

ELEMENT STEWARDSHIP ABSTRACT
for

Poa pratensis, Poa compressa

Kentucky Bluegrass, Canada Bluegrass

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The Nature Conservancy
Element Stewardship Abstract
For *Poa pratensis*

I. IDENTIFIERS

Common Name: KENTUCKY BLUEGRASS

Global Rank: G?

General Description:

Poa pratensis is a shallowly rooted, rhizomatous perennial grass.

Diagnostic Characteristics:

The genus *Poa* is distinguished by its flat leaf blades, 2-6 flowered panicles, 1-3 nerved glumes and tuft of cobwebby hairs at the base of the 5-nerved lemmas (Gleason 1957, Mohlenbrock 1972, Hitchcock 1950).

II. STEWARDSHIP SUMMARY

Poa pratensis is a problem throughout the prairie region wherever there is a history of grazing, prolonged rest, and midsummer mowing. *Poa compressa* appears to occur on similar but drier and perhaps better quality sites and to achieve somewhat less dominance.

It appears that the best program for eliminating *Poa pratensis* wherever there is a strong guild of warm season natives is to manage not only against *Poa* but for warm season natives, especially big bluestem. In such situations burning while *Poa* is in boot is likely to be effective. In northern mixed prairie an 18 month or irregular cycle of spring and fall burns may prove more desirable for maintaining native cool season co- dominants.

III. NATURAL HISTORY

Range:

Poa pratensis is found naturalized in all the continental states and in Canada from Labrador to the west coast, except in arid regions (Hitchcock 1950). It is less common in the Gulf states than farther north (Hitchcock 1950). Although it thrives in a variety of habitats, it does especially well on calcareous soils (Hitchcock 1950) and avoids acid soils (Gleason and Cronquist 1953).

Habitat:

There is some disagreement whether *Poa pratensis* is native in the northern tier of states and Canada (Fernald 1950, Great Plains Flora Assoc 1986, Gleason and Cronquist 1953) or native in Eurasia and introduced throughout its North American range (Hitchcock 1950, Mohlenbrock 1972, USDA 1948). Kentucky bluegrass is planted in some areas for forage and is widely used for turf.

Kentucky bluegrass is favored by moist conditions, including reservoir shores (Hoffman et al. 1980). It can withstand flooding (Schalitz 1977) flooding with subsequent freezing, ice and snow (Beard 1964). The interaction of the effects of soil texture and climate on *Poa pratensis* is demonstrated by its high frequency on drier sites of Ontario old fields on shallow circumneutral soils overlying gravel (Maycock and Guzikowa 1983), low frequency on sandy soils in Wisconsin (Kline pers. comm.), and absence from sandy soils in Nebraska (Steuter pers. comm.).

Reproduction:

On any given parent plant the number of axillary buds is dependent on the number of leaves. Etter (1951) reports that in dry, shady localities, Kentucky bluegrass may develop as few as 7 to 9 leaves, 12 to 14 in a meadow, and as many as 18 in a moist pasture. Each axillary bud has the developmental possibility of early tiller formation or delayed rhizome development.

In rangeland terminology a "tiller" often refers to any aerial shoot. In the strict parlance of developmental morphology a "tiller" is an aerial shoot that develops in the axillary bud of live leaf tissue (Etter 1951, Dahl and Hyder 1977). These new shoots develop root systems of their own and are hence a method of vegetative reproduction. Because of their origin, tillers always develop in close proximity to the parent plant. Young tillers derive their nutrition from the parent plant until they have attained full growth (Dahl and Hyder 1977). Although tillers develop true root systems of their own, these systems are not extensive (Etter 1951) and mature tillers neither translocate nor receive carbohydrates to and from other shoots derived from the same parent plant. There is a high mortality of tillers during the season of formation (Etter 1951).

Tillering is favored by cool temperatures (Etter 1951, Darrow 1939) and short day lengths (Evans and Watkins 1939, Evans 1927) and reaches its maximum in spring and fall, but declines in midsummer. Tillering is induced by early removal of developing flowering culms while the floral initiates are still enclosed within the sheath (booth stage) (Dahl and Hyder 1977). Etter (1951) reports that tillering is correlated with short leaves and, in a separate context, that *Poa pratensis* is more likely to develop long leaves in the shade. Well-lit situations that foster an abundance of shorter leaves may therefore enhance tillering. Etter (1951) reports that tillering is encouraged by April mowing to prevent flowering, fall grazing, fall nitrogen fertilization, fall irrigation and removal of dead plant material and shading.

Both *Poa pratensis* and *Poa compressa* are rhizomatous perennial grasses. Some North American fields of *Poa pratensis* are known to be as old as 60 years (USDA 1948). Volland (1978) attributes the inter-seasonal longevity of bluegrass to the activity of the rhizomes.

Axillary buds that have not formed tillers can develop into rhizomes, lateral shoots that penetrate the enveloping leaf sheath and develop underground (Dahl and Hyder 1977, Etter 1951). Rhizomes can form on the surface of the soil (Evans and Ely 1935, Etter

1951), but soon turn downward. Rhizomes account for bluegrass's sod-forming capability and can extend the horizontal growth of the plant as much as 2 square meters in 2 years (Kannenberg and Wrede 1934). The mode of elongation is the same as for aboveground shoots. The length of the rhizome is a function of the degree of internode elongation. Under conditions of drought or on excessively drained soils, short internodes (and hence short rhizomes) are produced. Short sprout-like rhizomes appear to increase under adverse conditions such as high temperatures (Harrison 1934) fire injury, or too close grazing and mowing (Etter 1951).

Rhizome formation and growth occurs throughout the year except late winter and early spring. Initiation of new rhizomes from axillary buds that have remained dormant overwinter invariably occurs when the inflorescence begins to elongate (Etter 1951). Brown (1939) found that rhizome elongation peaks between 60 and 70 degrees F. Evans and Ely (1935) report a midsummer peak of rhizome formation in Ohio. Summer-formed rhizomes can remain dormant until the following spring or develop into aerial shoots anytime during the growing season.

Rhizomes constitute a major sink for storage of carbohydrates in *Poa pratensis*. Brown (1943) reports that late autumn is the most favorable period for carbohydrate storage in Kentucky bluegrass. Carbohydrates are also synthesized more rapidly than they are used in early spring. During late spring-early summer there is a loss of carbohydrates from roots. Plants that remain uncut or are watered continue to lose carbohydrates from their roots. Plants that are mowed semimonthly or go unwatered do not experience such a loss (Brown 1943).

The major consequence of a high ratio of rhizomes to tillers is the formation of a dense sod. As the sod becomes increasingly tighter, fewer aerial shoots are formed (Volland 1978). In northern mixed prairie region this "sod-bound" condition can develop to such an extent that "bluegrass slicks" are formed, in which the thatch is so thick and the sod so tight that the bluegrass eventually dies (Steuter pers. comm., Kruse pers. comm.). In southern mixed prairie Weaver and Rowland (1952) observed an absence of Kentucky bluegrass in heavily mulched prairie, but in the Pacific Northwest Volland (pers. comm.) reports that although thinning occurs, bluegrass pastures appear to reach an equilibrium condition and do not choke themselves out.

Because the number of buds available for rhizome formation is dependent on the number previously used to form tillers, it seems logical that rhizome development would be favored by conditions the converse of those favoring tillers: allowing flowering to occur, protection from grazing and mowing, mulch build-up and shading.

Conditions that contribute to the death of rhizomes include overfertilization with nitrogen (Etter 1951), repeated close mowing (McKell et al. 1969) especially at temperatures in excess of 100 degrees F (Harrison 1934), overgrazing during drought at temperatures in excess of 100 degrees F (Wilkins 1935) and summer irrigation (Brown 1943) which

accelerates decomposition of old roots and causes the plant to draw down the carbohydrate reserves at unnatural rates (McKell et al. 1969).

Evans and Ely (1935) studied rhizome development in both *Poa pratensis* and *Poa compressa* and provide the following contrasts between the two species: Rhizomes of *Poa compressa* originate almost entirely below the surface of the soil whereas those of *Poa pratensis* often originate above ground and turn downward. Peak rhizome formation in *Poa pratensis* was observed in midsummer, in *Poa compressa* in late summer and early fall. Nearly all the spring-formed rhizomes of *Poa compressa* had formed aerial shoots by August, whereas only half of early-formed *Poa pratensis* rhizomes did so (Evans and Ely 1935).

Both rhizomes and tillers are morphological shoots. Both form true roots. Roots of *Poa pratensis* begin to grow in March in the northeast (Stuckey 1941) at air and soil temperatures below 45 degrees F (Sprague 1933). Maximum root elongation is in April (Stuckey 1941). Unlike rhizomes, roots cease formation and elongation in midsummer (Stuckey 1941, Sprague 1933) at temperatures above 80 degrees F (Brown 1939). Darrow (1939) found that roots incubated at 15 to 25 degrees C were whiter, more succulent and twice as long as those incubated at 35 degree C, perhaps helping to explain the apparently greater competitive advantage and persistence of *Poa* in cooler climates.

Kentucky bluegrass is well known for its ability to withstand and apparently thrive on successive defoliations. This ability contributes to its usefulness as a forage plant and lawn grass, but detracts from the usefulness of defoliation as a method of control. The biological basis of this characteristic lies in the development of the leaves. As the first leaf arises from the crown the blade elongates followed in sequence by the sheath, and the internode (Etter 1951, Dahl and Hyder 1977). In some grasses the internodes elongate considerably, carrying the shoot apex ever upward on the plant, above the level of previously formed leaves. But in Kentucky bluegrass the greatest growth occurs in the blade and sheaths, each successive blade growing upward apace with the elongation of the previously formed sheath. Internode elongation is minimal, leaving the shoot apex nearer the ground, below the level of the previously formed leaves. As long as defoliation is above the level of this apex, growth will continue on that particular shoot. This growth habit allows for more rapid recovery than on long-shoot plants whose recovery is based solely on tiller formation in response to the loss of apical dominance at the time of defoliation (Dahl and Hyder 1977).

McKell et al. (1969) report that defoliation of *Poa pratensis* at the time of full leaf expansion does not affect the leaf emergence rates of individual shoots, but the total number of leaves on the plant is reduced. Such periodic defoliation can actually have a positive effect on the plant because evapotranspiration is reduced with a concomitant reduction in the amount of carbohydrates withdrawn from storage in the rhizomes (Brown 1943).

Poa pratensis is a cool-season grass, greening up in early spring and coming into bloom in early summer (Nieland & Curtis 1956, Stuckey 1941). Evans and Watkins (1939) relate the more upright growth form and greater rhizome development of both *Poa pratensis* and *Poa compressa* in the early part of the season to the longer day lengths of early summer. In one Rhode Island study (Stuckey 1941) blossom primordia formed in May, *Poa pratensis* was in full bloom in June, with *Poa compressa* lagging somewhat behind in flower development, but bearing seed at the same time. In greenhouse studies in Wisconsin, Sprague and Graber (1938) observed increasing water use from spring into early summer by both unclipped plants and plants clipped at weekly intervals. As would be expected, unclipped plants used more water until they were clipped on June 13. Water use resumed to the pre-clipping level within two weeks. In a study of container-grown plants in Michigan designed to assess the competitiveness of groundcovers for apple orchards, Partridge (1941) found the highest water use by both *Poa pratensis* and *Poa compressa* from June 23 to July 18, but that *Poa pratensis* plants used an average of 2.6 inches more water than those of *Poa compressa* over the growing season.

Etter (1951) reports that the growth of each aerial shoot or underground rhizome is indeterminate until its shoot apex is triggered by environmental stimuli to initiate floral development. Each tiller or rhizome produces a single terminal aerial flowering stem (Etter 1951). Floral initiation is induced by a period of vernalization involving both an inductive developmental stage and a photoperiodic requirement (White pers. comm.) before the inflorescence is initiated (Dahl and Hyder 1977). Vernalization is not transferred from one shoot to another, with the consequence that aerial shoots from either tillers or rhizomes formed in any given year (whether spring or fall) must overwinter before they will bloom (Dahl and Hyder 1977, White pers. comm.). This requirement applies even though apical dominance is removed by removing the flowering culm.

Poa pratensis is generally considered an apomictic species, with reports of the proportion of "aberrants" (sexually reproducing individuals) in given populations varying from 0 to 100%, but usually less than 20% (Smith et al. 1946, Akerburg 1939, Brittingham 1943, Brown 1941).

In 4-year studies of the Newport cultivar of Kentucky bluegrass, Evans and Canode (1971) report in excess of 200 seeds per panicle in the first year. Maximum seed production of around 900 kg/ha was attained in the second year because of a great increase in the number of panicles per m². By the fourth year seed production leveled off around 4000 panicles/m² and around 100 seeds per panicle. Despite the high seed production, production of new plants from seeds in an established prairie is thought to be virtually nonexistent (Steuter pers. comm.). The only available data on the numbers of *Poa* seeds in soils are those of Van Altena and Minderhoud (1972) who report a maximum of 560 seeds/m² for *Poa pratensis* in soil samples from Netherlands pastures. The results of the Duval buried seed experiment indicate that *Poa pratensis* can germinate from depths as great as 42 inches, with over half the shallow seeds and over three-quarters of the deep seeds germinating within the first four years after burial (Toole 1946).

Poa pratensis is a fall germinating species. In laboratory studies of the germination requirements of *Poa pratensis*, Sprague (1933) found that freshly harvested seed required a cold treatment at 5 or 15 degrees C for 10-14 days for germination. Six months after harvest, such a period of cooling was not required. Alternating temperature was more effective in breaking initial dormancy than constant cool temperatures. The response of *Poa compressa* was more variable, but chilling the moistened seed at 10 degrees C for 10 days before subjection to alternating temperatures increased germination (Sprague 1933). In a study of species common to reservoir shores, Hoffman et al. (1980) found that *Poa pratensis* was among the species that germinated 10% or more in autumn and germinated better in water than on dry or moist filter paper.

Under unusual circumstances *Poa pratensis* has been reported as a viviparous plant (Beetle 1980). However, production of shoots directly in the spikelet of the inflorescence is not an effective means of reproduction in the wild (Aiken and Darbyshire 1984).

IV. CONDITION

Threats:

Kentucky bluegrass is a major problem species throughout the tallgrass and mixed grass prairies. *Poa compressa* is often considered together with *Poa pratensis* by researchers and managers, so it is difficult to obtain information specifically relating to Canada bluegrass. Svedarsky (pers. comm.) and Heitlinger (pers. comm.) indicate a sense that *Poa compressa* is less of a problem than *Poa pratensis*. W. Smith (pers. comm.) suggests that *Poa compressa* should be more of a problem on dry prairies than on mesic prairies.

In natural areas *Poa pratensis* competes with native species, reducing species diversity and altering the natural floristic composition. Its rhizomatous habit permits it to penetrate between the other plants. In northern mixed prairie (north of the Nebraska sandhills) *Poa pratensis* is believed to compete directly with cool season native grasses (Steuter pers. comm.).

Both species increase with grazing (Weaver 1954). Removal of grazing pressure alone is not sufficient to shift the balance of species composition back to native species (Volland 1978, Converse pers. comm.).

In rangelands in the mixed-prairie region, *Poa pratensis* is considered a problem because it is less nutritious and has a shorter season than native grassland species, despite the fact that its cool-season habit permits the cattle to be pastured earlier.

V. MANAGEMENT/MONITORING

Management Requirements:

There is a divided literature on the management of *Poa pratensis*. In the east central states it is valued as a forage and a turfgrass. However, in the true mixed grass prairie areas it is recognized that *Poa pratensis* is less desirable fodder than native species and management

systems have been developed to achieve the goal of reducing Poa and increasing the component of native grasses. It is important to keep in mind that these two latter goals go hand in hand. For this reason it is not feasible simply to turn the turfgrass literature around. Practices that will damage Poa may often damage the native species even more (Steuter pers. comm.). The management literature has devoted very little attention to the side effects of Poa management on native prairie forb species. There is a need for a better understanding of Poa control on overall diversity of native species.

BURNING: The most widely used management procedure for controlling *Poa pratensis* in natural areas is the use of fire. Several interactive factors appear to influence the effectiveness of burning as a management tool for reaction of Poa: the mix of warm and cool season grasses present in the target community, specific site characteristics that influence available moisture (climate, soil texture, topography, etc.), and the frequency and timing of burning. Comparison of studies reported in the literature is clouded by the dearth of data on the actual phenological state of Poa at the time of burning and the wide range of incomparable methods used to assess the results.

In the mixed prairie region of Nebraska and Kansas where floristic composition is generally divided into an exotic cool season guild dominated by *Poa pratensis* and a native warm season guild, annual spring burning (Owensby and Smith 1973, Towne and Owensby 1984), or combination of periodic fire with intensive spring grazing or continuous grazing effectively eliminates Kentucky bluegrass (Launchbaugh and Owensby 1978). However, the influence of initial grassland species composition is clearly shown in a study by Schacht and Stubbendieck (1985) in the loess hills of Nebraska. These investigators found that reduced cool season herbage yield (mainly *Poa pratensis*) persisted for two years in tracts where warm season grasses were initially present, but was short-lived on a tract where the warm season component was missing. These results suggest that it is not only spring injury to Poa, but the shift of competitive advantage to warm season natives that makes fire an effective tool for range conversion in mixed prairie.

A similar concomitant reduction of Poa and increase of warm season grasses in response to spring burning is reported throughout the tallgrass region (Ehrenreich 1959, Hill and Platt, 1975).

The influence of prairie composition in the response to fire becomes more complex in northern mixed prairie. North of the Nebraska sandhills in the Dakotas, there is a more even mix of native warm and cool season grasses (Steuter pers. comm.). There is only a short period of one or two weeks between the greening-up of Poa and of native co-dominant *Stipa* species. Unless fires are timed exactly within this period, the advantage of controlling Poa will be offset by damage to native cool season grasses. At Lostwood National Wildlife Refuge May burning over a six-year period has produced only gradual reduction of *Poa pratensis* with little reduction of *Poa compressa* (K. Smith pers. comm.). However, as litter has been reduced there appears to have been a spread of the cool season natives *Agropyron smithii* and *Stipa* species into areas dominated by Canada

bluegrass. This expansion of cool season natives suggests that even with some damage by fire the reduction of litter is offering a slight competitive advantage to native cool season grasses (K. Smith pers. comm.).

In Kansas and Nebraska three successive years of annual spring burning are considered sufficient for conversion of rangeland from *Poa pratensis* to dominance by native warm season grasses. In the north it appears that much longer periods of annual burning are required. Svedarsky et al. (1986) suggests that a ten-year period of annual burning is required before the relative proportions of warm season grasses and *Poa* are stabilized in favor of warm season dominants. In central North Dakota, refuge managers suggest that even longer periods may be required and that *Poa* may never be eliminated but only held in control by fire (Kruse pers. comm., K. Smith pers. comm.).

The rapid reappearance of *Poa* in areas which exhibit good first season response to fire suggests that in some instances burning may be having either no effect or a stimulatory effect on rhizome development. (Steuter pers. comm.). The optimum burn regime would be one that minimizes *Poa* rhizome development and concurrently favors native species. It seems likely that early burns while *Poa* flowering heads are in boot (around 4 inches) might favor the development of short-lived tillers over long-lived rhizomes. This hypothesis is undocumented. The only available data (Graber 1926) indicate that one year after both March and May burns in Wisconsin pastures, rhizome and root weight in burned plots on both dates was 34% less than in control plots.

If it is true that damage to rhizomes is comparable after early and late burns, timing of spring burns needs to be based on the tradeoff between damaging *Poa* and damaging desired native species.

The interaction of available moisture with season of burning appears to be important for production. In true mixed prairie early spring burns are considered less desirable for range management purposes than late spring burns because of reduced overall midsummer herbage yields (mainly from native warm season species) caused by early drying of the soil (Owensby and Smith 1973). Other authors suggest that such decreased productivity following early spring burns is only of consequence where rainfall is not dependable and in excess of 530 mm per year (Kucera et al. 1967, Hill and Platt 1975). For purposes of natural area management the issue of standing crop is less important than that of species composition. Choice of appropriate burning season will be more influenced by the frequency of desired species than their biomass.

Site conditions can influence response to early spring burning. Zedler and Loucks (1969) found that the response of June and August standing crop to April burns differed between dry-ridge and prairie depression sites. Both the overall standing crop and standing crop of bluegrass were significantly lower on burned than on unburned ridgetop control plots, whereas in depressions overall standing crop and standing crop of bluegrass were both higher than on lowland control plots. Differing responses of *Poa* to fire on upland and lowland sites have also been reported in North Dakota (Hadley 1970) and in South

Dakota (Engle and Bultsma 1984, Steuter 1987). However, in the Dakotas it is difficult to separate the effect of site/soil moisture from the effect of species composition because warm season competitors that respond well to spring fires are concentrated in lower sites.

At Ordway Prairie in South Dakota burning in both May and June reduced *Poa pratensis* on both upland and lowland sites. Upland sites were otherwise dominated by *Agropyron smithii* and native *Stipas*, which exhibited reduced herbage following both May and June burns. Lowlands were co-dominated by *Andropogon gerardi*, which increased after burning but was unable to offset a total overall herbage loss after June burns,. Reduction of *Poa* after spring burns persisted into a second year only on upland sites (Engle and Bultsma 1984).

Fall burns at Ordway Prairie, S.D. appear to produce a shift to dominance by the C3 photosynthetic pathway (cool season grasses appearing to enhance the competitive edge of native species over *Poa*) (Steuter 1987). This shift to dominance by native cool season grasses may have been caused by winter kill of both exotic cool season and native warm season grasses or by winter drought stress associated with the reduction of protective mulch (Steuter 1987). However, in central North Dakota prairies such a shift of competitive advantage to native cool season grasses following fall burns has not been observed (Kruse pers. comm.). The result of fall burns has been an increase in *Poa* canopy coverage a year after the burn (Kruse pers. comm.).

In overview, it appears that in tallgrass prairie where species composition is divided into discrete exotic cool season and native warm season guilds, repeated spring burns effectively control *Poa*. Burning at boot stage should shift the balance of shoot development in favor of tillers, reducing the longevity of the plant and the opportunity for sod formation. In the northern states as one moves westward from Wisconsin into the Dakotas, cool season natives become increasingly important components of upland sites. There, earlier timing of spring fires may be needed on upland sites to avoid damage to native cool season *Stipas* and *Agropyron smithii*. An as yet underexplored alternative is the use of fall burns on upland mixed prairie sites with a significant component of native cool season grasses. In glaciated areas of the northern states it may not be feasible to separate upland and lowland sites into discrete spring and fall management units (Steuter pers. comm.). A possible strategy to provide a competitive edge for cool season natives might be to use an 18- month burn cycle. *Poa* would be damaged by both spring and fall fires but spring damage to cool season grasses and fall damage to warm season grasses would be alternated.

GRAZING AND MOWING: Kentucky bluegrass is well known for its ability to withstand frequent defoliation. This attribute contributes to its usefulness as a turfgrass and a forage species and to its classification as an "increaser" under grazing. Despite the fact that Kentucky bluegrass persists well under defoliation (Jung et al. 1974) its yield is progressively reduced by frequent clipping (Ehrenreich 1959, Graber et al. 1927) at heights of 2 inches or less. Biswell and Weaver (1933) report chopped plants to have root volumes of 18.6%, root weight of 20.6% and root diameters of 76% those of unclipped

plants, despite increasing aboveground yields. The effect of clipping height is apparent from the results of Ahlgren's (1938) research in which plants cut repeatedly whenever they attained a height of 4 to 5 inches exhibited greater aboveground productivity than plants cut in boot or at maturity. Despite repeated cutting these plants increased in rhizome carbohydrates over the season. Graber (1933) found that total aboveground first year yield of plants clipped frequently at 1/2 inch was greater than that of plants cut 1 1/2 inches above the ground but the following year the closely cropped plants lost productivity, used more water, created a thinner stand and were invaded by 5 to 7 times more weeds.

Frequently clipped plants use less water because they have less foliar surface. Sprague and Graber (1938) found in simulations of continuous and deferred grazing that more frequent clipping (continuous grazing) resulted in less early season water consumption than clipping in mid-June (deferred grazing).

What is the relationship of these experimental studies to actual range practice? Intensive early grazing is known to decrease Kentucky bluegrass and increase big bluestem (Smith and Owensby 1978), whereas continuous grazing has the long-term effect of converting prairie to bluegrass sod (Weaver 1954). Weaver and Darland (1948) used exclosures to study seasonal grazing patterns on wheatgrass, bluegrass and prairie grass rangelands. They found that cattle always shifted their grazing to native prairie species (especially big bluestem) as soon as plants attained a height of a few inches. Although continuous grazing is one alternative recommended for reduction of Poa (Launchbaugh and Owensby 1978), this practice exposes the native warm season prairie grasses to differential grazing pressure, giving the competitive advantage to Poa. Despite its potential for harm because of low root carbohydrate and water levels, mid- summer mowing has the same effect. Although it is harmful for Poa it is more harmful for native grasses. In areas of South Dakota where hay quality and quantity are optimized by midsummer mowing the practice results in conversion to bluegrass dominance (Steuter pers. comm.). A similar pattern of increased bluegrass with summer mowing is exhibited in the Kansas Flint Hills (Launchbaugh and Owensby 1978). Minimum cover by Poa and maximum cover of Sorghastrum and Andropogon spp. is attained in the Flint Hills by June or November mowing (Launchbaugh and Owensby 1978).

As is the case with fire, it appears that the timing of defoliation (mowing or grazing) to reduce Poa is as much or more a matter of favoring its warm season competitiveness than of damaging the Poa itself. If this is the case, it may be that optimum grazing or mowing regimes for bluegrass control on northern mixed prairie will differ from those that are effective where the warm season guild is more important. Although Poa cover and frequency continue to increase in response to five grazing regimes in North Dakota, a three-year cycle of fall grazing produces the least increase in Poa frequency. A combination of triennial fall and spring grazing produces the least increase in Poa cover. Kruse (pers. comm.) suggests that in this area a fall graze followed by a hard spring graze might prove more effective than either treatment alone.

CHEMICAL CONTROL: Glyphosate can be used effectively for renovation of grasslands in areas where the cool season guild is dominated by exotic species such as *Poa pratensis* and *Bromus inermis* and native species dominate a distinct warm season guild. Martin and Moomaw (1974) report excellent control of bluegrass from applications of 2 lb/a (2.24 kg/ha) glyphosate in spring while warm season grasses were dormant. Waller and Schmidt (1983) report significant decreases in the productivity of *Poa pratensis* along with increasing big bluestem production as a result of April 21 applications of 1 lb/a (1.12 kg/ha) glyphosate on *Poa*-infested loams in southeastern Nebraska. Laboratory studies suggest that 2 month old shoots of *Poa pratensis* raised from seed are more susceptible than 4 month shoots to rates of application less than 1 lb/a (1.12 kg/ha) (Bingham et al. 1980).

Waller and Schmidt (1983) report a similar shift from *Poa* dominance to warm season dominance following April 21 applications of atrazine at a rate of 2 lb/a (2.24 kg/ha). The pre-emergence herbicides Zytren at 22.5 lb/a, Dacthal at 10 lb/a (11.40 kg/ha) and trifluralin at 1.5 lb/a reduced rhizome length and number and tiller production in two cultivated strains of Kentucky bluegrass grown in flats (Gaskin 1964).

It is difficult to envision a natural areas situation in which chemical control of *Poa pratensis* would be the method of preference. Unlike some other problem grasses like *Bromus inermis*, *Poa pratensis* and *Poa compressa* do not grow in pure stands, but occur intermixed with native species, including spring prairie forbs. Spot application to individual *Poa* plants is not feasible because of growth habit. Chemical conversion might be useful in parks or nature centers where prairies are being created de novo from old fields (White pers. comm.). Such a situation might apply in parks or nature centers where prairie demonstration areas are desired for educational purposes.

Monitoring Requirements:

The most common management objective in natural areas is the eradication of bluegrass. In northern mixed prairie of the midwest or wet bluegrass meadows of the Pacific northwest, this objective may be infeasible either because of climatic factors or because the balance of community composition does not provide a strong enough component of competitive warm season perennial grasses. Instead, competition from cool season grasses is more important, presenting a challenge to managers because of their desire to maintain the balance of cool season native species while concomitantly reducing *Poa*. In these areas reduction of vigor and containment of spread may be the only realistic management goals. Monitoring may be used to track the accomplishment of these objectives. There is a need for separate monitoring of *Poa pratensis* and *Poa compressa* in order to elucidate their differences in response to management. In addition to the need to monitor reduction of *Poa* species, there is a need to track the response of cool-season native species to various management strategies.

Vegetative *Poa* plants are not highly visible in mixed prairie conditions (Kruse pers. comm., Svedarsky pers. comm.). Different methods of sampling can produce apparently contradictory results (Volland 1978). Although the number of flowering plants is easy to

count, it is dependent on weather conditions (Volland pers. comm.), exhibits highly variable results in response to fire (Zedler and Loucks 1969, Curtis and Partch 1948, Old 1969, Ehrenreich and Aikman 1963, Henderson et al. 1983) and may be functionally meaningless in established sods (Steuter pers. comm., White pers. comm.).

Frequency of aerial stems can probably provide adequate information about the effectiveness of management with the least possible time investment (Volland pers. comm., Steuter pers. comm.). Steuter (pers. comm.) reports that any plot size larger than a point is likely to generate 100% frequency in mixed prairie conditions. Volland (pers. comm.) notes that a system of nested mini-plots ranging from .75 to 6 inches in diameter could be used to track the gradual thinning of a stand over time. If only one size plot is used, plot size should be adjusted to generate initial frequencies no greater than 85% in the densest areas (Volland pers. comm.).

Because natural area management goals involve the replacement of *Poa* by native species, it is important to monitor not only the decrease in *Poa*, but the increase or retention of desired native species. This is important because under sod-bound conditions *Poa* could decrease without any benefit to native species (Kruse pers. comm, Volland pers. comm.). There are also management practices such as midsummer mowing that could be detrimental to *Poa*, causing a decrease in its frequency, but would be even more detrimental to the native species we are trying to encourage (Steuter pers. comm.).

Monitoring Programs:

The following persons are involved in long-term projects monitoring the status of Kentucky bluegrass in natural communities:

Karen Smith, Refuge Manager, Des Lacs National Wildlife Refuge, Rt. 2, Box 98, Kenmare, North Dakota 58746. (701) 848-2722.

Al Steuter, Preserve Manager, Route 1, Box 346, Johnstown, NE 69214.

Dan Svedarsky, Associate Professor, University of Minnesota, Northwest Experimental Station, Crookston, MN 56716.

Arnold Kruse, Northern Prairie Wildlife Research Center, Jamestown, ND. (701) 252-6363.

Leonard Volland, Regional Ecologist, US Forest Service, USDA, P.O. Box 3623, Portland, OR 97208.

VI. RESEARCH

Management Research Programs:

Although reduction of *Poa* is a major objective of many prairie management regimes, there do not appear to be any actual research programs of *Poa* control at this time. The most

useful contact for updating this statement is: Mark Heitlinger, Midwest Regional Office, The Nature Conservancy, 1313 5th St., S.E., Minneapolis, MN 55414. (612) 379-2207.

Management Research Needs:

There is a need for more accurate documentation of the phenological stage of both *Poa* species at the time of burning. Results in the present literature are confounded by a terminology that refers to "early" and "late" spring burns or gives dates without reference to stage. Specifically, it might be useful to compare the effects of burns while the flowering heads are "in boot" (enclosed within the sheath) with burns after the flowering head has begun to elongate.

There is a need for research that specifically addresses the hypothesis that native cool season grasses may have a competitive advantage over *Poa* going into the winter after fall burning (Steuter pers. comm.). Because the preliminary results of fall burns are inconsistent (Kruse pers. comm., Steuter pers. comm.), such research needs to be conducted at more than one location and under a variety of site conditions.

There is also a need for research to determine the effects of spring burning on overall diversity of native species in areas where this management technique appears to be effective as a tool for conversion of dominance from *Poa* to native warm season grasses.

Some specific research questions that need experimental testing include the following:

Does burning *Poa pratensis* when culms are at the boot stage favor tillering over rhizome development? Can stands of bluegrass be weakened by progressively favoring short-lived tillers over long-lived rhizomes? Does fall burning on sites with cool season native grasses give these natives a better competitive advantage over *Poa* as contrasted with spring burning? Can an 18 month cycle of alternating spring and fall burns on a mixed northern prairie mosaic with both cool and warm season natives optimize competitive advantage to both native guilds compared with either spring or fall burning?

What is the threshold frequency or percent composition of big bluestem that promises effective shift of dominance from *Poa* to warm season natives by spring burning? Is it true that the competitive presence of warm season natives overrides other influences such as climate and topography? What is the effect of management strategies that favor dominance by warm season native grasses on the frequency and reproduction of both cool and warm season forb species?

What is the comparative effectiveness of fall vs. spring grazing as a tool for managing *Poa* in northern mixed prairie where cool season native grasses are important?

There is a need for a clear separation of *Poa compressa* from *Poa pratensis*, whatever the research question may be. At the moment the available data on *Poa compressa* are too spotty to provide a clear picture of either its biology or its response to management. *Poa* is often lumped with *Bromus inermis* in the rangeland management literature and the

response of "cool season exotics" is reported. The biological literature suggests that these two genera are not equally responsive to management on the same dates. There is a need for separate research on the response of these two genera in order better to understand how to optimize their management.

VII. ADDITIONAL TOPICS

VIII. INFORMATION SOURCES

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