Mycorrhizal dependence and growth habit of warm-season and cool-season tallgrass prairie plants

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Abstract

Warm-season (C_4) and cool-season (C_3) mycorrhizal grasses were 63–215 and 0.12–4.1 times larger in dry weight than non-inoculated controls, respectively. Nonmycorrhizal warm-season plants did not grow and frequently died, while cool-season plants grew moderately well in the absence of mycorrhizal symbiosis. Like warm-season grasses, tallgrass prairie forbs were highly dependent on mycorrhizal symbiosis, even though they are not known to employ the C_4 photosynthetic pathway. Thus, phenology may be more critical than photosynthetic pathway in determining mycorrhizal dependence. Warm-season grasses and forbs had coarser, less frequently branched root systems than cool-season grasses, supporting the hypothesis that mycorrhizal dependence is related to root morphology. Cool-season grasses may have developed more fibrous root systems because mycorrhizal nutrient uptake was not effective in the colder temperate environment in which they evolved. In contrast, warm-season plants and dependence on mycorrhizal fungi may have coevolved, because both symbionts are of tropical origin

Arbuscular mycorrhizae promote establishment of prairie species in a tallgrass prairie restoration

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Abstract

The effect that arbuscular mycorrhizal (AM) inoculum has on the development of an early successional tallgrass prairie restoration was investigated in field plots of a recently disturbed area in Minnesota, U.S.A. Mycorrhizal inoculum reproduced from a native prairie was placed below a mix of prairie seed. Two sets of control plots were established, those with seed only and those with seed and a sterilized soil. By the end of 15 months, plants in the inoculated plots had a significantly greater percentage of roots colonized by AM fungi. While inoculation had no effect on total percent cover of plants, percent cover of native planted grasses was significantly greater in the inoculated plots than in the two sets of controls. The increase in percent cover of native grasses may increase the rate of succession by allowing these grasses to outcompete the ruderal species also present at the site. Our findings suggest that inoculation with arbuscular mycorrhizae promotes the development of early successional tallgrass prairie communities.*Key words*: mycorrhizae, prairie, reclamation, plant community, inoculation, restoration.

Relationship between mycorrhizal dependence and competitive ability of two tallgrass prairie grasses

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Abstract

The impact of mycorrhizal symbiosis on growth of *Andropogon gerardii* (big bluestem) and *Koeleria pyranidata* (junegrass) was compared. *Andropogon gerardii* was 98% dependent on the symbiosis, whereas *K. pyranidata* displayed less than 0.02% dependence. Mycorrhizal fungus inoculation resulted in 50 times larger *A. gerardii* plants but did not alter growth of *K. pyranidata*. When competing in pairs, *A. gerardii* dominated when the mycorrhizal symbiosis was present and *K. pyranidata* dominated when it was not present. Dry weight of mycorrhizal *A. gerardii* was altered, whether grown alone or with *K. pyranidata*, but mycorrhizal *K. pyranidata* grew well only in the absence of competition and failed to grow appreciably if *A. gerardii* was present. Without mycorrhizal fungus inoculation, *A. gerardii* did not grow and had no deleterious effects on *K. pyranidata*. When P fertilization was substituted for mycorrhizal fungus inoculation, *A. gerardii* grew better alone than in competition with *K. pyranidata* at low P levels but was not affected by competition at high P levels. *Koeleria pyranidata* was not affected by competition at low P levels, but high P fertilization resulted in reduced dry weight of *K. pyranidata* plants when in competition with *A. gerardii*. Phenologic separation of growing seasons avoids interspecific competition between these two grasses and may be one mechanism contributing toward their coexistence. Since low temperatures limit mycorrhizal nutrient uptake, phenologic separation of growing seasons could also avoid the competitive advantage of warm-season grasses conferred by their mycorrhizal dependence.

Influence of mycorrhizal fungi and fertilization on big bluestem seedling biomass

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Abstract

The relationship between fertilization of prairie soils and mycorrhizal symbiosis in big bluestem (*Andropogon gerardii* Vit.) was explored. In 10 steamed prairie soils of varied P level, inoculation with a mycorrhizal fungus resulted in a 7- to 70-fold increase in big bluestem seedling biomass, compared to noninoculated controls. Fertilization with N and K (25-0-25) significantly increased biomass of mycorrhizal seedlings but did not alter growth of nonmycorrhizal seedlings. In a second experiment which assessed the impact of N and P on seedling growth, in both steamed and nonsterile soil, P fertilization did not significantly increase plant biomass, while N fertilization did substantially increase biomass of mycorrhizal, but not nonmycorrhizal plants. Fertilization with N and P together produced the greatest biomass in both mycorrhizal and nonmycorrhizal plants. Apparently, in the range soils tested N is the most limiting nutrient, despite the low P availability exhibited by these soils. In the absence of mycorrhizae, however, P is most limiting and no response to N is observed unless sufficient P is also applied. These studies confirm an extremely important role for mycorrhizal fungi on big bluestem seedling growth.

Key Words: phosphorus, nitrogen, *Glomus etunicatum*, mycorrhizae, *Andropogon gerardii*

Tallgrass prairie soils of the Kansas Flint Hills contain little plant-available phosphorus as estimated by chemical soil tests (Halm et al. 1972). In spite of this, these prairie soils are productive and plants grown in these soils do not respond to phosphorus fertilization (Moser and Anderson 1964). Hall et al. (1984) suggested that nitrogen fertilization can raise N/P ratios in shoots, in effect lowering plant P status and increasing demand for P. In prairie soils, however, even following N fertilization which significantly increases plant growth (Moser and Anderson 1964; Rains et al. 1975; Woolfolk et al. 1975; Wallace 1981), there is no significant response to P fertilization (Mader 1956). Presumably adequate supplies of phosphorus are made available for plant growth by microbial mineralization of organic P (Coleman et al. 1983). Other mechanisms by which soil microorganisms contribute to the P nutrition of prairie plants have received less attention.

Vesicular-arbuscular mycorrhizal (VAM) fungi are abundant in grassland soils (Hetrick and Bloom 1983, Dickman et al. 1984, Stahl and Christensen 1982) and readily colonize roots of prairie grasses and forbs (Hetrick and Bloom 1983, Zajicek et al. 1986). Warm-season prairie grasses and forbs display a high degree of dependence on mycorrhizae and to not appear to survive without the symbiosis (Hetrick et al. 1988a). While these fungi can increase plant drought tolerance and resistance to soil-borne pathogens, their primary role in the ecosystem may be to aid plants in acquiring soil nutrients (Hayman 1983). Hyphae in soil are abundant, highly branched, and extend beyond the zone of depletion which surrounds plant roots (Tinker and Gildon 1982). These hyphae absorb nutrients from soil and translocate them into the plant cortex. Thus, more surface area for nutrient absorption is available, allowing 4 times faster uptake rates of phosphorus as compared with nonmycorrhizal roots (Sanders and Tinker 1973). Grassland plants may be connected to each other by hyphae of mycorrhizal fungi and nutrients may flow between plants via these hyphal bridges (Chiariello et al. 1982). More recently, Hetrick et al. (1988b) demonstrated that mycorrhizal plants display a more elongate root growth pattern, allowing a greater soil volume to be explored for nutrients. Thus, several mechanisms exist whereby mycorrhizal fungi may play a critical role in nutrient acquisition for prairie plants.

The purpose of this study was to explore the relationship between fertilization of prairie soils and mycorrhizal symbiosis in big bluestem (*Andropogon gerardii* Vit.) seedlings.

Materials and Methods

Experiment 1

Tallgrass prairie soil was collected from 10 sites on Konza Prairie Research Natural Area (KPRNA), near Manhattan, Kans. Sites 1, 2, 4, and 5 were Chase silty clay loams (fine, montmorillonitic, mesic Aguic Argiudoll), and sites 3, 6, 7, 8, 9 and 10 were silty and cherty clay loams of the Benfield-Florence complex. Benfield soils are fine, mixed, mesic Udic Argiustolls and Florence soils are clayey-skeletal, montmorrillonitic, mesic Udic, Arguistolls. Phosphorus content of the soils (Table 1) was determined using the Bray I method for extractable P (Olsen and Sommers 1982) by the Kansas State University Soil Testing Laboratory. One-half of each of the 10 soils was steam pasteurized for 2 hours at 100° C, while the other half remained nonsterile. Twenty-four replicate cylindrical pots (6×25 cm) were then filled with 475 g (dry weight) steamed or nonsterile soil from the 10 locations.

Big bluestem seedlings (0.01-0.04 g dry weight) which had been germinated and grown in vermiculite for 2 weeks were transplanted into each pot (one seedling/pot). One-half of the pots containing steamed or nonsterile soil received inoculum of *Glomus etunicatum* Becker and Gerd. collected from sudangrass (*Sorghum vulgare* var. *sudanense* [Piper] Hitch.) pot cultures maintained in a 15–25° C greenhouse. These pot cultures were initiated from *G. etunicatum* spores collected from KPRNA. This species was widespread and abundant in earlier surveys of KPRNA (Hetrick and Bloom 1983). The spores were recovered by wet sieving, decanting, and centrifuging on a 20-40-60% sucrose-density gradient (Daniels and Skipper 1982). Spores were pipeted (400 spores/plant) onto roots of each seedling at transplanting. The 12 pots of each treatment were then subdivided into 2 groups of 6 pots. Six of these pots received fertilization every other week with 0.063 g Peter's No-Phos (25-0-25) special fertilizer solution (Peter's Fertilizer Products, Fogelsville, Penn. 18051) delivered in 25 ml water, and the remaining 6 pots remained unamended. Therefore, approximately 35 ppm N and 29 ppm K were added to each pot every other week. The pots were arranged in a randomized com-

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Dependence of 3 Nebraska Sandhills warm-season grasses on vesicular-arbuscular mycorrhizae

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Abstract

Vesicular-arbuscular mycorrhizae (VAM) are rare or absent in actively eroding soils of the Sandhills. The objective of this study was to determine if 3 major Sandhills warm-season grasses used in reseeding eroded Sandhills sites are highly mycorrhizal dependent, and evaluate the response of VAM at different phosphorus (P) levels. In 2 greenhouse experiments, sand bluestem [*Andropogon gerardii* var. *paucipilus* (Nash) Fern.], switchgrass (*Panicum virgatum* L.), and prairie sandreed [*Calamovilfa longifolia* (Hook) Scribn.] were grown in steam-sterilized sand in pots and inoculated with either indigenous Sandhills VAM, *Glomus deserticola*, or noninoculated. In the second experiment, VAM inoculated and control plants were treated with 5 P levels ranging from 5.4 to 27.0 mg P pot^{-1}. Increasing levels of P fertilizer caused an initial increase, then dramatic decrease, in percentage colonization by *Glomus deserticola* but had no effect on percentage colonization by indigenous Sandhills VAM. Mycorrhizal inoculated plants had a greater number of tillers, greater shoot weight, root weight, tissue P concentration and percentage P recovered, and a lower root/-shoot ratio and P efficiency than noninoculated plants. Noninoculated sand bluestem had significantly lower shoot P concentration but greater P efficiency over all P levels than any other grass-VAM treatment combination. Phosphorus fertilizer and VAM effects were often complementary at P levels up to 16.2 to 21.6 mg P pot^{-1}, with no change or a decrease in plant responses at higher P levels. These 3 major Sandhills warm-season grasses were highly mycorrhizal dependent. Successful reestablishment of these on eroded sites in the Sandhills may be greatly improved if soil reinoculation with VAM occurred prior to revegetation.

Key Words: phosphorus recovery, phosphorus-use efficiency, revegetation, grass seedlings, tillering

The Nebraska Sandhills comprise the largest continuous expanse of Tallgrass Prairie in the Great Plains, covering about 52,000 km^2 in northcentral and western Nebraska (Seevers et al. 1975). Upland soils of the Sandhills are composed primarily of fine sand of high erosion potential and low organic matter content, water-holding capacity, and available nutrients. Available P may be the soil nutrient that has the greatest influence on the vegetative composition of range sites in the Sandhills (Burzlaff 1962).

Many areas of the Sandhills have experienced excessive erosion as a result of overgrazing and the abandonment of farming operations on center pivot irrigation sites (Kocher and Stubbendieck 1986). Vesicular-arbuscular mycorrhizae (VAM) are abundant in undisturbed Sandhills soils, but rare or absent in actively eroding soils (Roder 1985, Reece et al. 1987). Reseeding these sites with native and introduced warm- and cool-season grasses has often been unsuccessful (King et al. 1989). Lack of success in seedling establishment in eroding Sandhills soils may be a result of very low levels of VAM fungi present in the soils at the time of seeding (Reece et al. 1987, Reeves et al. 1979).

Vesicular-arbuscular mycorrhizae readily colonize the roots of prairie grasses (Hetrick et al. 1988). Warm-season grasses display a high degree of dependence on mycorrhizae and are often unable to survive without them (Hetrick et al. 1988, 1989; Trappe 1981, Bethlenfalvay et al. 1984). Hetrick et al. (1989) reported that inoculation of sterilized prairie soils with mycorrhizae resulted in a 7 to 70 fold increase in big bluestem (*Andropogon gerardii* Vitman) seedling biomass. Plant response to mineral nutrients is often highly dependent on VAM. Hetrick et al. (1989) concluded that when mycorrhizae are present, N is the most limiting nutrient in most rangeland soils. However, in the absence of mycorrhizae, P is most limiting and no response to N is observed unless sufficient P is also applied.

Understanding the symbiotic relationship between VAM fungi and the native warm-season grasses of the Sandhills is essential for effective seeding of disturbed Sandhills soils. The purpose of this research was to examine relationships between VAM fungi and 3 native Sandhills warm-season grasses by (1) comparing the growth, P-uptake and P-use efficiency of these grasses with indigenous and introduced VAM fungi, and (2) evaluating the response at different P levels.

Materials and Methods

Inoculum Source and Treatments

Two greenhouse studies were conducted utilizing indigenous Sandhills VAM fungi from the Nebraska Sandhills, and the introduced VAM fungus *Glomus deserticola*. *Glomus deserticola* was chosen for comparison with indigenous Sandhills VAM because it is not native to the Sandhills but is found in more arid environments in the western U.S. Inoculum for the Sandhills VAM treatment was prepared by collecting large blocks of sod containing root material of native Sandhills grasses from the top 30 cm of a Valentine fine sand (fine sandy mixed mesic Typic Ustipsamment) at a rolling sands range site at the University of Nebraska's Gudmundsen Sandhills Laboratory, located in Grant County, 12 km northeast of Whitman, Neb. Soil at the collection site is low in mineral nutrients, especially in available P. Soil properties for the top 30 cm were: 0.81% OM, 0.04% total N (Kjeldahl), 5.7 mg kg^{-1} available P (Bray and Kurtz #1), and a pH (1:1 soil-water ratio) of 6.45. Major components of the plant community at the collection site included sand bluestem [*Andropogon gerardii* var. *paucipilus*

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