the northern root-knot nematode, *Meloidogyne hapla* Chitwood, invade nematode-resistant cultivars, including alfalfa (Griffin, 1975; Griffin and Elgin, 1977). Although fewer nematodes invaded resistant cultivars, nematodes may adversely affect their persistence and growth. There was a high rate of mortality to *Ditylenchus dipsaci* in nonhost onion and resistant alfalfa seedlings (Griffin, 1975).

Population differences in virulence occur within plant-parasitic nematodes (Mayr, 1969; Sidhu and Webster, 1981; Wallace, 1973; Wilson, 1980). Neighboring populations may differ, and no two spatially separated populations are identical (Rumbaugh and Townsend, 1985). Pathological relationships may differ due to mutation or natural selection due to long-term association with a plant selection or to environmental and climatic differences in different geographical regions. Griffin (1996) found that temperature and soil texture affected the pathogenic relationship between grasses and nematodes, including *P. neglectus.*

Pathotypic differences observed in the different *P. neglectus* populations in this study indicate that variability occurs within nematode species. These differences may occur in overlapping populations of similar or different species or in an isolated population. A temperature of 30 °C favored both pathogenicity and nematode reproduction, which is consistent with data from other studies with lesion nematodes, including *P. neglectus* (Griffin, 1993; Kimpinski and Willis, 1981; Olthof, 1990). Soil temperatures lower than 30 °C occur in the intermountain region of the United States. Natural selection or mutations may have created populations able to withstand high soil temperatures or severe moisture stress. Populations able to survive on crested wheatgrasses may reflect ability to feed on shallow-rooted grasses as opposed to deep-rooted alfalfa.

Pathotypic differences are found between plant-parasitic nematode species other than *P. neglectus* (Griffin and McKenry, 1989; Griffin et al., 1990; Ladygika, 1985; Olthof, 1968), and similar relationships may characterize geographically separated populations of other nematode species. Hence, all environmental and climatic factors must be considered in pathological, breeding, and screening programs.

Alfalfa has considerable value in rangeland improvement and has increased forage yields (Rumbaugh, and Townsend, 1985). Interplanting alfalfa with grasses improves annual grass growth and increases forage yields by increasing available soil nitrogen (Rumbaugh et al., 1982). An increase in available nitrogen from *Rhizobium* nodulation of alfalfa also should increase grass growth and have a buffering effect on nematode virulence and pathogenicity.

Although there were no differences in the pathogenicity of the three *P. neglectus* populations between single and interplantings of alfalfa and grasses, this study showed that lesion nematodes can significantly reduce the growth of alfalfa and grasses. Only recently have data been generated that show the possibility of breeding for resistance to lesion nematodes (Thies et al., 1994). Since *P. neglectus* is endemic to rangelands (Griffin, 1992; Thorne, 1961), it is important that geneticists and breeders recognize the importance of this nematode on rangeland vegetation and incorporate resistant germplasm into their breeding programs.

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