PROBLEMS IN ESTABLISHMENT AND MAINTENANCE OF MIXED SWARDS

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ABSTRACT
Most of the world's humid grasslands consist of mixed species swards which are harvested by grazing animals. Managing mixed swards to maintain the desired species is often difficult as perennial pastures tend toward biologically diverse communities over time, a result of genetic shifts in populations, competition, grazing frequency and intensity, and the environmental stress factors, temperature, water, soil fertility, pH, and pests. Maintaining legumes in mixed swards is a problem since cultivars of most species are ill suited for pasture and generally are short-lived, necessitating frequent replanting. Since grasslands are extremely dynamic and responsive to environmental stress, various management strategies are used to deal with the problems of mixed species swards. These include controlled grazing methods, growing and grazing different species as monocultures, fodder tree legumes with grasses, or simply grazing a grass-N monoculture. New approaches are needed in forage improvement where selection is done on the basis of method of utilization and general growth environment to improve tolerance to grazing, competition, unfavorable soil conditions, and pests.

KEYWORDS
competition, environmental stress, grazing tolerance, legumes

INTRODUCTION
Annual crops such as rice (*Oryza sativa* L.), maize (*Zea mays* L.), or cotton (*Gossypium hirsutum* L.), are maintained as monocultures by removing weeds culturally or with herbicides. Forage production of mechanically harvested species such as alfalfa (*Medicago sativa* L.) or hybrid bermudagrass [*Cynodon dactylon* (L.) Pers.] are also often grown as monocultures. However, the vast majority of the world's grasslands consist of mixed species grazed by livestock. Commonly, arid and semi-arid grasslands consist of many species. Intentionally or not, perennial grasslands in humid climates also consist of several grass, legume, and weed species. Establishing and maintaining a desired species mix in humid climate areas often results in problems for the pasture manager. This paper discusses some of these problems, why they occur, and possible solutions.

MIXED GRASSLAND SWARDS - WHY?
Mixed swards may offer special advantages or they may be simply a result of specific management or favorable environmental conditions.

(1) Complex ecosystems are often thought to be more efficient than simple ones and more productive than pure stands. In cold winter areas, the yield advantage of a mixed sward, such as planting a cool season perennial grass with alfalfa, may be relatively small (Chamblee and Collins, 1988). However, mild winter regions with year around rainfall allow seasonal changes of both C_3 and C_4 species dominance to permit increased yields over that of a monoculture (Hoveland, 1992). The different thermal responses of the C_3 and C_4 species in a mixture allow better utilization of the climate, resulting in higher productivity (Pearson and Ison, 1987).

(2) A legume planted with a grass can improve the nutritive quality of the forage consumed by livestock and provide nitrogen (N) to the pasture ecosystem (Hoveland, 1989).

(3) In many areas, the productive pasture season can be extended by adding a cool season grass and/or legume to a perennial warm season grass (Ball et al., 1996).

(4) A legume or another grass species can be added to dilute the toxic effects on livestock of a grass such as tall fescue (*Festuca arundinacea* Schreb.) or perennial ryegrass (*Lolium perenne* L.) infected with a fungal endophyte (Stuedemann and Thompson, 1993).

(5) The livestock bloat hazard of many legumes can be greatly reduced by maintaining grasses in the sward (Ball et al., 1996).

(6) Perennial forage species rarely remain monocultures and are often invaded by other species, especially when grazed, with the amount of invasion depending on environmental stress and management (Briske, 1989).

PROBLEMS IN ESTABLISHING AND MAINTAINING MIXED SWARDS
Prepared land. Establishment covers a sequence of events including seed imbibition, germination, emergence and competition with its neighbors. Successful establishment depends on viable seed, proper seeding depth, seedbed tilth, adequate nutrients, and favorable temperature and moisture. Soil obstruction by crusting can be a significant factor in seedling mortality, a problem that increases at lower latitude areas having high intensity rains, high temperatures, and low soil organic matter. Generally, the technology is available for successful establishment of forages in prepared seedbeds of humid areas and failures are a result of unfavorable weather, weeds, or poor planting methods. Clement (1996) concludes that there is little opportunity for profitable research on operational aspects of pasture establishment as it is a mature technology.

Generally, establishment of one legume and one grass species on prepared land is often difficult because a herbicide cannot be used, thus insuring that there will be a significant weed component. Allelopathy by weeds and forage plants may reduce germination and establishment of desirable planted species (Smith and Martin, 1994). Intense competition for scarce resources occurs in pastures. The growth rate of species changes during consecutive phases of development but the rate of change differs among species (Laude and Swanson, 1942). Therefore, the advantage of one species over another in a mixture may change with developmental phase.

A special situation with intense competition exists when a companion crop is planted with alfalfa. Over 60% of the area sown to alfalfa in the northern USA and Canada is planted with a companion cereal crop to reduce risk of soil erosion, suppress weeds, and provide a useable crop during the establishment year (Tesar and Marble). A companion cereal crop results in greater alfalfa mortality and this is increased in dry years (Simmons et al., 1995). Harvesting a barley (*Hordeum vulgara* L.) or oat (*Avena sativa* L.) companion crop at an immature stage for forage rather than at grain stage can overcome alfalfa stand losses (Brink and Marten, 1986). Early-maturing annual ryegrass (*Lolium multiflorum* Lam.) cultivars are less competitive than cereals with alfalfa, especially under dry conditions (Sulc et al., 1993; Sulc and Albrecht, 1996).

No-till planting.
Planting a grass or legume into an established grass sod poses a special challenge as small seedlings must compete with mature plants. Since cool season perennial grasses continue to grow after no-till seeding a legume, it is important that the sod be closely grazed or

mowed to reduce competition. Sod suppression with a herbicide is an effective method for reducing competition to the new grass or legume seedlings. In the case of perennial warm season grass sods such as bermudagrass, establishment of cool season annual species can be successful when seeding is done after cold weather results in dormancy of the grass sod. Close grazing of these grass sods is essential in mild winter areas or grass growth will reduce stands of early emerged seedlings of annual clovers (Evers et al., 1988).

Pasture species stability.

Established perennial pastures are unstable with respect to species composition (Snaydon, 1978). This instability is due to plant competition, environmental stress, and grazing. Genetic changes over years within populations of pasture species occur as surviving plants have a best-fit relationship with management and environment. With all of these factors, it should not be surprising that it is often virtually impossible to maintain a particular balance of one grass and one legume in a pasture over a number of years. This problem is not serious where a system of short-rotation pastures are used with arable crops, but it becomes apparent in permanent pastures where stability is dependent on species adaptation to the environment. Perennial pastures under continuous stocking over time tend toward biologically diverse communities with a wide range of species.

Genetic changes within populations of pasture plants contribute to substantial shifts in pasture swards. This may be quite rapid in winter annual species where differences in temperature or photoperiod at various locations may result in shifts in flowering date and winter dormancy (Hoveland and Johnson, 1967).

Long-lived perennial grasses are often thought of as relatively stable. This is generally true in the case of vegetatively propagated stoloniferous or rhizomatous species such as digitgrass (*Digitaria eriantha* Steud.), hybrid bermudagrass, and kikuyugrass (*Pennisetum clandestinum* Hoehst. ex Chiov.). However, with seed-propagated perennial cool season grasses, genetic composition of a pasture population can change appreciably within a few years (Charles, 1966). These changes can affect dry forage production, bloom date, plant height, leaf size, and tillering which in turn affect competitive ability.

Competition.

Competition plays a major role in determining the species composition of a pasture community. Donald (1963) has defined competition as “when each of two or more organisms seeks the measure it wants of any particular factor or thing and when the immediate supply of the factor or thing is below the combined demand of the organisms.” A large, aggressive plant or species as a result of rapid initial growth can secure more than its share of resources and will eventually dominate slower growing or smaller plants and the population (Harper, 1978). This natural competitive drive is modified by environment and management.

In their review, Turkington and Mehrhoff (1990) conclude that competition is important but only within the limits set by a variety of environmental/biotic constraints. Competitive ability and yielding ability of pasture plants are not necessarily related and there may be a negative relationship (Rhodes and Stern 1978). Thus, over time the more grazing-tolerant species within a community will acquire a greater proportion of the available resources (Briske, 1989). It is important to remember that features of agronomic value such as forage yield are rarely ones that confer survival value (Donald, 1963).

Light is one of the most limiting factors in interspecies forage plant competition and the success or failure of a species is often determined by the grazing or cutting management. Individual leaf efficiency in light utilization differs greatly among species (Brown et al., 1966). However, this often means little in a mixed species sward as the amount of light received by an individual leaf is affected by one leaf shading another. The most successful plant species are those which have their foliage in an advantageous position relative to the foliage of its competitors for light (Haynes, 1980). For example, those plants growing at the top of the canopy intercept a disproportionate quantity of light on the basis of leaf area. Maintenance of legumes with grasses in a pasture can often be ascribed to successful management of light to favor legume species. When moisture and nutrient levels are favorable, infrequent defoliation may result in shading of clover and competitively suppressing it (Harris, 1990).

Environmental stress.

Factors such as high or low temperature, drought or flooding, low soil fertility, soil acidity, and nematodes contribute to instability in pasture species composition. Even though only one or two species are planted, invading species can often dilute the sward in a short time when stress factors are especially severe. When soil fertility declines, tolerant species may invade and eventually dominate the sward as is the case with bahiagrass (*Paspalum notatum* Flugge) encroachment of hybrid bermudagrass (Rouquette et al. 1994). Grasses compete more strongly than legumes for K, giving them a competitive advantage when this element is limiting (Hunt and Wagner, 1963). Likewise, increasing soil acidity will favor grasses over cool season legumes (Buxton, 1989).

Changes in rainfall patterns affect species composition such as with white clover (*Trifolium repens* L.) being abundant in cool season grass pastures during wet years, but sparse during dry years. The shift in dominance of one species over another in response to rainfall changes is well illustrated in transition zones where both warm season and cool season perennial grasses are important components of the sward. In the southeastern USA transition zone, tall fescue will dominate a pasture mixture during a wet year, while in a dry hot summer, bermudagrass will be more abundant (Ball et al. 1996).

Grazing management.

Varying the stocking rate or rotational stocking can modify the botanical composition of a pasture, a result of selectivity by the grazing animal, treading, excretion, and competition among pasture plants (Watkin and Clements, 1987). Successful maintenance of desired species in a mixed sward is dependent on a defoliation strategy that favors the most easily damaged component. Frequent cutting or frequent close grazing of an alfalfa-cool season perennial grass mixture will rapidly result in dominance by the grass (Hoveland, 1996). In contrast, cutting or rotational grazing of a mixture to allow a 4- to 5-week rest period will generally result in alfalfa dominance. However, differences in tiller density among grass species can greatly affect the degree of competition with alfalfa (Pearen and Baron, 1996).

Extremely aggressive rhizomatous warm season perennial grasses such as bermudagrass will invade continuously stocked alfalfa pastures, especially at higher grazing pressure (Bates et al., 1996). In contrast, alfalfa will dominate an alfalfa-bermudagrass mixture under a hay-cut system (Brown and Byrd, 1990; Stringer et al., 1994). In this case, alfalfa with adequate root carbohydrates has rapid regrowth after cutting and shades out the light-starved bermudagrass. Generally, rotationally stocked pastures tend to have fewer numbers of species than continually stocked pastures (Pearson and Ison, 1987). Rotational stocking also is needed to maintain productivity and stands of species that are less tolerant of close continuous grazing such as alfalfa or endophyte-free tall fescue (Hoveland, 1996; Hoveland et al., 1997a).

WHY DO WE HAVE SO MANY PROBLEMS IN ESTABLISHMENT AND MAINTENANCE OF MIXED SWARDS?

Establishment and maintenance of several grass species in a mixed sward may result in some problems but it is infinitely easier to do than to grow a stable legume-grass population. Burton (1986) concluded that lack of persistence is the greatest weakness of perennial forage legumes in the USA. Thus, it may be useful to focus on the problems of grass-legume swards. It has been said that legumes are intruders in grasslands. In natural grasslands they constitute a minute amount of the vegetation or they may be absent. Unless legumes are unpalatable woody species, they are difficult to grow and maintain in mixtures. Yet, we insist on growing them for their N-fixation and high nutritive quality. A sward consisting of 15-20% legume species is considered a success. Some legumes are more easily managed when grown in a monoculture and cut or grazed. Although grass-legume mixtures may be quite successful in experimental plots, farmers often find legumes undependable in pastures. Why do farmers experience so many problems in establishment and management of legumes in mixed swards, even when they use good grazing management?

(1) Most soils already have a large seed or vegetative bank of vigorous well-adapted species (weeds) that can germinate and compete well when we make conditions favorable for our desired species. These “weeds” are often more tolerant of soil, pest, and drought conditions that are unfavorable for the legume species. Generally, annual weeds develop more rapidly than perennial forage legume seedlings.

(2) Most legumes are not very competitive with grasses in a grazed environment. The generally shallow root systems of many legume species are inferior to perennial grasses allowing them to be competitive and make substantial growth only under conditions of high available water (Pearson and Ison, 1987). Except for white clover, the morphology of most legumes is inferior to that of grasses for frequent close defoliation by livestock. Siratro (*Macroptilium atropurpureum* (DC.) Urb.), a viney tropical legume, initially appeared to have a bright future in Australia and was widely planted, but failed because it could not tolerate farm grazing pressures (Humphries, 1990). Adding to the problem, most forage legumes are more susceptible than grasses to pests. Disease outbreaks destroyed large legume-grass farming areas of stylosanthes (*Stylosanthes humilis* Kunth) in Australia (Clements, 1996). Often, virus diseases are responsible for weakening perennial legumes and making them less competitive with grasses.

(3) The forage plants that we attempt to grow have often not been selected for pasture use (Bouton et al., 1997). In mixed grass-white clover swards, clover expansion and persistence differs greatly depending on whether it is clipped or grazed (Edwards et al., 1996). The majority of pastures are planted on land not well adapted for arable crops. It is poorer land that may have acid soils, low fertility, imperfect drainage, or droughty soils. Forage plant cultivar improvement has overwhelmingly centered on yield improvement, a desirable objective for conserved forage, but often of less importance for pasture. Until recently there was little emphasis on selection for tolerance to grazing, acid soil, or low P. Cultivars have been selected for high yield with mechanical harvest on good soils.

Intermediate-leaf types of white clover have been more persistent than long-leaf ladino types in grass swards when grazed closely and are being selected for pasture use (Bouton and Hoveland, 1996; Brock, 1988; Caradus and Williams, 1989; Clark and McFadden, 1997). Although most red clover (*Trifolium pratense* L.) in the USA is planted for grazing, none of the commercial cultivars have any tolerance to close continuous grazing (Bouton and Hoveland, 1996). Alfalfa grazing tolerance at one time was thought to be related to low-yielding creeping rooted types. However, selection of hay-type cultivars under close continuous grazing for several years has resulted in high-yielding, grazing-tolerant alfalfa (Bouton et al., 1993).

Legume cultivar selection has generally not been done in competition with the grass species with which they will be used. Grass species differ in their competitive ability (Rumbaugh and Pedery, 1990; Sheaffer et al., 1990). Generally, perennial warm season grasses are much more competitive than the cool season grasses with associated legumes (Clements, 1989). Tall fescue is more aggressive than perennial ryegrass with white clover (Crush and Campbell, 1993). Likewise, tall fescue is more dominant than other cool season perennial grasses with no-till planted alfalfa (Hoveland et al., 1997a). Interestingly, fungal endophyte (*Neotyphodium coenophialum* (Morgan-Jones & W. Games) Glenn, Bacon & Hamlin) infection has no effect on tall fescue competition with alfalfa.

(4) In transition zones between true temperate and subtropical areas, the greater stress tolerance of perennial stoloniferous and rhizomatous warm season perennial grasses give them a competitive advantage over associated perennial cool season grasses and legumes (Hoveland et al., 1997b). Nematodes may be abundant in these soils, severely damaging roots of the more susceptible cool season species. Subsoil acidity, combined with aluminum toxicity in many areas, limits roots of cool season grasses and legumes to a greater extent than the more tolerant warm season species. Consequently, warm season perennial grass species have a marked advantage over cool season grass cultivars, selected on favorable soils in the absence of competition.

POSSIBLE SOLUTIONS TO THE PROBLEMS IN MIXED SWARDS

Managed grasslands are extremely dynamic, changing rapidly in response to rainfall, temperature, soil fertility, cutting, and grazing. With harvested grasslands, particularly in temperate climates, farmers often manage to maintain a desirable balance of species for several years with substantial inputs of fertilizer and pesticides. With pastures, it is different. Grazing animals introduce heterogeneity in a pasture as they selectively defoliate, urinate, defecate, scratch, paw, walk, run, and lie on the plants (Harper, 1978). All of this creates high unpredictability and fluctuating environments in a mixed species pasture. With all this variation, it is no wonder that heterogeneous populations are more likely to be successful than genetically uniform cultivars that are selected to be successful in closely managed environments (Snaydon, 1978).

Rotational stocking.

Rotational stocking can reduce sward variation by rapidly removing a large amount of forage and then allowing a controlled recovery period (Chapman and LeMaire, 1993). Control of defoliation frequency and severity is more difficult in continuously stocked pastures. Endophyte-free tall fescue does not persist long in association with bermudagrass when continuously stocked. However, rotational stocking successfully maintained endophyte-free tall fescue in bermudagrass pastures when grazed year around by beef cattle (Hoveland et al., 1997b). Likewise, rotational stocking offers an opportunity to favor persistence of alfalfa in mixed grass pastures.

Tree legumes in pastures.

Another approach to dealing with the problems of managing grass-legume mixtures is to grow a fodder tree legume in a grass pasture to supply high quality legume leaves to the grazing livestock and nitrogen to the associated grass understory. The success of leucaena (*Leucaena leucocephala*) in Australia suggests that this legume tree offers promise in other tropical regions (Wildin, 1993). The ornamental tree legume, mimosa (*Albizia julbrisin* Durazzin), offers the advantages of high-quality leaves for grazing, greater cold tolerance, and without the toxic properties of leucaena (Morrison and Bransby, 1997). Willow (*Salix* spp.) also shows promise as a grazing plant because of the leaf nutritive value (Douglas et al., 1996).

Grass-nitrogen pastures.

Many farmers in stressful environments have abandoned the practice of incorporating legumes into grassland because of poor legume persistence and greater management problems. Very simply, it is much easier to manage an all grass pasture system sustained with fertilizer N (Humphries, 1990). Overall productivity of grass-N pastures is more consistent and dependable than grass-legume pastures in stressful environments (Hoveland, 1989). This is especially attractive in areas where large amounts of poultry, swine, or cattle manures are available at relatively low cost. In addition, control of broadleaf weeds with herbicides is feasible since susceptible legumes are not part of the pasture ecosystem.

Pasture cultivar improvement.

Long-term, progress in improved persistence of grass and legume species in mixtures will depend on selection of cultivars under conditions in which they will be used (Hodgson, J. 1981). Van Keuren (1961) concluded that yields of orchardgrass (*Dactylis glomerata* L.) strains grown alone and harvested at pasture stage were not a reliable method of predicting yield of the grass strains growing with a legume. Atwood and Garber (1942) recommended that selection of cultivars destined for mixtures should be done in the presence of other species. With so many cultivars destined to be used for grazing, it is highly desirable that selection of new cultivars be carried out under grazed conditions and in competition with forage species, including weeds, common to the area of adaptation.

There is evidence that surviving perennial ryegrass genotypes in closely grazed old pastures are more competitive than the original cultivar against weeds and associated species (Charles, 1972). Although legumes such as alfalfa, red clover, and birdsfoot trefoil *(Lotus corniculatus* L.) depend for their survival on plant crowns and tap roots rather than stolons or rhizomes, it is apparent that there is potential for selection of more grazing-tolerant types (Bouton et al., 1993; Caradus and Williams, 1989; Clements, 1989). Stoloniferous red clover and rhizomatous birdsfoot trefoil offer further possibilities to be more grazing-tolerant and competitive in mixtures than current cultivars (Beuselinck et al., 1996; Smith and Bishop, 1993). Harris (1990) sums it up well in his conclusion that “A key adaptation of all persistent pasture plants is the ability to withstand grazing.” Greater attention to this, along with more disease tolerance would be of great benefit in improving legume persistence and assisting in management of mixed species swards.

SUMMARY

Intentionally or not, perennial grasslands in humid climates often contain a number of grass, legume, and weed species. The task of the farmer is to manage grassland, by cutting or grazing to economically convert it into animal product, while maintaining a sustainable mixed species ecosystem. Perennial grasslands are dynamic and responsive to environmental stresses, grazing pressure, and climate. Inputs of fertilizer, lime, herbicides, and controlled grazing can assist in stabilizing the composition of mixed swards. However, legumes are generally the weakest component in grazed grasslands and most difficult to maintain. There is a great need for improved legumes that are tolerant of competition, grazing, and environmental stresses to make them more attractive for practical use in mixed species swards.

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