Journal of Nematology 23(3):306-315. 1991.

Relationship of *Ditylenchus dipsaci* and Harvest Practices to the Persistence of Alfalfa[1]

G. D. GRIFFIN[2]

Abstract: Persistence of dormant Ranger and nondormant Moapa alfalfas, both susceptible to *Ditylenchus dipsaci*, varied with stand age and cutting frequency. Stand reduction increased with cutting frequency. In *D. dipsaci*-infested soil, stand reductions in Ranger 1, 4, and 5 years old exceeded reductions in stands 2 and 3 years old; persistence was greatest in 2-year-old stands. In Moapa alfalfa, *D. dipsaci* reduced stands the most in years 2 and 3; whereas persistence was greatest in 1-year-old stands. Harvesting Ranger alfalfa one, two, three, and four times during the growing season reduced 2-year-old stands by 10, 14, 19, and 29% in *D. dipsaci*-infested soil and by 2, 4, 4, and 7% in uninfested soil, respectively. Comparable reductions in Moapa alfalfa were 13, 16, 18, and 38% in infested soil and 0, 2, 4, and 6% in uninfested soil. Cutting frequency had less effect on persistence of resistant semidormant Lahontan grown in *D. dipsaci*-infested soil relative to susceptible cultivars. Increasing the number of cuttings per year decreased storage of total nonstructural carbohydrate and adversely affected persistence of alfalfa stands and yields; the greatest negative effects occurred on both resistant and susceptible alfalfa in *D. dipsaci*-infested soil.
Key words: alfalfa, alfalfa stem nematode, *Ditylenchus dipsaci*, harvest management, *Medicago sativa*, pathogenicity, persistence, nonstructural carbohydrate, yield.

Alfalfa (*Medicago sativa* L.) is the most popular cultivated forage in North America (1). The alfalfa stem nematode, *Ditylenchus dipsaci* (Kühn) Filipjev, is found in all alfalfa-producing areas in the western United States (10). Its ability to parasitize alfalfa under a variety of environmental conditions makes it the most important nematode parasite of alfalfa (16). Nematode parasitism adversely affects alfalfa stands, hay yields, and crown and root storage of total nonstructural carbohydrate (TNC) (2,9,10,12).

Alfalfa stand persistence is affected by cultural and environmental factors (5,6,8,23) and the relationship of cultural practices to plant pathogens (2,10,11). As a result, alfalfa management practices must be considered when developing pest-resistant alfalfa cultivars (9,20). For example, only alfalfa plants combining bacterial wilt resistance and winterhardiness performed well when cut 2–4 times per year (20). A similar relationship characterized the performance of alfalfa resistant and susceptible to Fusarium wilt and *Colletotrichum trifolii* (Bain) (13).

Alfalfa plants use stored TNC composed of starch and sugars (glucose, fructose, sucrose) in the roots and crowns for energy during drought, onset of cold hardening, and early spring growth (12). Once carbon assimilation via photosynthesis exceeds the energy requirement, a plant uses less TNC for growth and TNC accumulates in the roots and crowns (7). Maximum accumulation of TNC in roots occurs between the time of 10% flowering and full bloom (4).

Alfalfa yields and stand persistence are usually affected by root and crown TNC (20), which in turn is affected by harvest management practices (18,19,21); plant growth after the final cutting is necessary to restore root and crown TNC and to increase cold hardiness.

Objectives of this study were to determine 1) the relationship between cutting frequency, time of harvest, and the pathogenicity of *D. dipsaci* on alfalfa yields and stand persistence and 2) how these factors affect the storage of TNC in root and crown tissue and stand persistence of alfalfa resistant and susceptible to *D. dipsaci*.

MATERIALS AND METHODS

Alfalfa cultivars used in all studies were Ranger, a dormant alfalfa susceptible to *Ditylenchus dipsaci*; Lahontan, a semidor-

---

Received for publication 3 May 1990.
[1] Cooperative investigation by USDA ARS and the Utah Agricultural Experiment Station. Journal Paper No. 3959.
[2] Nematologist, USDA ARS, Forage and Range Research Laboratory, Utah State University, Logan, UT 84322.

mant resistant cultivar; and Moapa, a nondormant susceptible cultivar (3,10).

Field study 1: Field studies were conducted at St. George and West Jordan, Utah, to determine the effect of *D. dipsaci* on the persistence and yield of nematode resistant and susceptible alfalfa in environmentally different areas. Physical characteristics of the study locations: 1) St. George—loamy-skeletal, mixed, thermic, shallow Typic Paleorthid soil (74% sand, 16% silt, 10% clay; pH 7.2; 2% OM); elevation 878 m; mean maximum, minimum, average temperatures of 25.2 C, 6.7 C, and 21.5 C, respectively; and average annual precipitation 21.5 cm. 2) West Jordan—fine, mixed, mesic, Calcixerollic Xerochrepts soil (68% sand, 18% silt, 14% clay; 3% OM, pH 7.2); elevation 1,286 m; mean maximum, minimum, average temperatures of 15.2 C, 6.1 C, 9.2 C, respectively; and average annual precipitation 37.9 cm (9). Lahontan and Ranger were planted at West Jordan, and Lahontan and Moapa were planted at St. George. Sixteen plots (15 × 15 m) were established in a randomized block in each area, and each alfalfa cultivar was replicated eight times. Plots were planted at St. George on 3 March and at West Jordan on 5 April. Plots received a yearly application of 400 kg K_2O/ha (15). After 60 days of growth, plots were thinned to 80 plants/m^2 (14). Plots were flood irrigated during the growing season with regular irrigation water containing *D. dipsaci*-infested waste water collected from nematode-infested alfalfa fields.

As in a previous study (9), it was not possible to maintain nematode-free control plots at the study sites because waste water from nematode-infested fields runs into the irrigation canal, and all plots, regardless of initial care, soon become infested with the nematode. Hence, no attempt was made to establish uninfested control plots. Special care was taken to establish plots in fields where other diseases were not prevalent.

Fields were monitored over a 5-year period, and nematode-parasitized plants, stand counts, and alfalfa yields were determined. No effort was made to determine numbers of nematodes per parasitized plant because 1) numbers of nematodes per plant fluctuate significantly depending on environmental conditions (9), 2) ca. 30% of Lahontan plants are susceptible to *D. dipsaci*, and ca. 5% of Ranger and Moapa plants are resistant to *D. dipsaci*, and 3) *D. dipsaci* infects both resistant and susceptible alfalfa cultivars (9). Therefore, parasitized plants were determined through visual observations. Four cuttings were made at St. George and three at West Jordan. Standard harvesting practices were followed for each area, and cuttings at approximately 10% bloom were made at regular harvest dates for each area (16 May, 21 June, 26 July, and 3 September at St. George; 16 June, 18 July, and 2 September at West Jordan). Data were analyzed by ANOVA and means were separated using Duncan's new multiple-range test.

Field study 2: A second field study conducted in plots adjoining study plots in field study 1 at St. George and West Jordan concerned the effects of *D. dipsaci* infestation and the number and dates of cutting on stand persistence and yield of resistant and susceptible alfalfa. Plot establishment, alfalfa cultivars, and experimental procedures were similar to those in study 1, except three and four cuttings were made at both locations. St. George: three cuttings—19 May, 24 June, and 27 July; four cuttings—19 May, 24 June, 27 July, and 7 September. West Jordan: three cuttings—10 June, 13 July, and 4 September; four cuttings—10 June, 13 July, 4 September, and 28 October. Data were collected over a 5-year period and were analyzed as in study 1.

Field study 3: An additional study at West Jordan concerned the effect of cutting dates on the depressive effect of *D. dipsaci* on resistant and susceptible alfalfa. The plot design was similar to that of studies 1 and 2 except it involved only three cuttings and varying the date of the third cutting. Third cutting dates (within 4 days) were 1 September, 20 September, and 10 October. Data were analyzed as in study 1.

Microplot study: The effects of the fre-

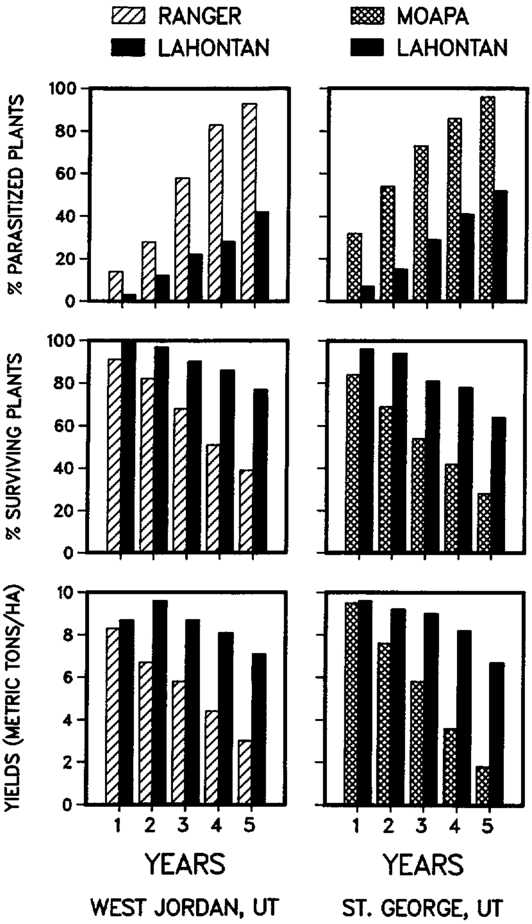

FIG. 1. Effect of *Ditylenchus dipsaci* on persistence and yields of resistant semidormant Lahontan, susceptible dormant Ranger, and susceptible nondormant Moapa alfalfa over a 5-year period at West Jordan and St. George, Utah. LSD ($P \leq 0.05$) = 9.3 for percentage of plants surviving and 1.9 for yields.

quency of cutting on persistence, yields, and TNC in *D. dipsaci*-infested and uninfested control plots of Lahontan, Ranger, and Moapa were studied in microplots at Logan. Experimental plots were established at a site where irrigation water was free of *D. dipsaci* contamination. Site elevation was 1,405 m, and mean maximum, minimum, average temperatures were 14.8 C, 0.3 C, 6.1 C, respectively. Average annual precipitation was 43.8 cm (9). Microplots fabricated from fiberglass were 3.0 m d × 0.6 m deep and open at the bottom. The fiberglass containers were buried to a depth of 0.46 m. Native soil was replaced with a fumigated (1,3-D) Kidman fine sandy loam soil (coarse-loamy mixed Calcic Haploxeroll—73% sand, 16% silt, 11% clay; pH 7.3; 1% OM). Plots were seeded on 14 April and thinned to 80 plants/m^2 after 60 days. At bloom, plants were hand clipped and plots were inoculated with nematode-infected dried alfalfa clippings from an infested field (17). Chopped clippings were spread over the microplots in a 2-cm-thick layer and immediately sprinkle irrigated. By the end of the first growing season, 74–82% of the plants were parasitized and 94–100% were parasitized at the end of the second growing season.

One to four cuttings (cutting dates varied by no more than 6 days) were made over a 5-year period. Treatments (cutting frequencies) were 1) one cutting: on 12 July (green seed pod); 2) two cuttings: on 3 July (initiation of green seed pod) and 28 August (full bloom); 3) three cuttings: on 15 June, 18 July, and 5 September at 10% bloom; 4) four cuttings: on 15 June, 18 July, 5 September, and 30 October. Plots were irrigated immediately after harvest to favor nematode invasion of crown buds (9). Treatments, including uninfested control plots, were replicated four times. Two plants were harvested at random from each plot during late November. Crown samples, 5 cm long, and root samples, 15 cm long from the uppermost part of the root, were collected and analyzed for percentage of TNC by a method previously described (24). Data on stand persistence, yields, and TNC were analyzed as in the field studies.

RESULTS

Field study 1: Ditylenchus dipsaci reduced ($P \leq 0.05$) persistence and yields of resistant Lahontan and susceptible Ranger and Moapa alfalfas at West Jordan and St. George (Fig. 1). Persistence of Ranger at West Jordan exceeded that of Moapa at St. George. The opposite was true of Lahontan at the two sites. Decreases in yields were closely correlated (St. George, $r = 0.921$; West Jordan, $r = 0.892$) with stand persistence; reductions in stands and yields of

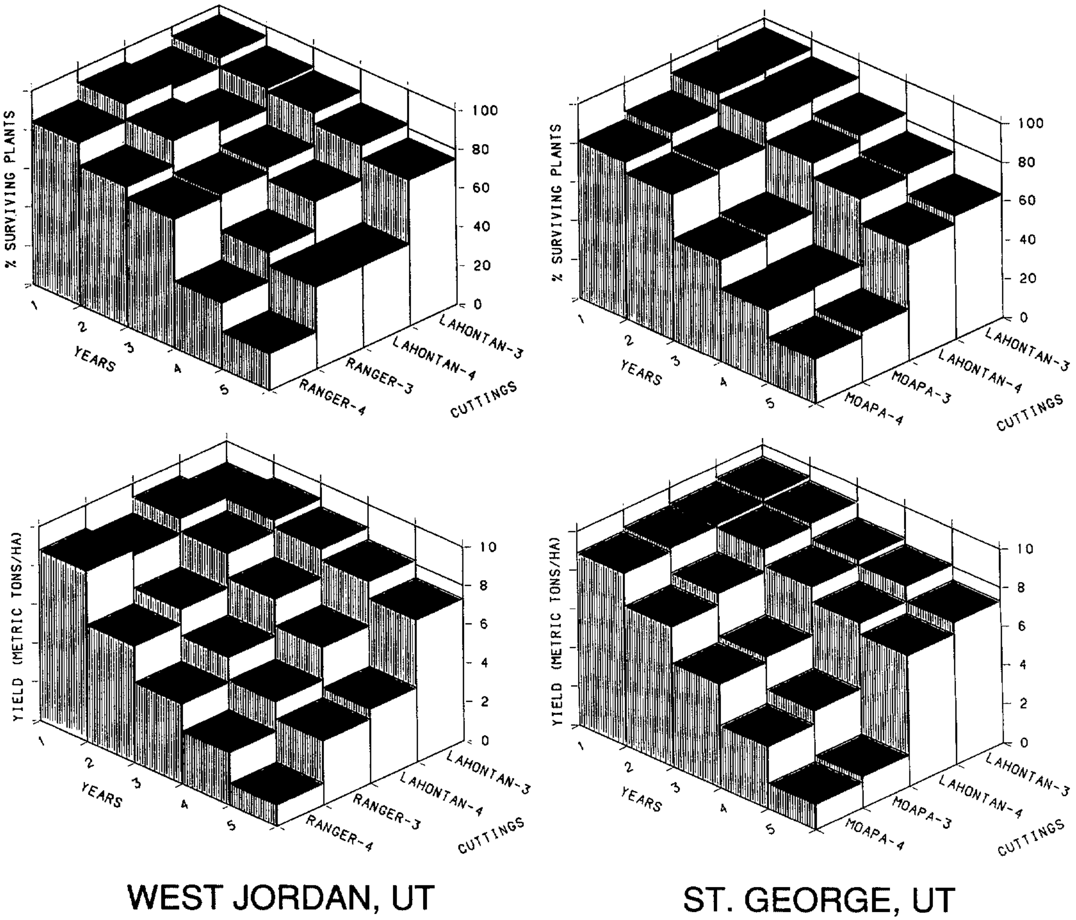

FIG. 2. Effect of *Ditylenchus dipsaci* on persistence and yields of resistant semidormant Lahontan, susceptible dormant Ranger, and susceptible nondormant Moapa alfalfa after three and four cuttings over a 5-year period at West Jordan and St. George, Utah. LSD ($P \leq 0.05$) = 11.4 for percentage of plants surviving and 2.1 for yields.

both Lahontan and Moapa alfalfas were greater at St. George.

Field study 2: The combined effects of *D. dipsaci* parasitism and the number of cuttings affected ($P \leq 0.05$) the persistence and yield of susceptible and resistant alfalfa at West Jordan but not at St. George (Fig. 2). Persistence of Ranger was reduced more ($P \leq 0.05$) than that of Lahontan after 3 years at West Jordan; four cuttings, however, reduced ($P \leq 0.05$) the stand of Lahontan. After 5 years, the stand densities of Lahontan after four cuttings were similar to those of Ranger after three cuttings at West Jordan.

Persistence of Moapa at St. George was similar to that shown in field study 1, whereas persistence did not differ after three and four cuttings. Persistence of Lahontan was also similar to field study 1 at St. George, and persistence of Lahontan plants after 5 years exceeded persistence of Moapa plants after 3 years.

Alfalfa yields paralleled stand persistence. At West Jordan, maximum yields of alfalfa were obtained with three cuttings of Lahontan, whereas the poorest yields were obtained with four cuttings of Ranger. At St. George, yields of Moapa after 2 years were similar to the yields of Lahontan after 4 and 5 years; there were no differences in yields of either Lahontan or Moapa subjected to three or four cuttings.

Field study 3: Extending the date of the

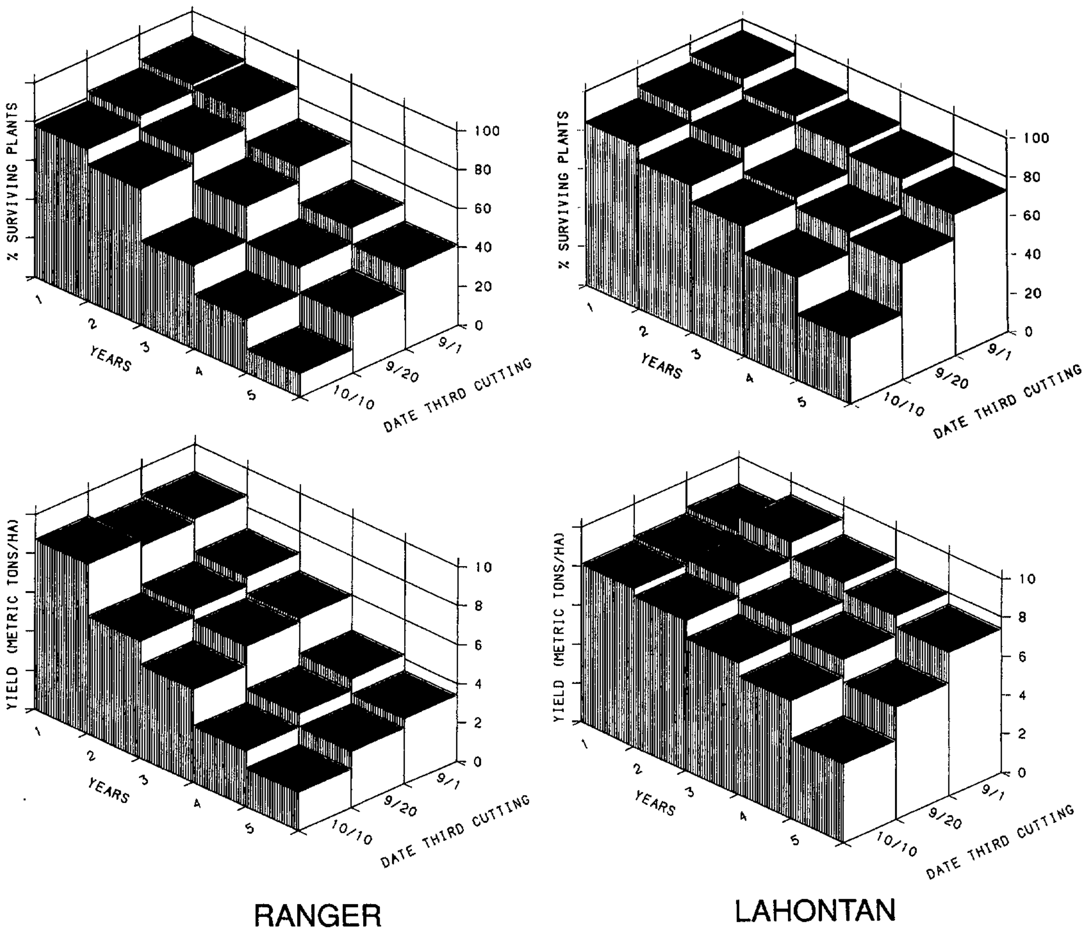

FIG. 3. Relationship of *Ditylenchus dipsaci* and time of third cutting differential on persistence and yield of resistant semidormant Lahontan and susceptible dormant Ranger alfalfa over a 5-year period at West Jordan, Utah. LSD ($P \leq 0.05$) = 9.0 for percentage of plants surviving and 1.6 for yields.

third cutting reduced ($P \leq 0.05$) stand persistence and yields of both Ranger and Lahontan (Fig. 3). After 5 years, persistence rates of Lahontan plants after three and four cuttings were 73 and 34%, respectively. Persistence rates of Ranger after similar harvest practices were 41 and 12%.

Microplot study: Alfalfa persistence, yield, and TNC decreased as the number of cuttings per year increased at Logan regardless of *D. dipsaci* parasitism. The depressive effect of *D. dipsaci* and harvest frequency was not as pronounced on resistant Lahontan alfalfa as it was on susceptible Ranger and Moapa. The most depressive effect of *D. dipsaci* on Lahontan was in plots cut four times.

The persistence of Ranger and Moapa alfalfa from nematode-infested plots declined ($P \leq 0.05$) over the 5-year period at all cutting frequencies (Fig. 4). Ranger alfalfa stands were reduced ($P \leq 0.05$) only in uninfested plots subjected to four harvests per year, whereas Moapa stands in uninfested plots were reduced ($P \leq 0.05$) after two or more cuttings per year. Persistence of Lahontan alfalfa was less affected by *D. dipsaci* than was persistence of Ranger and Moapa, but stand decline in nematode-infested Lahontan plots was greater ($P \leq 0.05$) than in uninfested plots. Stand decline of Lahontan was also greater ($P \leq 0.05$) in uninfested plots harvested four times rather than three times a year.

Alfalfa yields of all cultivars were negatively correlated to frequency of cutting in

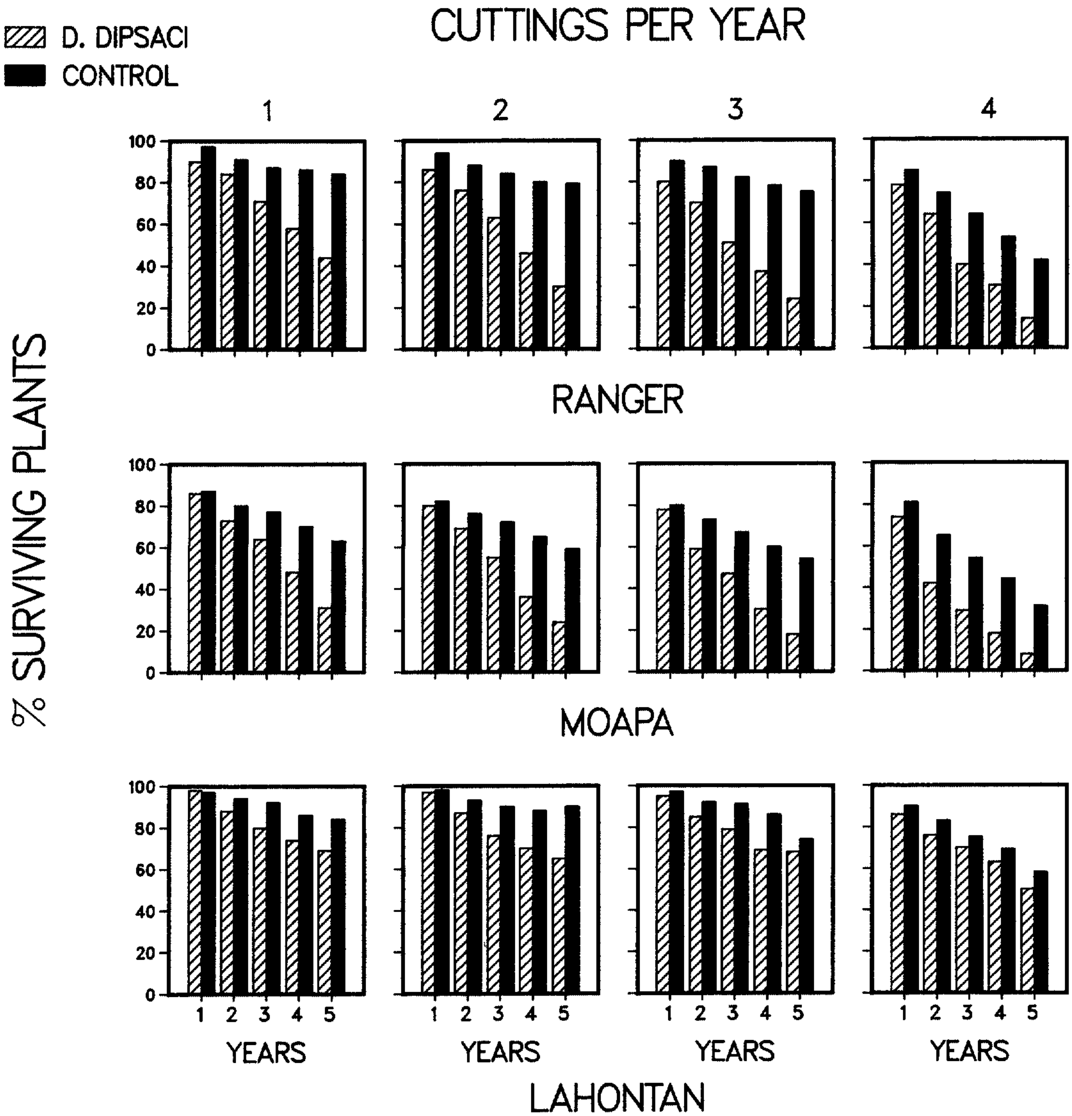

FIG. 4. Relationship of *Ditylenchus dipsaci* and harvesting sequence on persistence of resistant semidormant Lahontan, susceptible dormant Ranger, and susceptible nondormant Moapa alfalfa over a 5-year period at Logan, Utah. LSD ($P \leq 0.05$) = 8.

both nematode-infested and uninfested control plots. In nematode-infested plots, correlation coefficients were Ranger = −0.916, Moapa = −0.890, Lahontan = −0.871. In uninfested nematode plots, correlation coefficients were Ranger = −0.893, Moapa = −0.874, Lahontan = −0.857.

In nematode-infested plots, the smallest yield reduction occurred after one cutting and the greatest yield reduction occurred after four cuttings, regardless of cultivar resistance or susceptibility (Fig. 5). Yields of Ranger and Moapa declined in infested plots cut 2–4 times per year. The lowest yields were in nematode-infested Moapa plots after 5 years, whereas the greatest yields were in uninfested plots of Ranger and Lahontan after 3 years. Yields of Ranger and Lahontan in uninfested plots harvested 1–3 times per year did not differ ($P \leq 0.05$) over 5 years. However, yields declined ($P \leq 0.05$) when stands were cut four times per year.

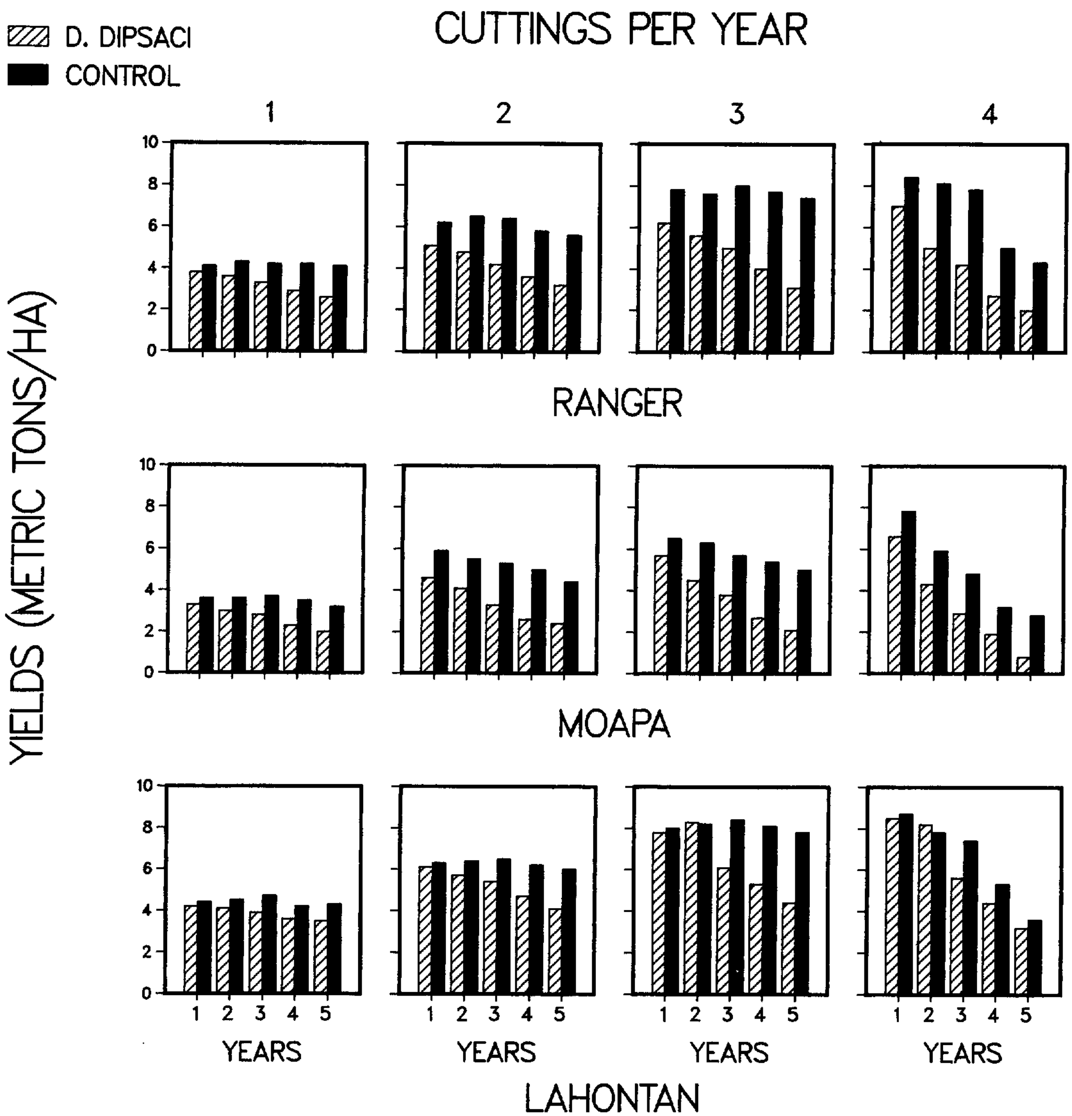

FIG. 5. Relationship of *Ditylenchus dipsaci* and harvesting sequence on yield of resistant semidormant Lahontan, susceptible dormant Ranger, and susceptible nondormant Moapa alfalfa over a 5-year period at Logan, Utah. LSD ($P \leq 0.05$) = 1.5.

The percentage of TNC in the three alfalfa cultivars paralleled persistence and yields in nematode-infested and uninfested plots (Fig. 6). In nematode-infested plots, correlation coefficients were Ranger = −0.872, Moapa = −0.858, Lahontan = −0.807. In uninfested nematode plots, correlation coefficients were Ranger = −0.854, Moapa = −0.831, Lahontan = −0.808. Reduction of TNC ($P \leq 0.05$) was greatest in Moapa and Ranger *D. dipsaci*-infested plots. The greatest reduction in TNC in uninfested nematode plots occurred in plants subjected to four cuttings, and the older the stand, the greater the decline in TNC.

Discussion

The growth and persistence of alfalfa cultivars are influenced by genetic factors and environmental conditions, as was evident in the differential persistence and yields of Ranger, Moapa, and Lahontan cultivars grown at Logan, St. George, and

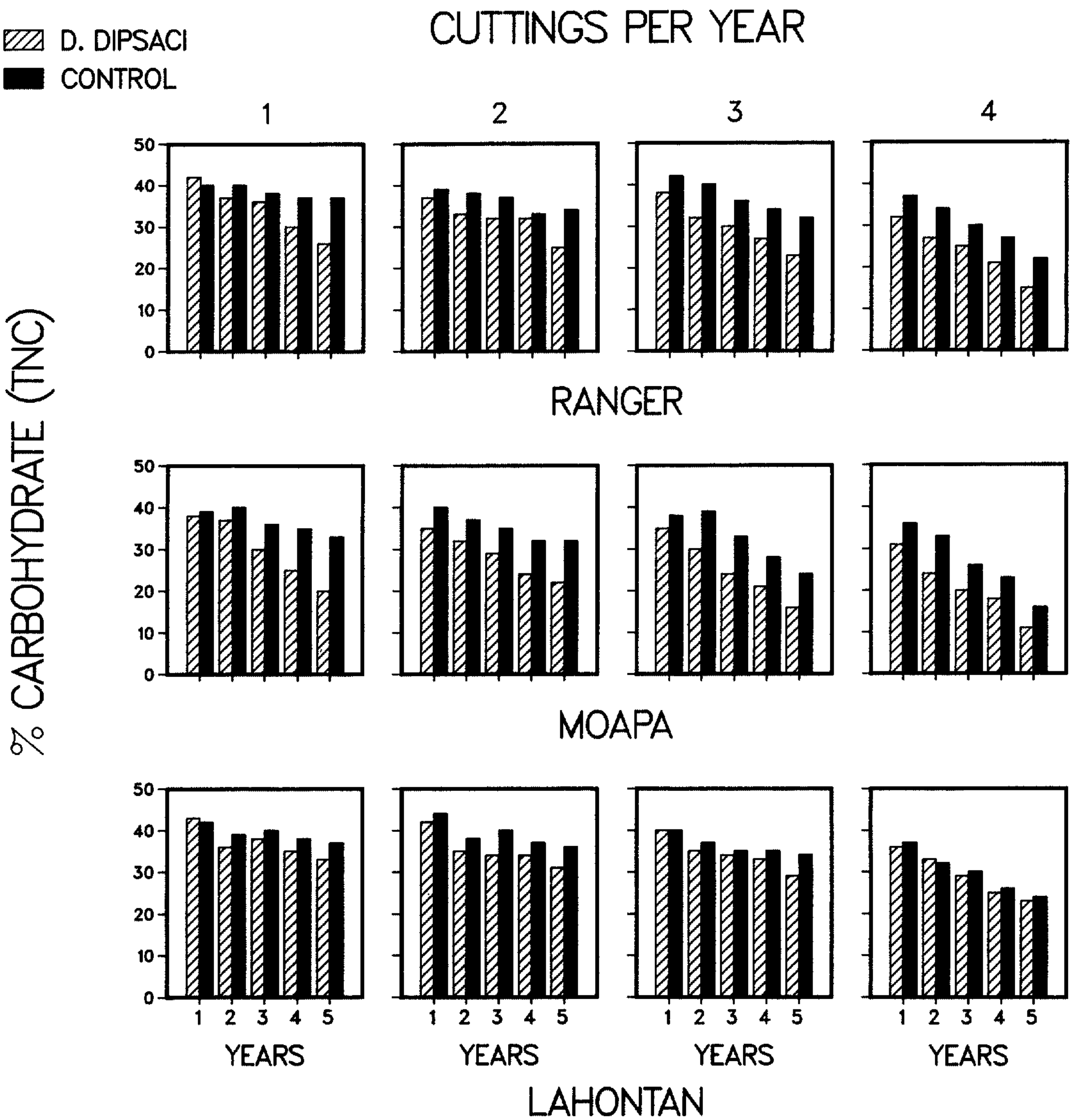

FIG. 6. Relationship of *Ditylenchus dipsaci* and harvesting sequence on total nonstructural carbohydrate (TNC) of roots and crowns of resistant semidormant Lahontan, susceptible dormant Ranger, and susceptible nondormant Moapa alfalfa over a 5-year period at Logan, Utah. LSD ($P \leq 0.05$) = 3.4.

West Jordan. The longer growing season at St. George meant that four cuttings did not have a detrimental effect on alfalfa stand longevity or yields. Because of a shorter growing season at West Jordan and Logan, four cuttings reduced stands and yields. Over the 5-year period at Logan, cumulative yields from four cuttings were lower ($P \leq 0.05$) than cumulative yields from three cuttings for the three alfalfa cultivars. In uninfested plots, average yields were 1.5 t/ha lower from four than from three cuttings at Logan. Rumbaugh (pers. comm.) found that alfalfa stands survived for 8 years at Brookings, South Dakota. If alfalfa stands could persist as long in northern Utah under normal cultural practices, four cuttings per year would have even more detrimental effects on yields and persistence than were shown in this study.

The effect of improper harvest practices associated with *D. dipsaci* escalated stand and yield losses, which is consistent with the fact that only alfalfa plants combining bacterial wilt resistance and winterhardiness performed well when cut 2–4 times annually (22). A previous study (9) found that soil moisture and certain agronomic practices, such as burning for weed control, affected persistence and yield of alfalfa in *D. dipsaci*-infested soil. Findings of this study show that the number of cuttings also influences the effects of *D. dipsaci* on the growth of alfalfa.

The results of this study agree with a previous report (2) and show that *D. dipsaci* and the frequency of cutting, as well as *D. dipsaci* and time of harvest, significantly affects the persistence and yield of alfalfa and the accumulation of TNC in roots and crowns. This in turn affects the persistence of both *D. dipsaci*-resistant and susceptible alfalfa during periods of drought, onset of cold hardening, and early spring growth (12). Alfalfa persistence and yields are also affected more by frequency of cutting and time of harvest under northern than southern climatic conditions.

Alfalfa growers, extension specialists, and forage scientists should consider how the timing and frequency of harvest may interact with plant pathogens, including *D. dipsaci,* to affect the persistence, growth, and yield of alfalfa.

Literature Cited

1. Barnes, D. K., B. P. Goplen, and J. E. Baylor. 1988. Highlights in the USA and Canada. P. 124 *in* A. A. Hanson, D. K. Barnes, and R. R. Hill, Jr., eds. Alfalfa and alfalfa improvement. Agronomy No. 29, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, WI.

2. Boelter, R. H., F. A. Gray, and R. H. Delaney. 1985. Effect of *Ditylenchus dipsaci* on alfalfa mortality, winterkill, and yield. Journal of Nematology 17:140–144.

3. Cook, R., and K. Evans. 1987. Resistance and tolerance. Pp. 179–231 *in* R. H. Brown and B. R. Kerry, eds. Principles and practice of nematode control in crops. New York: Academic Press.

4. Cooper, C. S., and C. A. Watson. 1968. Total available carbohydrates in roots of sainfoin (*Onobrychis vicaefolia* Scop.) and alfalfa (*Medicago sativa* L.) when grown under several management regimes. Crop Science 8:83–85.

5. Counce, P. A., J. H. Bouton, and R. H. Brown. 1984. Screening and characterizing alfalfa for persistence under mowing and continuous grazing. Crop Science 24:282–285.

6. Dexter, S. T. 1964. Alternative three-cutting systems for alfalfa. Agronomy 56:386–388.

7. Feltner, K. C., and M. A. Massengale. 1965. Influence of temperature and harvest management on growth, level of carbohydrates in the roots and survival of alfalfa (*Medicago sativa* L.). Crop Science 5:585–588.

8. Gasser, H., and L. Lachance. 1969. Effect of dates of cutting on dry matter production and chemical content of alfalfa and birdsfoot trefoil. Canadian Journal Plant Science 49:339–349.

9. Griffin, G. D. 1987. The importance of environmental factors and cultural practices on parasitism of alfalfa by *Ditylenchus dipsaci.* Journal of Nematology 19:267–276.

10. Griffin, G. D. 1984. Nematode parasites of alfalfa, cereals, and grasses. Pp. 243–321 *in* W. R. Nickle, ed. Plant and insect nematodes. New York: Marcel Dekker.

11. Griffin, G. D. 1974. Effect of acclimation temperature on infection of alfalfa by *Ditylenchus dipsaci.* Journal of Nematology 6:57–59.

12. Heichel, G. H., R. H. Delaney, and H. T. Cralle. 1988. Carbon assimilation, partitioning, and utilization. Pp. 195–228 *in* A. A. Hanson, D. K. Barnes, and R. R. Hill, Jr., eds. Alfalfa and alfalfa improvement. Agronomy No. 29, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, WI.

13. Hill, R. R., and J. E. Baylor. 1983. Genotype × environment analysis for yield in alfalfa. Crop Science 23:811–814.

14. Kust, C. A., and D. Smith. 1961. Influence of harvest management on levels of carbohydrate reserves, longevity of stand and yields of hay and protein from Vernal alfalfa. Crop Science 1:267–269.

15. Lanyon, L. E., and W. K. Griffith. 1988. Nutrition and fertilizer use. Pp. 333–372 *in* A. A. Hanson, D. K. Barnes, and R. R. Hill, Jr., eds. Alfalfa and alfalfa improvement. Agronomy No. 29, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, WI.

16. Leath, K. T., D. C. Erwin, and G. D. Griffin. 1988. Diseases and nematodes. Pp. 621–670 *in* A. A. Hanson, D. K. Barnes, and R. R. Hill, Jr., eds. Alfalfa and alfalfa improvement. Agronomy No. 29, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, WI.

17. Perry, R. N. 1977. The effect of previous desiccation on the ability of 4th-stage larvae of *Ditylenchus dipsaci* to control rate of water loss and to survive drying. Parasitology 75:215–231.

18. Reynolds, J. H., and D. Smith. 1962. Trend of carbohydrate reserve in alfalfa, smooth bromegrass, and timothy grown under various cutting schedules. Crop Science 2:333–336.

19. Robison, G. D., and M. A. Massengale. 1968. Effect of harvest management and temperature on forage yield, root carbohydrate, plant density, and leaf area relationships on alfalfa. Crop Science 8:147–151.

20. Sheaffer, C. C., G. D. Lacefield, and V. L. Marble. 1988. Cutting schedules and stands. Pp. 411–437 *in* A. A. Hanson, D. K. Barnes, and R. R. Hill, Jr., eds. Alfalfa and alfalfa improvement. Agronomy No. 29, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, WI.

21. Smith, D. 1962. Carbohydrate root reserves in alfalfa, red clover, and birdsfoot trefoil under several management schedules. Crop Science 2:75–78.

22. Twamley, B. E. 1960. Variety, fertilizer, management interaction in alfalfa. Canadian Journal Plant Science 40:130–138.

23. Tysdal, H. M., and T. A. Kiesselbach. 1939. The differential response of alfalfa varieties to time of cutting. Journal American Society Agronomy 31: 513–519.

24. Weinmann, H. 1947. Determination of total available carbohydrates in plants. Plant Physiology 22:279–290.