Journal of the Arkansas Academy of Science

Volume 47 Article 23

1993

Role of Endophytes in Tall Fescue

E. L. Piper
University of Arkansas, Fayetteville

C. P. West
University of Arkansas, Fayetteville

The Role of Endophytes in Tall Fescue

E. L. Piper and C. P. West
Departments of Animal Science and Agronomy
University of Arkansas*, Fayetteville, AR 72701

Abstract

Tall fescue (*Festuca arundinacea* Schreb.) is the most commonly grown cool season grass used for pastures in Arkansas. Most tall fescue contains a fungal endophyte (*Acremonium coenophialum* Morgan-Jones & Gams), which causes fescue toxicosis in livestock and costs cattle producers millions of dollars annually in lost production. Endophyte presence is known to reduce wild mammal populations in areas where tall fescue is prevalent. The endophyte spends its entire life cycle within the plant and is transmitted through the seed. The association is mutualistic with the plant providing nutrients for the endophyte and the endophyte conferring drought, insect, and nematode resistance to the plant. Several classes of alkaloids exist in endophyte-infected tall fescue including ergopeptides and lolines. The ergopeptides are animal toxins, whereas the lolines deter insects. Our present work is on elucidating physiological mechanisms explaining animal disorders and improved host drought tolerance due to endophyte, and on identifying endophyte strains that are not toxic to livestock but that improve drought and pest resistance in tall fescue.

*Published with the approval of the Director, Agriculture Experiment Station.

Introduction

Tall fescue (*Festuca arundinacea* Schreb.) is the most commonly grown cool season grass in Arkansas and is used for forage, turf and roadside erosion control. The presence of a fungal endophyte (*Acremonium coenophialum* Morgan-Jones & Gams) in tall fescue is associated with a condition in livestock called fescue toxicosis. The endophyte lives in a symbiotic relationship with the grass in which the fungus provides pest resistance and protection against drought for the host while the plant provides nutrition and a means of dissemination for the fungus. The endophyte-tall fescue association makes a significant impact on the landscape and land use of Arkansas owing to its high resistance to herbivory and environmental stress and to its enhanced agronomic attributes. The purpose of the paper is to summarize the current state of knowledge of aspects of tall fescue-endophyte association that involve cost to mammals and invertebrates and benefits to the host plant.

Plant/Endophyte/Animal Relationships

Incidence of Endophyte.--The principle tall fescue cultivar grown in Arkansas is "Kentucky-31" which was selected from a pasture population in Kentucky and was released in 1941. The cultivar grew and persisted on marginal land better than other cool season perennial grasses. As a consequence, Kentucky-31 was widely planted across the east-central and southeastern U. S.. Since over 90% of fescue pastures in the U. S. contain the endophyte (Shelby and Dalrymple, 1987), the original population probably contained the endophyte. Seventy eight percent of tall fescue plants examined from Arkansas pastures contained the endophyte (Daniels et al., 1985).

Endophytic fungi are common to many grass species (White, 1987). Many of the *Claviceps* spp. to which *A. coenophialum* is related produce conidia and ascospores. They parasitize grass leaves and inflorescences, reproduce sexually and disseminate spores to other plants (Clay, 1991). In contrast, *A. coenophialum*, which does not sporulate, lives between the cell walls of the plant in a mutualistic relationship and is spread through seed transmission by its host (Bacon and Siegel, 1988).

Fescue Toxicosis in Mammals.--The association between tall fescue, the presence of an endophyte and fescue toxicosis was made after measuring high endophyte infection rates in fields in which cattle (*Bos* spp.) were suffering from fescue toxicosis and low infection rates in fields where cattle showed no symptoms (Bacon et al., 1977). Fescue toxicosis symptoms which are particularly prominent during hot, humid weather are referred to as "summer slump" and "physiological distress". They include: 1) reduced weight gains; 2) lowered feed intake; 3) elevated body temperature; 4) increased breathing rate; 5) excess salivation; 6) increased time spent in shade or water; 7) lowered milk production; 8) rough hair coat; 9) reduced reproductive rates; and 10) lowered serum prolactin levels (Stuedemann and Hoveland, 1988). In addition, a condition referred to as "fescue foot", which is usually seen during cold weather, results in animals with sore feet or, in more severe cases, loss of extremities (Yates et al., 1979). Fescue toxicosis is estimated to cost U. S. cattle

producers over $600,000,000, annually (Hoveland, 1990).

Several alkaloids are reported in endophyte-infected tall fescue. The lolines (pyrrolizidine alkaloids) are believed to be effective insect deterrents (Yates et al., 1989) and may have a vasomotor effect on mammals (Oliver et al., 1990). The endophyte also produces ergot alkaloids, a group of compounds that have long been known to be mammalian toxins. These alkaloids include the ergopeptine alkaloids, of which ergovaline is the principle alkaloid, and lysergic acid derivatives (Lyons et al., 1986). In our laboratory, we have shown that ergopeptides will inhibit prolactin secretion *in vitro* (Hays et al., 1992). Using changes in tail temperature as an indicator of modification in peripheral blood flow, we have shown that ergopeptides and lysergic acid derivatives can induce peripheral vasoconstriction (Brown et al., 1993). These data suggest that the ergot alkaloids are, in part, responsible for fescue toxicosis.

Four to five times more wild mammals were trapped on endophyte-free vs endophyte-infected tall fescue pastures (Pelton et al., 1991). This suggests that, as observed with livestock, growth or reproductive rates may be reduced in small mammals living on endophyte-infected fescue sods. At least part of the year, many small mammals would rely on fescue seed as a major portion of their diet. The highest concentration of ergot alkaloids found in the plant are in endophyte-infected seed. Wild birds (*Junco hyemalis*) selected endophyte-free fescue seed over endophyte-infected seed when offered the seed free choice (Clay, 1989). Depressed prolactin levels that wild birds incur from eating endophyte-infected seed may inhibit egg laying.

New Zealand researchers have associated the presence of an endophyte (*A. lolii*) in perennial ryegrass (*Lolium perenne* L.) with a tremorogenic condition in sheep called ryegrass staggers (Fletcher and Harvey, 1981). A neurogenic toxin, lolitrem B, has been isolated from endophyte-infected ryegrass and is believed to cause ryegrass staggers (Gallagher et al., 1981).

Insect and Nematode Deterrence.--The presence of endophyte in grasses has been shown to deter insect herbivory. When endophyte in perennial ryegrass was associated with outbreaks of ryegrass staggers, endophyte-free cultivars were planted. These cultivars were highly susceptible to attacks (Barker et al., 1984) from Argentine stem weevil (*Listronotus bonariensis* Kuschel). The insect deterrent in endophyte-infected perennial ryegrass is peramine, an alkaloid that is also found in endophyte-infected tall fescue (Siegel et al., 1990). High concentrations of pyrrolizidine (N-acetyl and N-formyl loline) alkaloids are found in endophyte-infected tall fescue (Bush et al., 1982). These alkaloids are produced by the plant in response to the endophyte presence and act as insect toxins (Yates et al., 1989).

Density of endophyte-free tall fescue stands are often decreased despite an apparent lack of mammalian or insect herbivory (Clay, 1991). Reduced plant competitiveness and persistence may be in part due to predation by root-feeding nematodes, especially in combination with drought stress (West and Gwinn, 1993). Incidence of the ectoparasite *Tylenchorhenchous acutus* Allen and endoparasite *Pratylenchus scribneri* Steiner were lower in field plots planted to endophyte-infected than endophyte-free tall fescue (West et al., 1988). Endophyte presence strongly inhibited reproduction of the endoparasite *Meloidogyne marylandi* Jepson and Golden in tall fescue roots (Elmi et al., 1990). The chemical agents in endophytic tall fescue affecting nematodes have not been identified.

Endophyte and Host Drought Resistance.--The presence of the endophyte in tall fescue increases drought stress tolerance and persistence, and hence expands the geographic range of adaptation of tall fescue (West and Gwinn, 1993). Tiller density in endophyte-free stands was 62% of endophyte-infected stands after a severe summer drought (West et al., 1993). Endophyte-infected plants exhibited leaf rolling sooner than endophyte-free plants of the same genotype during the onset of drought stress (Arachevaleta et al., 1989). The reverse or no difference was found in field trials (West et al., 1988, 1993). In greenhouse experiments, Elmi (1992) found that transpiration rate and stomatal conductance in endophyte-infected plants were lower than in endophyte-free plants when subjected to drought stress, indicating a short-term, drought postponement mechanism. Endophyte-infected plants showed increased survival after severe drought compared with noninfected plants (Elmi, 1992). Increased survival of endophyte-infected plants was associated with higher osmotic adjustment in the leaf growing zone suggesting an additional mechanism of drought tolerance at low water potential for longer-term stress. Increased persistence of tall fescue during drought due to endophyte presence is a major biological benefit to the plant and economic benefit to the pasture manager.

Beneficial Uses of Endophytes.--As part of the program to reduce the cost to Arkansas agriculture of fescue toxicosis we are screening a large number of germplasm sources of tall fescue from its regions of origin for low or no production of ergopeptine alkaloids and high levels of insect-deterring alkaloids. Our data indicate that there is a great deal of diversity in the alkaloid profiles of endophyte-infected plants. Work is presently underway to transfer endophytes producing no mammalian toxins into endophyte-free cultivars. The goal of this research is to produce a tall fescue-endophyte combination that is not toxic to livestock but that retainspest and drought resistance.

Acknowledgements

Rat prolactin I-6, RP-3 and antisera S-9 were obtained from the National Hormone and Pituitary Program. This work was supported by grants from the Arkansas Department of Higher Education, Southern Regional IPM (CSRS-USDA) and Research Center for Alternative Pest Control (CSRS-USDA).

Literature Cited

Arachevaleta, M., C. W. Bacon, C. S. Hoveland and **D. E. Radcliffe**. 1989. Effect of the tall fescue endophyte on plant response to environmental stress. Agron J. 81:83-90.

Bacon, C. W., and **J. K. Porter, J. D. Robbins** and **E. S. Luttrell.** 1977. *Epichloe typhina* from toxic tall fescue grasses. Appl. and Environ. Microbiol. 34:576-581.

Bacon, C. W. and **M. R. Siegel**. 1988. Endophyte parasitism of tall fescue. J. Prod. Agric. 1:44-55.

Barker, G. M., R. P. Pottinger, P. J. Addison and **R. A. Prestidge**. 1984. Effect of *Lolium* endophyte fungus infections on behavior to adult Argentine stem weevil. N. Z. J. Agric. Res. 27:271-277.

Brown, K. L., E. L. Piper, G. C. Duff and **Z. B. Johnson**. 1993. Effects of ergot alkaloids on tail temperatures of Holstein steers. J. Anim. Sci. 70 (Suppl. 1):32.

Bush, L. P., P. L. Cornelius, R. C. Buckner, D. R. Varney, R. A. Chapman, P. B. Burrus, II, C. W. Kennedy, T. A. Jones and **M. J. Saunders**. 1982. Association of N-acetyl loline and N-formyl loline with *Epichloe typhina* in tall fescue. Crop Sci. 22(5):941-943.

Clay, K. 1989. Trespassers will be poisoned. Natural History 9:8-14.

Clay, K. 1991. Fungal endophytes, grasses and herbivores.In P. Barbosa, V. A. Krischik and C. G. Jones (ed.) Microbial Mediation of Plant-Herbivore Interactions. p. 5, John Wiley and Sons, New York.

Daniels, L. B., E. L. Piper, B. J. Hankins, G. Gee, T. S. Nelson and **J. Gergerich.** 1985. Infestation level of the endophyte *Acremonium coenophialum* in fescue pastures in twenty-one Arkansas counties. Ark. Farm Res. 34(1):9.

Elmi, A. A. 1992. Physiological effects of endophyte and nematodes on water relations in tall fescue. Ph.D. diss. University of Arkansas, Fayetteville. DAI 53-08B, Diss Abstr. Order # 9237355.

Elmi, A. A., C. P. West, T. L. Kirkpatrick and **R. T. Robbins**. 1990. *Acremonium* endophyte inhibits root-knot nematode reproduction in tall fescue. Ark. Farm Res. 39(6):3.

Fletcher, L. R. and **I. C. Harvey**. 1981. An association of a *Lolium* endophyte with ryegrass staggers. N. Z. Vet. J. 29:185-186.

Gallagher, R. T., E. P. White and **P. H. Mortimer**. 1981. Ryegrass staggers: Isolation of potent neurotoxins lolitrem A and lolitrem B from staggers-producing pastures. N. Z. Vet. J. 29:189-90.

Hays, D. H., E. L. Piper, R. W. McNew and **A. S. Moubarak.** 1992. Effects of ergopeptide fraction on *in vitro* pituitary prolactin release. J. Anim. Sci. 70:(Suppl. 1)71.

Hoveland, C. S. 1990. Importance and economic significance of the *Acremonium* endophytes to performance of animals and grass plants. (Pp. 3-12) *In:* Acremonium /Grass Interactions, R. Joost and S. Quisenberry, eds. Elsevier.

Lyons, P. C., R. D. Plattner and **C. W. Bacon**. 1986. Occurrence of peptide and clavine ergot alkaloids in tall fescue grass. Science 232:487-489.

Oliver, J. W., R. G. Powell, L. K. Abney, R. D. Linnabary and **R. J. Petroski**. 1990. N-acetyl loline induced vasoconstriction of lateral saphenous vein (cranial branch) of cattle. Proc. of Int. Symp. on *Acremonium*/Grass interactions. p. 239. Nov. 3-7, New Orleans.

Pelton, M. R., H. A. Fribourg, J. W. Laundre and **T. D. Reynolds.** 1991. Preliminary assessments of small wild mammal populations in tall fescue habitats. Tenn. Farm & Home Sci. 160:68-71.

Shelby, R. A. and **L. W. Dalrymple.** 1987. Incidence and distribution of the tall fescue endophyte in the United States. Plant Dis. 71:783-786.

Siegel, M. R., G. C. M. Latch, L. P. Bush, F. F. Fannin, D. D. Rowan, B. A. Tapper, C. W. Bacon and **M. C. Johnson.** 1990. Fungal endophyte-infected grasses: Alkaloid accumulation and aphid response. J. Chem. Ecol. 16:3301-3315.

Stuedemann, J. A. and **C. S. Hoveland**. 1988. Fescue endophyte: history and impact on animal agriculture. J. Prod. Agric. 1:39-44.

West, C. P. and **K. D. Gwinn.** 1993. Role of *Acremonium* in drought and pest tolerances of grasses. N. Z. J. of Agric. Res. In Press.

West, C. P., E. Izekor, D. M. Oosterhuis and **R. T. Robbins.** 1988. The effect of *Acremonium coenophialum* on the growth and nematode infection of tall fescue. Plant Soil. 112:3-6.

West, C.P., E. Izekor, K.E. Turner and **A.A. Elmi.** 1993. Endophye effects on growth and pesistence of tall fescue along a water-supply gradient. Agron. J. 85:264-270.

White, J. F. Jr. 1987. Widespread distribution of endo phytes in the Poaceae. Plant Disease. 71:340-342.

Yates, S. G., J. C. Fenster and **R. J. Barlelt.** 1989. Assay of tall fescue seed extracts, fractions and alkaloids using the large milkweed bug. J. Agric. Food Chem.

37:354-357.

Yates, S. G., J. A. Rothfus, G. B. Garner and **C. N. Cornell.** 1979. Video thermometry for assay of fescue foot in cattle. Am. J. Vet. Res. 40:1192-1196.