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Grass Interplanting in Horticulture Cropping Systems

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Of the 5000 grass species identified worldwide, more than 1400 may be found in the United States (17). The potential benefits of interplantings in horticultural crops justifies the effort to identify the most appropriate grasses for this practice. Grass interplantings are used to reduce erosion, increase water infiltration into the soil, improve traffic-carrying ability, improve soil structure, limit weed invasion, moderate soil temperatures, and reduce soil contamination of crops. Disadvantages in using grasses for interplantings include increased competition for water and nutrients, harborage of pests, and expense of establishment and maintenance.

Desired characteristics of grasses for horticultural interplantings include low growth, fast germination and cover, dense and weed-resistant cover, drought and shade tolerance, and wear-resistance. Turfgrasses often exhibit more desirable characteristics for horticultural crop interplantings than cereal and forage grasses. Disadvantages of cereal and forage grasses include a tall, upright growth habit and the fact that many are annuals. Occasionally these characteristics may be desirable, and cereals and forages may be used for interplanting.

The success of grass in interplantings depends upon satisfaction of its environmental requirements. Based upon temperatures for most-active growth, turfgrasses are divided into 2 broad groups. Cool-season turfgrasses have a temperature optimum of 16° to 24°C while those with an optimum of 27° to 35° are warm-season (3). Also, the latter become dormant and top growth turns brown at temperatures near freezing.

Cool-season turfgrasses, such as Kentucky bluegrass (*Poa pratensis* L.), fine fescue (*Festuca* spp.), and tall fescue (*F. arundinacea* Schreb.) are grown as interplantings across the northern two-thirds of the United States and into Canada. The zone of adaptation for warm-season turfgrasses, such as bermudagrass (*Cynodon* spp.) and zoysiagrass (*Zoysia* spp.), is primarily the southern one-third of the United States. There is a transition zone of varying width across the United States in which both cool- and warm-season turfgrasses are common. This zone has a climate not especially suited for either warm- or cool-season turfgrasses, and weed problems are frequently serious because of poor turfgrass performance. There are, of course, some major exceptions to the typical pattern of occurrence of warm-season grasses in the south and cool-season grasses in the north. For example, buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], a native warm-season grass of the High Plains in the United States, may be found growing from Mexico to near the Canadian border.

Selection of the most appropriate grass for interplanting requires consideration of numerous characteristics. In some instances, a blend (cultivars of the same species) or mixture (a combination of 2 or more species) of grasses may be needed to offset problems such as the lack of tolerance of buffalograss (when used as a monoculture) to heavy shade. A review of some of the more important characteristics involved in selecting grasses for interplantings will follow. One or 2 of the traits enumerated will likely be given high priority on any site. Only the more common turf and forage grasses are mentioned, and there may be other grasses of equal or greater value in meeting local needs.

Rate of establishment

A major concern when choosing grasses for interplanting is ease of establishment. Seeds of many commonly grown cool-season turf and forage grasses are readily available. Warm-season grasses, such as St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] are established almost totally by vegetative plantings, while others, such as Japanese lawngrass (*Zoysia japonica* Steud.), centipedegrass [*Eremochloa ophiuroides* (Munro) Hack.], common bermudagrass [*Cynodon dactylon* (L.) Pers.], bahiagrass (*Paspalum notatum* Flugge.), and carpetgrasses (*Axonopus* spp.) may be established by seed or vegetatively.

Rapidity of germination and initial growth (seedling vigor) of a grass is exceedingly important for erosion and weed control and for equipment access. Erosion is often severe in the tropics and subtropics, and rate of establishment of a cover can be of primary concern. Conditions needed for success in seedling establishment are vigorous (adapted) seedlings and a favorable environment (24). Grass seed may germinate in a few days or it may take several weeks or months. Pregermination of seed before planting may speed establishment. Turf and forage grasses usually require only a few days to germinate with good growing conditions. For instance, annual ryegrass (*Lolium multiflorum* Lam.) germinates in 5–8 days, red fescue (*F. rubra* L.) 5–12 days, tall fescue 6–12 days, and Kentucky bluegrass 6–30 days (22). Perennial ryegrass (*L. perenne* L.) planted in late summer and irrigated may emerge in 5 to 6 days. Many horticultural crops are row-, drip-, or furrow-irrigated, and establishment of interplanted grasses is given secondary consideration. Thus, germination may be greatly delayed and establishment poor.

Many commercially available, turf-type perennial ryegrasses are desirable for interplantings because of extremely fast germination and establishment rates and resistance to weed invasion (6). Range grasses such as buffalograss and another warm-season grass, blue grama [*Bouteloua gracills* (H.B.K.) Lag. ex Steud.], have desirable traits for interplantings, but can be quite slow to germinate and establish a cover under natural conditions.

Height and spreading characteristics

Tall growing grasses [e.g., smooth bromegrass (*Bromus inermis* Leyss.), orchardgrass (*Dactylis glomerata* L.), and timothy (*Phleum pratense* L.)] require frequent mowing, while low- and intermediate-height grasses (e.g., buffalograss, Kentucky bluegrass, and zoysiagrass) may need only infrequent cuttings for weed control or to reduce fire hazard. Tall-growing grasses are likely to attract rodents and shelter them from predators unless maintained at a low height. Mice prefer vegetation about 30 cm high (7).

Grasses used for turf are selected for low growth and they are maintained to keep a low sward. Forage grasses are normally tall-growing grasses selected and used for high production of topgrowth. Characteristic seed head heights for representative warm- and cool-season turf and forage grasses under good growing conditions are buffalograss (10–20 cm); bermudagrass (15–30 cm); Kentucky bluegrass (20–75 cm); hard fescue [*F. ovina duriuscula* (L.) Koch] and creeping red fescue (45–90 cm); perennial and annual ryegrass and fairway wheatgrass [*Agropyron cristatum* (L.) Gaertn.] (60–90 cm); and tall fescue (60–120 cm) (5). Most grasses under sod-bound conditions and especially under conditions of low maintenance will be near or below the lower heights.

Selecting and breeding low-growing turfgrasses has been an area of emphasis during the last 2 decades. For example, under sod-bound conditions, 'Baron' Kentucky bluegrass may have a mature height of about 10 cm compared to seed head height of about 45 cm for common-type Kentucky bluegrass. Turf-type (moderately low growing, with good density and cutting quality) perennial ryegrasses are widely considered for interplantings. There are numerous cultivars of perennial ryegrass commercially available. A few common cultivars, e.g., 'Linn', 'Noriea', and 'Pelo' are fast-growing with poor density, and would not be acceptable cultivars for interplanting under most circumstances (6).

Major advances have recently been made in reducing height and increasing the density of tall fescue. Generally, the new turf-types such as 'Rebel', 'Falcon', 'Olympic', and 'Mustang' would be preferred over the coarse-textured, open, and tall-growing cultivars (e.g., 'Alta', 'Kentucky 31', or 'Fawn').

Rhizome or stolon production that allows a plant to spread and fill voids is a desirable lawn grass characteristic. This spreadability can be a serious drawback in interplanting, often causing severe crop competition and harvesting problems. Sod-forming grasses planted at low seeding rates can provide a dense turf in only a few months under optimum growing conditions. Use of strong sod-forming grasses in horticulture crops may require frequent cultivation or herbicide use.

The slow spread by tillering of bunch grasses is desirable for most interplanting situations. Commonly cultivated cool-season turfgrasses, other than annual and perennial ryegrass and tall, hard, and chewings fescue (*F. rubra commutata* Gaud.) are sod-forming grasses. However, not all sod-formers spread rapidly. Bahiagrass spreads slowly by rhizomes, while bermudagrass is known for its rapid spread and weedy nature, especially in warm areas. Other bunchgrasses that may have occasional interplanting use are fairway and crested wheatgrass [*A. desertorum* (Fisch.) Schult.], blue grama, orchardgrass, and weeping alkaligrass [*Puccinellia distans* (L.) Parl.].

Root characteristics

Root characteristics of both interplanted grasses and horticultural crops are influenced by species, sunlight, pesticides, temperature, fertilization, irrigation, spacing, soil aeration, and mowing. Lower or more frequent mowing causes decreased rooting (22). Frequent mowing to control grass vigor has been found to be more effective for water than for nitrogen conservation (26). The fact that grasses extract nitrogen from the soil and reduce its availability can be incorporated in management objectives (20). Red fescue and bentgrass (*Agrostis* spp.) have been reported, on a deep clay soil, to extract available soil moisture to 30 cm, Kentucky bluegrass to 75 cm, tall fescue to 105 cm, and bermudagrass to a depth of more than 120 cm (16). Soil moisture may be removed from deep in the soil, but roots of both warm- and cool-season grasses concentrate near the soil surface. An average of 50% of the roots of dallisgrass (*Paspalum dilatatum* Poir.), bahiagrass, coastal and common bermudagrass, and sericea lespedeza (*Lespedeza cuneata* Don) were found in the upper 8 cm of a fine sandy loam soil, and 76% were in the upper 30 cm (8). In a 45-cm depth of a silt loam soil, smooth bromegrass had 55.7% of its roots in the top 8 cm, orchardgrass 81.6%, Kentucky bluegrass 88.4%, and timothy 89.6% (14).

A shallow-rooted turf can have nitrogen leached rapidly by irrigation or rainfall to below the root zone. However, a massive system of fibrous roots near the surface may impede leaching. Controlled irrigation to place nitrogen properly is thus required to optimize nitrogen use by the horticultural crop.

Water use and drought tolerance

Water use by grasses in interplantings is a factor that has restricted their use, especially in arid and semi-arid regions. Factors such as species, amount of vegetative ground cover, shade, and fertility levels influence evapotranspiration (ET). Research in the last few years (much of it using small, weighing lysimeters) has provided important information on water use by turfgrasses.

ET rates are generally higher for cool- than for warm-season grasses (4, 11, 21). For example, 'Tifway' bermudagrass (*C. dactylon* L. x *C. transvaalensis* Davy) and buffalograss used about 20% less water than 'Merion' Kentucky bluegrass and 'Rebel' tall fescue (11). In Colorado, the total water use (when the turf was watered to ensure 100% ET) for 4 cool-season turfgrasses in June, July, and Aug. 1983 was 585 mm for tall fescue, 541 mm for Kentucky bluegrass, 539 mm for perennial ryegrass, and 501 mm for fine fescue (24). In addition to the kind of grass grown, the amount of cover may influence ET. Grass grown in rows with 50% to 75% cover had higher ET rates than with full cover or bare soil (23). In another study (9), a full canopy of turfgrass with only 30% live biomass had an ET that was nearly 70% of a canopy with 100% live biomass. Also, the amount of water used by interplanted grasses may be greatly affected by the shade of horticultural crops. It has been demonstrated that water use may increase linearly with increase in incident radiation (10).

The persistence of grasses is important in arid and semi-arid regions when horticultural crops are supplied with drip or furrow irrigation. Various rankings of turfgrasses for drought resistance or tolerance have been presented (3, 13, 22). Recent work (25) indicates some of the more commonly used lawngrasses are more drought tolerant than previously thought. Also, as with other cultivars, cool-season turfgrasses differ in their capacity to recover from severe drought.

Bermudagrass, blue grama, and buffalograss may become more commonly used for interplantings in drier parts of the United States. Although such grasses may inhabit very dry sites and persist under extremely dry conditions, they will go dormant in the summer without rain (or if they are not irrigated every few weeks). Dormant turf may be unacceptable for interplantings because of lack of traffic tolerance and increased dust and fire hazard. To avoid sparse and rough ground cover often typical of bunch-type grasses, irrigation may be required during extended dry periods.

A few turfgrasses are considered to have good drought tolerance. These include fairway and crested wheatgrass, smooth bromegrass, and western wheatgrass (*Agropyron smithii* Rydb.). The latter 2 are strong rhizome-producing grasses frequently grown for revegetation of disturbed lands. 'Covar' sheep fescue (*Festuca ovina* L.), introduced from Turkey, is a bunch grass adapted to a mean annual precipitation of 2000–3600 mm (28).

Some of the grasses widely used for interplantings are considered to have only medium to fair drought tolerance. Among these are perennial ryegrass, Kentucky bluegrass, turf-type fine fescues, tall fescue, Canada bluegrass, timothy, and orchardgrass. These grasses may persist as sparse stands under semiarid conditions; however, irrigation is necessary to support suitable cover for most situations. Relative drought tolerances of turfgrasses have been established primarily by field observations. Rankings of 3 common cool-season turfgrasses indicate that red fescue is better than Kentucky bluegrass, and perennial ryegrass is poorer than either of these (3, 13, 22). However, withholding irrigation in the semi-arid climate of Fort Collins, Colo. during Summer 1982 and 1983, with irrigation provided in September for recovery, revealed the relative drought tolerance was perennial ryegrass > Kentucky bluegrass > fine fescue (including red fescue) (25). In this study (25), wide differences in cultivar tolerance to drought were observed. Among the cultivars that performed well under drought conditions were 'Majestic' and 'America' Kentucky bluegrass; and 'Aristocrat', 'Bellatrix', 'Citation', and 'Yorktown' perennial ryegrass. No fine fescues performed well, although some of the hard fescues did better than other fine fescues tested.

Heat and cold tolerance

In most instances, turfgrasses grown in their zone of adaptation will have both heat- and cold-tolerance that will exceed that of the horticultural crop being grown. There are, however, important exceptions that should be considered. In a listing (3) of the relative heat hardiness of 19 turfgrasses, the 6 that received excellent ratings were warm-season grasses and included zoysiagrass, bermudagrass, carpetgrass, and buffalograss. Bahiagrass should also be included in this category. In the same comparison, tall fescue, normally a good performer in the transition zone, was rated good (3). Three grasses including Kentucky bluegrass, were rated medium. Six, including Canada bluegrass, chewings fescue, and perennial ryegrass, were rated fair.

Some definitive work has been done on low-temperature hardiness of turfgrasses. In Colorado (15), cold hardiness was expressed as LT_{50}, or the lowest test temperature at which 50% or more of the crowns survived. Creeping bentgrass (*Agrostis palustris* Huds.) tolerated the lowest temperatures (LT_{50} at $-35°C$). In Michigan (2), creeping bentgrass and Kentucky bluegrass were considered to have excellent and good low-temperature hardiness, respectively. The cold hardiness (LT_{50}) of Kentucky bluegrass in Colorado ranged from $-21°$ for 'Merion' to $-30°$ for 'Windsor'. The limited cold hardiness of perennial ryegrass (2, 15) is a major concern, especially since it is widely used for interplanting. However, there is a wide range in cultivar hardiness: among 11 tested in Colorado (15), there was a LT_{50} range of 10°—'Common' at $-5°$ to 'Manhattan' and 'Diplomat' at $-15°$.

Warm-season turfgrasses have a wide variability in cold hardiness. Buffalograss has excellent cold hardiness; whereas bahiagrass and carpetgrass are considered to have poor cold hardiness (3). Bermudagrass exhibits poor cold hardiness, resulting in devastating losses in cold winters in the transition zone. Research (19) at Fort Collins, Colo. indicated that only one of 8 bermudagrass cultivars would survive a cold winter (soil temperature of 11.1°C); the one surviving bermudagrass was collected at Brookings, S.D.

Shade tolerance

Light reduction caused by tall-growing horticultural crops is an important consideration in choosing grasses for interplanting. The amount of light reaching the grass under horticultural crops depends largely on radiation intensity—a grass that does poorly in shade in the Pacific Northwest may do well in Colorado or Utah.

Some turfgrasses will tolerate dense shade. Rough-stalk bluegrass (*P. trivialis* L.) can perform well under cool, moist conditions. In dry soil, fine fescue usually has outstanding shade tolerance. Tall fescue, especially in the transition zone, does well in the shade. In California (29), 'Falcon', 'Houndog', and 'Rebel' tall fescue performed better under tree shade than 'Alta'. Perennial ryegrasses can have good shade tolerance. Kentucky bluegrass, in general, has only fair shade tolerance, but a few cultivars such as 'Bensun' and 'Nugget' have shown better shade tolerance than 'Park' (12). Bermudagrass and buffalograss have poor shade adaptation, whereas St. Augustinegrass and zoysiagrass have excellent and good adaptation, respectively (3).

Wear tolerance

The wear or traffic tolerance of grasses in horticultural crop interplantings can be quite important, especially in major thoroughfares and where crops are harvested on a daily basis. Specially designed equipment has been built to simulate wear damage for turfgrass research. One problem is that it is difficult to differentiate between wear injury and soil compaction effects. Performance evaluations under test conditions reflect both of these.

In a study (27) where wheel traffic caused wear injury, 'Manhattan' perennial ryegrass was most tolerant, 'Kentucky 31' and 'Merion' Kentucky bluegrass ranked 2nd, and 'Pennlawn' red fescue and annual ryegrass were intermediate. 'Cascade' chewings fescue and rough-stalk bluegrass ranked lowest. Wear tolerance can differ greatly between cultivars of a species. A comparison (1) of several Kentucky bluegrasses showed 'A-34' ('Bensun'), 'Merion', and 'Baron' to be superior, and 'Sydsport' and 'Campus' were particularly inferior.

In general, warm-season grasses are more wear-tolerant than cool-season grasses. Investigations in California (30) indicated that 2 zoysiagrasses (*Z. japonica* Steud. and *Z. matrella* L.) and 'Alta' tall fescue were the most wear-tolerant of the grasses tested. Except for 'Alta' tall fescue, the other 5 cool-season turfgrasses ranked intermediate to low. Bermudagrass and zoysiagrass will withstand heavy traffic, but the former will recover more rapidly after the surface cover becomes worn (18). Buffalograss, once well-established, will withstand traffic well, even when dormant.

Summary

Several of the grasses that are available for forage and turfgrass use are adapted for horticultural crop interplanting. Several low-growing, dense, and nonaggressive grasses that establish easily and tolerate environmental stresses associated with interplantings are available. For most situations, use of well adapted and widely used grasses in an area will assure success. Consideration of turf and forage grass performance in the area of use can enhance the chance of success with interplanted grasses.

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Legume Cover Crops for Improving Crop and Soil Management in the Southern United States

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Legumes were an important component of crop rotations in the southern United States before World War II. In the post-war years, however, inexpensive and abundant fertilizer N diminished the role of N-fixing plants in cropping systems. There has been little research since 1960 on winter legumes in terms of their contribution to soil and crop management. Recent escalated costs of fertilizer N manufacture and concern over soil erosion has renewed interest in legumes and their role in cropping systems. Winter legume cover crops may provide significant quantities of fixed N while conserving soil and water resources and sustaining or improving soil productivity. This review presents both old and new information on the role of legumes in improving soil and crop management, particularly in the southern United States.

ADAPTED LEGUME SPECIES

General characteristics

The southern United States has a long growing season and adequate rainfall; hence, there are many legume species adapted to this region (Table 1). The greatest success with winter legumes as cover crops has been obtained with vetch (*Vicia* spp.), crimson clover (*Trifolium incarnatum* L.), subterranean clover (*Trifolium subterraneum* L.), and field (winter) peas [*Pisum sativum* subsp. *arvense* (L.) Poir.]. Vetch may have some advantage over crimson clover in the upper South because of its cold tolerance, but the life cycle of the latter more nearly meets the growth requirements for a winter legume over most of the region. 'Tibbee' crimson clover is particularly well adapted for cover crop use. It produces abundant fall and winter growth, matures early, and has good reseeding ability. A winter-hardy selection of berseem clover (*Trifolium alexandrinum* L.) also appears to have potential for the region, but has not been evaluated widely. Subterranean clover has excellent reseeding ability, but does not produce as much biomass or N in most of the South as some other legumes. Austrian winter peas have been used extensively in the past, but are a host for nematodes and other pathogens, so use with some crops is restricted (2, 3).

Several legumes listed in Table 1 have restricted adaptation. Lupines (*Lupinus* spp.) (Table 1) are grown primarily in Florida and southern Georgia. Several new cultivars of common vetch released by Auburn Univ. are adapted to specific Coastal Plain areas. Rough peas (*Lathyrus hirsutus* L.) are grown on the clay soils of Alabama, Mississippi, and western Tennessee. There are also several annual species of *Medicago*, such as bur clover, button clover, and snail clover, that seem adapted to wet, clay soils in Louisiana and east Texas. These are not listed in Table 1 because their culture is limited.

Dry matter production and nitrogen accumulation

Older literature on dry matter production by winter legumes in the South is abundant (3, 15, 30). Total dry matter production in the lower South was generally in the order crimson clover > hairy vetch > winter peas. However, cultivars and cultural practices are quite different today than when these studies were conducted.

Recent results from Kentucky, North Carolina, and Georgia for dry matter production and N accumulation by several winter legumes (above-ground portion only) are shown in Table 2. These results were obtained at the time of planting subsequent crops and the legumes were generally in the bloom stage. Hairy vetch (*V. villosa* Roth) performed well at all locations. In addition, it contained N levels greater than or equal to most other legumes tested. In Kentucky, it produced more dry matter and accumulated more N than bigflower vetch (*V. grandiflora* Scop.) or crimson clover. In North Carolina and Georgia, it produced only moderate amounts of dry matter, but had high N content. Winter peas did well in North Carolina, particularly in the mountain region. Crimson clover is well-adapted and superior to most other legumes in the lower South.

Roots were not measured for the legumes listed in Table 2, but Mitchell and Teel (49) reported the top growth contained 80% to 90% of the total N. It is apparent from the data of Touchton et al. (64), however, that roots alone can make a significant N contribution to subsequent crops.

Nitrogen contribution to subsequent crops

Initial emphasis on work with legume cover crops occurred in the early part of this century by Pieters and McKee (55). They

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