THE EFFECTS ON RAPID ESTABLISHMENT AND SUBSEQUENT TURF QUALITY OF AGGRESSIVE GRASSES SEEDED WITH POA PRATENSIS L.

By

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Thesis submitted to the Graduate Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE
in
Agronomy

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May 1970

Blacksburg, Virginia

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ACKNOWLEDGMENTS

The author is indebted to for serving as chairman of his committee, outlining his graduate program, and making helpful suggestions throughout the study.

Special appreciation is also extended to and for the encouragement and helpful criticisms, as well as serving on the graduate committee. Gratitude is also extended to for helping with the computer analysis, to fellow graduate students for their suggestions, and to for typing the manuscript.

The greatest appreciation is expressed to the author's wife, , for her endurance and encouragement throughout the study and preparation of this manuscript.

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INTRODUCTION

The necessity for rapid turf establishment, with excellent subsequent turf quality in virtually every season of the year has created a challenge to turfgrass managers and researchers. One way to meet the challenge is by sod production and installation, but this is not always feasiable, especially with a limited budget.

Another approach to the problem of providing rapid coverage and a permanent high quality turf is that of mixing a species with Kentucky bluegrass that would quickly germinate, yet allow a gradual, uniform transition to pure bluegrass. Such mixtures could eliminate erosion, satisfy the people who judge turf by the rapidity that green grass appears, and provide high quality permanent turf.

For turfgrass species to be compatible in a mixture they should be able to withstand close, continuous mowing while providing a dense, uniform sod of high aesthetic value. Kentucky bluegrass provides an excellent high quality, persistent turf, but it is slow to become established. However, some turf species such as the ryegrasses germinate quickly and provide ground cover in a few weeks, but they may not persist; therefore, they are not generally recommended unless erosion is a hazard. NK-100 and Pelo are persistent perennial ryegrasses that germinate rapidly, and they tend to allow bluegrass encroachment when used in mixtures with them. Creeping red fescue is widely used in mixtures in the cool regions of the United States because of its shade tolerance and fine texture, but it does not germinate as rapidly as the perennial ryegrasses. Redtop germinates quicker than bluegrass, and if it makes up a substantial part of the mixture could increase the

initial cover; however, it is sometimes objectionable because of its wide, pale green leaves that show up with age.

With the above factors in mind, an experiment was conducted to determine the following objectives:

(1) To evaluate the rapidity of turf development when aggressive grasses were seeded with Kentucky bluegrass in fall, spring, and summer seedings; (2) to study the shift in botanical composition and turf quality with two mowing heights; (3) to measure sod strength and rooting ability of the various mixtures; (4) to determine if annual or perennial ryegrass excrete inhibitory substances that retard bluegrass germination and early growth; and (5) to determine if bluegrass yield is reduced when roots of annual and perennial ryegrass are grown in association with bluegrass roots in a soil media.

LITERATURE REVIEW

Turf Mixtures

Turf monocultures are generally more attractive than a mixture of several species. However, turfgrass mixtures provide for wide adaptation to soil and climatic conditions (Blaser et al., 1956; Blaser, 1963), more tolerance to pests (Beard, 1965), quick sod establishment (reduced erosion) and lower seed costs (Davis, 1967).

Turfs made of mixtures seldom have uniform texture, and the faster growing species tend to inhibit the slower growing, often the most permanent grasses. Few species are equally compatible to given managements (Erdmann and Harrison, 1947; Musser, 1962; Davis, 1967).

Because of the severe competition that certain grasses impose on the permanent grasses, some researchers (Juska et al., 1956) question the use of rapidly germinating species in mixtures.

Competition Among Species

Clements's definition of plant competition, as recorded by Donald (1963) states: "Competition never occurs between two plants as long as the nutrient material, the water content, the light, and the temperature are in excess of the needs of both. When the immediate supply of a single necessary factor falls below the combined demands of the plants, the competition begins." Competition in seedling communities is usually influenced by size of seed, rate of germination, and rate of development. Blaser et al. (1952) also stressed that seedling competition was a strong factor in later botanical composition.

Grasses which become dominant in mixtures are generally characterized by good adaptation to natural and imposed environmental conditions, excellent persistence during stress periods, and a rhizomatous or stoloniferous growth habit (Schmidt and Blaser, 1969).

In Ohio, a mixture of 60% creeping red fescue and 40% Merion bluegrass was essentially all Merion within one year after a September seeding (Davis, 1958). Also in Ohio, an initial seeding of 90% tall fescue and 10% Kentucky bluegrass gradually shifted to bluegrass when well fertilized (Miller, 1967). It was inferred that this botanical composition was altered by winter injury of fescue. In 1959, Juska and Hanson found that the best quality turf was produced by mixtures of 75% Merion bluegrass and 25% red fescue mowed at 1-3/4 inches.

Mixtures with domestic ryegrass included had least desirable appearance, with the poorest mixture being the one containing 90% Merion bluegrass and 10% ryegrass (Juska et al., 1956). Schmidt et al. (1967) reported that 20% by weight of annual ryegrass in a mixture inhibited bluegrass sod development and decreased ground cover and color relative to bluegrass seeded alone. However, 5% by weight of redtop resulted in better cover and color than bluegrass seeded alone.

Using dry matter as a criteria, Blaser et al. (1956) and Parks and Henderlong (1967) classified annual and perennial ryegrass as the most aggressive of the turf grasses studied. Creeping red fescue was considered nonaggressive by Blaser et al. (1956) and as intermediate by Parks and Henderlong (1967), and both groups considered Kentucky bluegrass and redtop nonaggressive.

When sown alone in greenhouse (Erdmann and Harrison, 1947) and in field experiments (Juska et al., 1956) annual ryegrass followed by redtop were first to germinate, and they made the fastest growth. Bluegrass growth was hindered when sown in mixtures of both grasses. Erdmann and Harrison (1947) found that annual ryegrass inhibited creeping red fescue and Kentucky bluegrass more than redtop. Juska et al. (1955) later showed that redtop was more competitive to Merion bluegrass than domestic ryegrass when seeded on equal weight basis. Although creeping red fescue hindered Kentucky bluegrass establishment (Juska et al., 1956), the inhibition was less than that with perennial ryegrass (Engel, 1961). Engel (1961) reported that Kentucky bluegrass was a very poor competitor in the first 8-12 weeks of seedling growth, and annual ryegrass was more competitive toward bluegrass than perennial ryegrass, and redtop was less competitive than either ryegrass. Kaerwer (1968) stated that NK-100 perennial ryegrass, in a mature sod, was highly compatible with Kentucky bluegrass.

Mowing Management

It is agreed that most cool season grasses generally persist best at 1-1/2 to 2-in. mowing heights. However, lower clipping heights are used to evaluate grasses for specialized turf, such as golf fairways (Juska et al., 1955; Davis, 1958; Younger, 1962; and Goss and Law, 1967).

Botanical composition of mixtures can be altered by height of mowing (Juska et al., 1955 and 1956; Davis, 1958; Schmidt and Blaser, 1969). Low clipping, 1/2-1 in., tends to aid creeping red fescue and

Kentucky bluegrass in their competitive relationship with more aggressive grasses such as redtop and ryegrass (Juska et al., 1956). Bluegrass and creeping red fescue were more resistant to invasion of bentgrass under a 2-in. mowing height than at 3/4 in. (Davis, 1958); also non-stoloniferous grasses were favored by 2-inch clipping height.

Engel et al. (1969), with a mixed Kentucky bluegrass-bentgrass-red fescue turf at cutting heights from 3/4 to 3 in. found: (1) bluegrass was most tolerant of severe intermittent defoliation and red fescue was least tolerant; (2) Kentucky bluegrass appeared more competitive at intermediate cutting heights (1-1/2 to 2 in.); and (3) species balance did not shift quickly with the varied mowing procedures.

Mowing also affects root development of several grasses as reported by Stapledon and Milton (1930), Crider (1955), and Juska et al. (1961). The rate of root initiation and extension was drastically reduced by intensive mowing (Frazier and Daniel, 1960).

It was observed that root growth stopped following removal of 40% or more of the foliage from forage species (Crider, 1955). Stapledon and Milton (1930) found tillering and root inhibition of Dactylis glomerata were directly associated with the severity of clipping. Turf clipped at two inches was more favorable for rhizome growth of Kentucky bluegrass than at 1 in. (Juska and Hanson, 1961), and 1-in. cutting was more favorable than 1/2 in. (Goss and Law, 1967). Lobenstein and Daniel (1962) found that three selections of bluegrass clipped at 3/4 in. produced 62% less rhizome growth and 52% fewer crowns than at 3-in. clipping, but the number of tillers per crown were not altered significantly by clipping height.

Cool season grasses cut at 1/2 in. were significantly lower in wear resistance than those cut at 2 in. (Younger, 1962), but turf quality scores were better for 2-in. clipping as compared to 1 in. (Juska and Hanson, 1961).

Seeding Seasons

Blaser (1963) proposed that mixtures be altered for different seeding seasons due to seasonal changes in microclimate, soil, and biotic factors. Davis (1967) emphasized that Kentucky bluegrass was slower in germination and growth rate than ryegrass, redtop, or creeping red fescue, especially in a spring seeding.

Frazier and Daniel (1960) acknowledged that the best germination of Merion bluegrass, red fescue, tall fescue, and bentgrass occurred at the most favorable temperature for continued growth, which would presumably be in spring and fall. The optimum temperature for germination varies with species from 20-90°F (Koller et al., 1962). Species showing marked depression of germination by low temperatures (40-50°C) would not appear to be suited for very early spring sowings in the field (Chippindale, 1949).

The optimum germination of Pelo ryegrass and Park and Merion bluegrasses occurred at 75-65°F day-night temperatures (Henderlong, 1970). Sprague (1943) observed a reduction of Kentucky bluegrass germination at 70-85°F when compared to lower temperatures. Competitional effects are greatly increased where species with differential temperature requirements are sown together (Chippindale, 1949).

Blaser et al. (1956) found that Italian ryegrass, perennial ryegrass

and red fescue were 2.2-2.4 times as vigorous when seeded in March as in August. The growth rates of redtop and Kentucky bluegrass were 1.5 and 4.5 times as great in March as in August. Of the turf-type grasses studied by Blaser et al. (1956), Kentucky bluegrass appeared to be hindered most by August seeding and redtop least. These researchers attributed the differential response in growth to the variable temperature and moisture status during March as compared to August. The low soil and atmospheric temperatures along with high soil moisture during the spring season were more favorable for the cool season grasses than the high temperatures and low moisture of the August seedings.

Composition of mixtures containing bluegrass and ryegrass, six weeks after fall and spring seeding, revealed less bluegrass in the spring seeding; and Keckley (1969) contended that it was an indication of more competition from ryegrass during spring season.

Morrish and Harrison (1948) reported that the April seedings produced excellent coverage in Michigan, regardless of mixture or seeding rate, and that June seedings were poorest. Domestic ryegrass produced the quickest cover of the June seedings. The August seedings of bluegrasses and fescues produced a much better cover by September than similar seedings made in June. Mixtures with domestic ryegrass or redtop tended to dominate the more desirable species in the early stage of growth, and establishment of turf cover was better when the more permanent species were seeded alone.

After a four-year period, Park bluegrass provided better coverage than Kentucky bluegrass, and Davis (1958) attributed the difference to

time of seeding. Park bluegrass was seeded in April and Kentucky bluegrass was seeded in September.

Root and Tiller Development

Tillering is of considerable importance to some grasses as a means of lateral spreading and increasing their size (Soper and Mitchell, 1956; Musser, 1962; Daniel and Roberts, 1966; Hanson et al., 1969).

In Rhode Island, (Stuckey, 1941) new tillers developed very quickly after seedlings became established, especially on Kentucky bluegrass and perennial ryegrass.

Langer (1963) stated that optimum temperatures for tillering differed with genotype, and Mitchell (1956) recorded tillering to be rapid at 55 and 64°F in perennial ryegrass and 64 and 73°F in short rotation ryegrass. Henderlong (1970) declared that new tiller initiation of several cool season grasses was generally greater at rather high temperatures (90-80°F day-night), whereas total root development was favored by a lower temperature (60-50°F).

Peterson and Lommis (1949) found that short days increased the tillering rate of cool-season grasses; therefore maximum tillering of most turf species would take place during early spring and late fall. Jacques and Schwass (1956) discovered seasonal trends in tiller numbers of Italian ryegrass, perennial ryegrass, and tall fescue with an appreciable reduction of tillers and roots of Italian ryegrass during the summer.

Excellent sod production depends on rhizome formation, and rhizomes are of immense value for spreading into vacant areas. If seedings could be made in seasons favorable for rhizome production, dense sod could be obtained more rapidly.

Brown (1939) observed that Kentucky bluegrass rhizome formation was encouraged by high temperatures, and Wakins (1940) acknowledged that the maximum number of rhizomes were produced under normal day length in late spring or summer. Hanson and Juska (1961) also observed that Kentucky bluegrass produced very few rhizomes from September to April.

In general, root development is favored by cool temperatures, high light intensity, and short to medium day lengths (Soper and Mitchell, 1956; Hanson and Juska, 1961; Henderlong, 1970). Stuckey (1941) recorded maximum root growth at soil temperatures of 50-60°F and a ceasation at 80°F. Beard and Daniel (1965) contended that root growth rate of creeping bentgrass was no different at 60, 70, and 80°F, but was reduced at 90°F; however, the total amount of roots decreased as temperature increased.

Several researchers have noticed a retardation in root growth from June till October, with maximum root and tiller growth occurring during spring (Stuckey, 1941; Juska and Hanson, 1961). However, roots of Merion bluegrass, red fescue, tall fescue, and bentgrass were generally more vigorous in fall than in spring (Frazier and Daniel, 1960).

Stuckey (1941) classified root systems of Kentucky bluegrass as perennial and redtop, meadow fescue, and perennial ryegrass as annual

root systems.

Sod Development

The vigorous rhizome development of Kentucky bluegrass plus its broad adaptation to cool, humid environments are principle reasons for its wide use in the sod industry (Beard and Rieke, 1969). Without rhizomes, Kentucky bluegrass sod is easily torn (Daniel and Roberts, 1966); therefore rhizome or stolon development is considered as a critical factor in both sod strength and rooting capabilities (Beard and Rieke, 1969).

Rieke et al. (1968) developed a device to obtain an estimate of the contribution of roots and rhizomes to sod strength. Sod strength was recorded as the weight required to tear a sod piece at the interface of a mobile and a stationary platform. Dunn and Engel (1970) used a device that allowed them to determine rooting ability by pulling a piece of sod horizontally from the soil surface, and they equated rooting ability to resistance to shear. King and Beard (1969) constructed a block and tackle technique where the vertical pulling force measured the root development of a recently sodded turf.

Nature of Natural Plant Inhibitors

There is a vast amount of literature on the subject of biological inhibitors, and several investigations have shown that the development and activity of seeds and seedlings may be affected by the metabolism of neighboring species (Loehwing, 1937; Bonner, 1950; Woods, 1960). Loehwing (1937), in a review on the effect of plant extracts and

exudates on germination and growth, concluded that literature did not provide evidence of soluble toxic substances in any normally aerated soil. Bonner (1950), in a review of the literature, suggested that evidence of substances affecting the growth of other plants did exist, and that the association or non-association of different species as a result of specific chemical compounds secreted by them may, therefore, be of common occurrence.

Ahlgren and Aamodt (1939) presented data that indicated that harmful root interactions may occur between various species of pasture grasses and legumes, including Kentucky bluegrass. Bonner and Galston (1944) found that substances unfavorable for the growth of guayule plants emanate from the roots of actively growing plants of this species.

Osvald (1949) reported that grass exudates (produced by three weeks of growth) absorbed by filter paper had small effect on the germination of rape seed, but a very obvious effect on the development of the seedling rape root. Perennial ryegrass extracts caused very abnormal root development of rape seedings. Fescue, growing in association with rape plants in nutrient solution or distilled water, significantly reduced the growth or rape leaves (Peters, 1968). Also, when half the rape and fescue root systems were independently supplied with nutrient solution and half of their root systems were grown together in distilled water, fescue inhibited the growth of rape roots in distilled water (Peters, 1968), thus suggesting root exudation and not competition for nutrients.

MATERIALS AND METHODS

Five companion grasses were seeded at three rates, with Kentucky bluegrass (Poa pratensis L.) providing 15 mixtures and one check of 100% bluegrass. Grasses used were redtop (Agrostis alba L.), Pennlawn creeping red fescue (Festuca rubra L.), domestic ryegrass (Lolium multiflorum L.), and two improved turf-type perennial ryegrasses (Lolium perenne L.), varieties Pelo and NK-100. The Kentucky bluegrass component was made of a 50-50 mixture of Merion and Kenblue.

The seeding rate was calculated to give a population of 3600 pure live seeds (PLS) of Kentucky bluegrass per square foot (1 ft.^{2}). Companion grasses were seeded at the rate of 5, 10, and 20 percent PLS of bluegrass to make the mixtures (Table I).

One-tenth gram lots of seed were weighed and counted to determine the number of seeds per pound. PLS was calculated from percent germination and purity tests.

Mixtures were seeded on September 7, 1968 (fall seeding), May 13, 1969 (spring seeding), and July 16, 1969 (summer seeding).

A split-plot field design was utilized with cutting heights of 1 in. and 2 in. as the main plots and mixtures as sub-plots. All mixtures and cutting heights were assigned at random within seeding seasons with three replications.

The experimental area was a Frederick silt loam, deep and well drained soil with 3% slope, at the Virginia Polytechnic Institute Turf Research Center, Blacksburg, Virginia. The area was tilled and hand raked to a uniform grade; debris and rocks larger than 1 in.

Table I. Composition of seed mixtures expressed on a weight basis.

Companion Grass	Percent Companion Grass (PLS)		
	5	10	20
	Percent by Weight		
None*			
Redtop	1.7	3.4	6.5
C. R. Fescue	20.7	34.3	51.1
A. Ryegrass	37.8	54.9	70.9
Pelo	25.6	40.7	57.9
NK-100	29.8	46.0	63.0

*Bluegrass alone.

in diameter were removed. Results from soil test analysis indicated pH values of 6.1-6.7 with medium to high P and K levels.

Before each seeding, two pounds of nitrogen per 1000 $ft.^2$ from 13-3-9 fertilizer was raked into the top one inch of the seed bed. Sawdust, as a carrier, was blended with the mixtures to obtain uniform seedings on 6 ft. x 7.5 ft. plots. The soil was lightly rolled immediately after seeding and irrigated daily until the seedlings were well established. After establishment, the grasses were irrigated only when plants appeared to be moisture deficient.

One half the initial fertilizer rate was applied to the fall seeding the following spring (1969), and all seedings received one-half the initial fertilizer rate in October 1969.

The grasses were generally mowed so that not more than one-half of the leaf area was removed at any one time, except the first clipping. Plots were mowed on a five- to six-day schedule during the growing season, and clippings were removed whenever top growth was excessive. All plots were initially mowed at the two-in. height. The lower mowing treatment (1 in.) began on April 24, 1969, June 27, 1969, and September 4, 1969, for the fall, spring, and summer seedings, respectively.

Data Collection

Visual measurements, as commonly reported in the literature (Davis, 1958; Juska and Hanson, 1959; Roberts, 1959; Blaser, 1963; Miller, 1967) were used to determine turf quality and botanical composition. Botanical composition of mixtures was established at

six weeks and one year after seeding. Plot coverage was determined by estimating the percent ground cover several times during the season.

Appearance ratings, dependent on uniformity in texture, color, and ground cover, were estimated at the same time as cover.

Height measurements of ten plants per plot were taken from each mixture in each seeding before the first clipping as indices of vigor of the various companion grasses. Also height and weight measurements of ten randomly selected bluegrass plants were taken from the fall seeding to evaluate the influence of the companion grass competition.

Sod Strength and Rooting Ability

Rooting ability and sod strength of the various mixtures maintained at 2-in. cutting height were measured one year after the fall and spring seedings. Three ft. x 1 ft. x 1.5 in. sod blocks from the fall seeding were evaluated on August 23, 1969. One end of the sod was clamped to a mobile platform and the other to a stationary platform. Sand was added to a pail, which was attached to the mobile platform with a cable, until the sod broke. The weight of the sand and container required to break the sod was designated as sod strength.

After mixtures were tested for sod strength they were immediately placed into 12 x 18 in. flats with 1/4 in. wire mesh bottoms, similar to those reported by King and Beard (1969). The flats of sod were placed on a well prepared seedbed that was fertilized with two lbs. N/100 $ft.^2$ from 13-3-9. After a rooting period of six weeks, the amount of energy required to remove the sod from the soil was determined in accordance with the procedure prepared by King and Beard (1969).

Sod strength measurements for the spring seeding during May 1970 (sod one year of age) were conducted in a similar manner as for fall seeding. The difference between the procedures was using a winch to move the mobile platform. A spring-scale, placed between the sod and the winch, determined the energy required to break the sod. The sod was placed in the wire mesh flats and permitted to grow for four weeks before testing for rooting ability. The principle of determining rooting ability for spring seeding was as for the fall seeding, except that a spring-scale hung from the tripod between the flat and a block and tackle, determined the maximum energy required to lift the sod.

All values for rooting ability were corrected by subtracting the weight of soil which was attached to the root system.

Mixtures containing 5% companion grass at low clipping height were tested for comparison with the high clipping.

All data were subjected to analysis of variance. Least significant difference (LSD) served to ascertain differences between means.

Incubation Study

Seeds of Kentucky bluegrass and ryegrass were placed on blotter paper at a ratio of 2:1, 1.25:1, and 1:0 (Kentucky bluegrass:ryegrass) using annual and perennial ryegrass (NK-100).

Treatments were replicated four times in a controlled growth chamber in a randomized complete block design. Conditions in the chamber were eight hours of light at 25°C and 16 hours of darkness at 15°C. Distilled water was used for germination.

On the 13th, 19th, and 21st days after first watering, the percent germination and root and shoot lengths were determined from five randomly chosen bluegrass plants per blotter.

Root Interactions in Soil Media

Boxes were used to grow Kentucky bluegrass roots in the presence and absence of ryegrass (annual and NK-100 perennial) root systems. The root systems were kept separated by seeding each species (bluegrass and ryegrass) in a different plastic bag (placed in a box 4 in. x 12 in. x 18 in.) containing the same volume of soil with the same surface area. Where the root systems were allowed to grow together, plastic bags were not used, but there was a transparent surface divider through the middle of the box to avoid seed drift and overlapping of top growth into opposite sides of box.

A Frederick silt loam soil with a pH of 6.3 and high P and K levels was placed in the containers and seeded with 180 (PLS) annual and NK-100 ryegrass seeds and 3600 (PLS) Park bluegrass per $ft.^2$. A check consisted of bluegrass seeded on the entire area of a container.

Top weights of Kentucky bluegrass were recorded (dry weight) at weekly intervals for the sixth through the thirteenth week to determine the effects from association of ryegrass root systems.

RESULTS

Botanical Composition

Fall Seeding

Generally, high (2 in.) clipping and heavy rates of seeding the companion grasses reduced the percentage of Kentucky bluegrass in the turf population (Table II); the percentage of bluegrass being inversely proportional to the percentage of the companion grass seeded. Low (1 in.) clipping generally favored the bluegrass population, and the competition from the companion grasses further decreased after one year.

The companion grasses constituted greater percentages of the sward the spring following establishment except for mixtures containing annual ryegrass and redtop, where the Kentucky bluegrass percentages were 576 and 9% larger than the previous fall. Mixtures of creeping red fescue contained 30% less bluegrass in the spring than the previous fall. The two lowest rates of seeding the perennial ryegrass had 35% fewer bluegrass plants in the spring than in the fall, but at the highest seeding rate there was 52% more bluegrass in the spring after a fall seeding.

After one year at low clipping, the mixtures with 5, 10, and 20% companion grasses, respectively, averaged 79, 77, and 71% bluegrass. Under high clipping the bluegrass averaged 63, 57, and 53% of the turf population. Bluegrass-annual ryegrass mixtures, regardless of clipping height or seeding rate, were all bluegrass after one year.

The bluegrass population for all mixtures with red fescue decreased 20% from that of the previous year (combined clipping heights).

Table II. The effects of fall seeded companion grasses with two clipping heights on the percent Kentucky bluegrass at three dates.

Companion Grass	Percent Companion Grass (PLS) 5 Oct. 1968	5 April 1969	5 Oct. 1969	10 Oct. 1968	10 April 1969	10 Oct. 1969	20 Oct. 1968	20 April 1969	20 Oct. 1969
	Percent Kentucky Bluegrass								
Cut to a 1-inch height									
Redtop	90.0	86.7	90.0	80.0	86.7	87.3	71.7	83.3	79.0
C. R. Fescue	91.7	70.0	80.7	90.0	65.0	77.3	83.7	53.3	70.7
A. Ryegrass	23.5	88.3	100.0	11.0	81.7	100.0	6.7	73.3	100.0
Pelo	36.0	14.0	65.0	21.7	13.3	58.3	12.3	30.0	50.0
NK-100	28.3	30.0	60.0	17.7	23.3	61.0	15.0	30.0	56.0
Cut to a 2-inch height									
Redtop	85.7	85.7	86.0	81.7	91.7	86.7	65.0	75.0	71.7
C. R. Fescue	95.0	66.7	70.0	86.7	73.3	62.3	81.7	53.3	61.7
A. Ryegrass	21.7	75.0	100.0	12.7	78.3	100.0	7.3	70.0	100.0
Pelo	37.7	13.3	31.0	18.3	13.3	18.3	15.0	11.7	12.3
NK-100	36.7	15.0	27.7	26.7	21.7	16.0	16.7	18.3	20.0

LSD (.05) 8.5, applicable to differences between cutting height means at the same mixture and date.

LSD (.05) 12.7, applicable to differences between two mixture means at the same cutting height and date.

LSD (.05) 12.3, applicable to differences between two dates at the same cutting height and mixture.

For all redtop-bluegrass mixtures, bluegrass averaged 79% in the fall of 1968 and remained about the same (83%) one year later.

In the fall of 1968, the lowest percentage of Kentucky bluegrass (22%) occurred in the perennial ryegrass mixtures. After one year the bluegrass percentage in these mixtures had increased from 22% to 58% under low clipping, but there was no significant change (25% to 21%) under high clipping.

Spring Seeding

Generally there was an inverse relationship between the Kentucky bluegrass population and seeding rate of companion grasses (Table III) in the spring seeding.

The percentage increase in bluegrass from June thru October, 1969, was slightly larger for the highest rate of seeding the companion grasses; however, during October the mixtures of the lowest seedings were an average of 108% larger than the mixtures with 20% companion grass (Table III). After one year there were no differences in bluegrass populations regardless of the rate of seeding the companion grass.

There was a significant increase in bluegrass from June thru October, 1969 (Table IV), but under low clipping a vast reduction occurred in the bluegrass population during the winter of 1969-70, while there was no change in composition at high clipping.

Although (Table IV) the population of bluegrass at low clipping significantly increased by 33% from June until October 1969, percentage of bluegrass at one year was only 13% larger than at six weeks.

Table III. The effects of spring seeded (May 1969) companion grasses, with combined clipping heights, on the percent Kentucky bluegrass at three dates.

Companion Grass	Percent Companion Grass (PLS)								
	5			10			20		
	June 1969	Oct. 1969	May 1970	June 1969	Oct. 1969	May 1970	June 1969	Oct. 1969	May 1970
	Percent Kentucky Bluegrass								
Redtop	91.8	85.0	73.7	84.2	80.7	71.5	75.0	78.7	62.8
C. R. Fescue	55.8	76.5	62.5	49.2	70.8	59.2	30.8	62.5	53.0
A. Ryegrass	33.3	79.2	71.2	25.0	40.8	64.2	20.3	38.3	56.7
Pelo	25.8	39.2	13.7	19.0	33.0	13.3	17.3	17.0	11.7
NK-100	26.7	51.0	20.8	14.7	32.8	18.5	6.0	13.5	12.0

LSD (.05) 13.2, applicable to differences between two dates of estimation for the same mixture.

LSD (.05) 13.2, applicable to differences between two mixtures on the same date.

Table IV. The influence of clipping heights on the percent Kentucky bluegrass in spring seeded (May 1969) mixtures.

Clipping Heights	Date of Observation: June 1969	Oct. 1969	May 1970
	Percent Kentucky Bluegrass		
1 in.	42.6	64.4	47.5
2 in.	41.7	48.0	48.0
Means	42.2	56.2	47.8

LSD (.05) 8.2, applicable to differences between two cutting heights on the same date.

LSD (.05) 4.7, applicable to differences between two dates at the same cutting height.

LSD (.05) 3.3 for separation of date means.

Six weeks after seeding, companion grasses could be ranked according to percentage of bluegrass in the mixtures as follows: redtop (84%) > creeping red fescue (45%) > annual ryegrass (26%), Pelo (21%), and NK-100 (16%). After one year the rank was: redtop (69%), creeping red fescue (58%), and annual ryegrass (64%) > Pelo (13%), and NK-100 (17%).

Summer Seeding

Although there was a decrease in bluegrass composition with increased rates of seeding redtop or creeping red fescue six weeks after summer seeding (Table V), there were no significant differences among ryegrass mixtures regardless of seeding rate. The inverse relationship between bluegrass and seeding rates of companion grasses was still evident after one year.

Low clipping generally favored Kentucky bluegrass, averaging 12% more than for high clipping (Table VI). After six weeks, the average Kentucky bluegrass population in mixtures was as follows: creeping red fescue (68%) > redtop (39%) > annual ryegrass (14%), Pelo (13%), and NK-100 (15%). After one year the relationship was: redtop (75%), creeping red fescue (65%), and annual ryegrass (69%) > Pelo (10%), and NK-100 (10%). When averaging all mixtures for the summer seedings, Kentucky bluegrass increased by 45% from six weeks to one year after seeding.

Botanical Composition Six Weeks After Seeding in Three Seeding Seasons

Fall seeding averaged 16 and 43% more favorable for early development (six weeks of age) of Kentucky bluegrass than spring and summer

Table V. The effects of summer seeded (July 1969) companion grasses, with combined clipping heights, on the percent Kentucky bluegrass at three dates.

Companion Grass	Percent Companion Grass (PLS)								
	5			10			20		
	Sept. 1969	Oct. 1969	July 1970	Sept. 1969	Oct. 1969	July 1970	Sept. 1969	Oct. 1969	July 1970
	Percent Kentucky Bluegrass								
Redtop	51.7	48.3	83.0	41.7	50.3	72.5	24.7	37.5	70.8
C. R. Fescue	87.8	86.3	70.8	67.5	79.0	69.2	49.2	65.8	55.8
A. Ryegrass	14.5	15.0	75.8	14.5	9.2	70.0	11.7	7.2	62.5
Pelo	17.8	10.0	12.5	14.8	6.3	9.0	7.7	4.8	9.3
NK-100	15.5	11.0	10.8	18.7	9.3	12.0	10.2	5.8	8.2

LSD (.05) 7.8, applicable to differences between two dates at the same mixture.

LSD (.05) 10.3, applicable to differences between two mixture means on the same date.

Table VI. The influence of clipping heights on the percent Kentucky bluegrass in summer (July 1969) seeded mixtures.

Clipping Heights	Date of Observation: Sept 1969	Oct. 1969	July 1970	Means
	Percent Kentucky Bluegrass			
1 in.	35.0	36.6	53.0	41.5
2 in.	33.5	31.6	46.0	37.5
Means	34.2	34.1	49.5	

LSD (.05), 2.3 for separation of clipping means.

LSD (.05), 1.9 for separation of date means.

LSD (.05), 2.8 applicable to differences between two dates at the same clipping height.

LSD (.05), 3.7 applicable to differences between two clipping heights on the same date.

seedings, respectively (Table VII). The fall and spring seedings of mixtures with redtop had over two-fold more bluegrass than the summer seeding. The fall seeding of mixtures containing creeping red fescue had 54% more bluegrass than spring and 29% more than summer seedings. The fall seeding of mixtures with the perennial ryegrasses had 43 and 67% more Kentucky bluegrass than the spring and summer seedings, respectively; whereas spring seeded mixtures with annual ryegrass included 116 and 92% more bluegrass than the fall and summer seedings respectively.

Botanical Composition One Year After Seeding in Three Seeding Seasons

Fall seeded mixtures averaged 43% more Kentucky bluegrass after one year than those seeded in spring, and 38% more than those seeded in the summer (Table VIII).

Fall seeded mixtures including redtop had 22% more bluegrass after one year than when spring seeded, but only 10% more than summer seedings. Fall seeded mixtures with creeping red fescue, clipped at one and two inches respectively, had 28 and 14% more bluegrass than spring seeded ones, but only 12 and 4% more than the summer seeding, for the respective clipping heights (Table VIII).

After one year of low clipping, fall seeded mixtures with annual ryegrass contained 66% more bluegrass than spring seeded, and only 24% more than the summer seeding. However, at high clipping, the fall seeding had 74% more bluegrass than when summer seeded and 50% more than when spring seeded.

When fall seeded mixtures with Pelo and NK-100 were clipped low, five-fold more bluegrass was observed than in summer seedings, and

Table VII. The effects of companion grasses on the percentage of Kentucky bluegrass six weeks after seeding.

Companion Grass	Percent Companion Grass (PLS)								
	5			10			20		
	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer
	Percent Kentucky bluegrass								
Redtop	87.8	91.8	51.7	80.8	84.2	41.7	68.3	75.0	24.7
C. R. Fescue	93.3	55.8	87.8	88.3	49.2	67.5	82.7	30.8	49.2
A. Ryegrass	22.5	33.3	14.5	11.8	25.0	14.5	7.0	20.3	11.7
Pelo	36.8	25.8	17.8	20.0	19.0	14.8	13.7	17.3	7.7
NK-100	32.5	26.7	15.5	22.2	14.7	18.7	15.8	6.0	10.2

LSD (.05) 7.9, applicable to differences between two mixtures within the fall seeding.

LSD (.05) 12.2, applicable to differences between two mixtures within the spring seeding.

LSD (.05) 9.2, applicable to differences between two mixtures within the summer seeding.

Table VIII. The influence of companion grasses and clipping heights on the percent Kentucky bluegrass one year after seeding in three seasons.

Companion Grass	Percent Companion Grass (PLS)								
	5			10			20		
	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer
	Percent Kentucky Bluegrass								
	Cut to a 1-inch height								
Redtop	90.0	78.3	84.3	87.3	74.7	75.0	79.0	58.2	73.3
C. R. Fescue	80.7	61.7	75.0	77.3	61.7	71.7	70.7	55.0	58.3
A. Ryegrass	100.0	65.0	90.0	100.0	61.7	81.7	100.0	55.0	71.7
Pelo	65.0	12.3	14.0	58.3	13.3	10.0	50.0	11.7	10.0
NK-100	60.0	22.7	12.3	61.0	16.0	12.3	56.0	13.3	8.7
	Cut to a 2-inch height								
Redtop	86.0	69.0	81.7	86.7	68.3	70.0	71.7	67.3	68.3
C. R. Fescue	70.0	63.3	66.7	62.3	56.7	66.7	61.7	51.0	53.3
A. Ryegrass	100.0	77.3	61.7	100.0	66.7	58.3	100.0	58.3	53.3
Pelo	31.0	15.0	11.0	18.3	13.3	8.0	12.3	11.7	8.7
NK-100	27.7	19.0	9.3	16.0	21.0	11.7	20.0	10.7	7.7

LSD (.05) 8.3, applicable to differences between two cutting means at the same mixture and in the same season.

LSD (.05) 14.1, applicable to differences between two mixture means at the same cutting height and in the same season.

LSD (.05) 13.3, applicable to differences between two season means at the same cutting height and the same mixture.

three- to four-fold more than when spring seeded (Table VIII).

Under high clipping, fall seeded mixtures with perennial ryegrass had 113% more bluegrass than when summer seeded, but only 43% more than when spring seeded.

Plot Coverage

Fall Seeding

Six weeks after the September (1968) seeding, plot coverage tended to improve as seeding rates of redtop or the perennial ryegrasses increased, but the reverse was true of mixtures with creeping red fescue and annual ryegrass (Table IX). The 20% rate of seeding companion grasses with bluegrass had 34% less cover during February, while the 5 and 10% rates of seeding had 22 and 28% less cover, respectively.

After the winter of 1968-69, coverage was generally inversely proportional to the rate of seeding NK-100, Pelo, and annual ryegrass, while the coverage of the Kentucky bluegrass blend and mixtures with redtop and creeping red fescue remained about the same after April, regardless of amount seeded (Table IX). Percent ground cover six weeks after seeding was significantly lower than at any other time, except during February (1969). There were significant increases in ground cover from February to October 1969. Six weeks after seeding, mixtures containing redtop, Pelo, and NK-100 averaged about 7% more cover than pure bluegrass or mixtures with red fescue, or annual ryegrass.

Mixtures with annual ryegrass caused the largest average loss of stand (43% reduction) thru the winter, and creeping red fescue the

Table IX. The influence of companion grasses seeded with Kentucky bluegrass in fall (Sept. 1968) seedings on ground cover (combined for two clipping heights).

Companion Grass	Dates of Observation 1968 Oct.	1969 Feb.	Apr.	May	June	Aug.	Sept.	Oct.
	Percent ground cover							
	5 percent companion grass (PLS)							
None*	72.5	60.0	89.7	88.7	88.3	93.2	94.3	95.5
Redtop	75.5	61.7	89.5	87.2	88.2	92.5	93.2	95.3
C. R. Fescue	75.7	65.0	90.7	88.7	87.8	91.8	92.5	95.2
A. Ryegrass	75.8	50.0	71.7	75.8	74.7	85.0	90.3	91.2
Pelo	77.3	63.3	87.0	88.0	89.2	87.2	90.5	92.2
NK-100	78.8	60.0	86.5	88.5	88.0	87.8	91.5	93.5
	10 percent companion grass (PLS)							
None*	----	----	----	----	----	----	----	----
Redtop	80.0	63.3	88.2	88.7	88.2	91.8	94.2	94.8
C. R. Fescue	74.7	60.0	89.7	89.7	88.5	90.8	93.0	95.3
A. Ryegrass	74.7	41.7	64.2	69.2	68.3	83.8	88.5	91.7
Pelo	80.5	61.7	86.2	87.8	86.7	82.8	87.2	93.2
NK-100	82.8	58.3	83.7	83.5	85.5	84.5	91.2	92.5
	20 percent companion grass (PLS)							
None*	----	----	----	----	----	----	----	----
Redtop	84.7	61.7	89.0	90.2	88.7	91.2	93.5	96.3
C. R. Fescue	72.5	61.7	91.3	90.2	90.0	90.7	93.2	95.7
A. Ryegrass	70.5	28.3	33.3	48.3	45.8	71.3	85.2	89.7
Pelo	84.5	56.7	79.7	83.0	85.7	82.3	88.3	92.7
NK-100	80.2	53.3	74.2	81.7	80.0	83.8	87.3	89.7

LSD (.05) 5.1, applicable to differences between two dates for the same mixture.

LSD (.05) 5.5, applicable to differences between two mixtures on the same date.

*Bluegrass alone.

least (16%). After one year, all mixtures provided the same amount of cover as the Kentucky bluegrass blend, with the exception of the high seedings of annual and NK-100 ryegrass, both of which were significantly poorer (Table IX).

Spring Seeding

Four weeks after seeding, ground coverage was directly proportional to the rates of seeding all companion grasses (Table X). The direct relationship continued throughout the season for mixtures with redtop, but coverage by the mixtures containing ryegrass was generally inversely related to seeding rate after the fourth week (June 12). Between June and September (1969), coverage by mixtures containing creeping red fescue was best provided by the 20, 5, and 10% rates of seeding, in that order. At four weeks, the most rapid ground coverage was provided by the mixtures in the following order: annual ryegrass (84%) > NK-100 (68%), and Pelo (63%) > redtop (41%) > Kentucky bluegrass (32%), and creeping red fescue (30%) (Table X).

Pure Kentucky bluegrass provided as much ground cover three months after seeding (August) and thereafter as any mixture.

Summer Seeding

Plot coverage, at the low clipping height, increased directly with seeding rates of redtop and creeping red fescue, but was generally not affected by seeding rates of the ryegrasses (Table XI). At high clipping the percent cover was not affected by rates of seeding the companion grasses.

Under low clipping, the mixtures containing any of the ryegrass

Table X. The influence of companion grasses seeded with Kentucky bluegrass in spring (May 1969) seedings on ground cover (combined for two clipping heights).

Companion Grass	Dates of Observation 1969 June 12	June 24	July 13	Aug. 2	Aug. 30	Sept. 27	Oct. 18
	Percent ground cover						
	5 percent companion grass (PLS)						
None*	32.3	49.5	69.8	85.8	86.7	86.5	86.8
Redtop	38.3	52.5	63.8	80.5	85.3	84.8	85.7
C. R. Fescue	26.2	46.7	63.3	78.7	83.2	83.5	82.3
A. Ryegrass	74.5	79.0	51.5	70.3	75.0	80.8	81.7
Pelo	45.8	74.8	74.3	84.3	83.0	85.0	84.5
NK-100	58.2	81.8	75.2	83.3	81.0	82.5	84.5
	10 percent companion grass (PLS)						
None*	----	----	----	----	----	----	----
Redtop	37.0	48.3	64.8	82.2	83.5	83.3	85.0
C. R. Fescue	27.5	42.5	52.2	71.3	81.2	83.0	82.3
A. Ryegrass	84.5	64.3	28.0	48.8	59.5	76.5	80.7
Pelo	63.2	82.8	75.0	80.0	75.2	83.7	84.3
NK-100	68.0	83.2	68.8	78.5	76.0	81.2	80.3
	20 percent companion grass (PLS)						
None*	----	----	----	----	----	----	----
Redtop	46.7	73.3	76.7	87.7	88.5	87.0	86.3
C. R. Fescue	35.0	58.3	72.3	84.8	87.8	86.5	85.8
A. Ryegrass	91.7	61.2	8.7	28.3	44.7	66.2	72.5
Pelo	79.7	86.5	67.5	66.5	63.5	75.3	81.2
NK-100	79.2	79.2	50.8	56.0	60.2	77.7	82.0

LSD (.05) 8.9, applicable to differences between two mixtures on the same date.

LSD (.05) 10.6, applicable to differences between two dates within the same mixture.

*Bluegrass alone.

Table XI. The influence of companion grasses seeded with Kentucky bluegrass in summer (July 1969) seedings and clipping heights on ground cover.

Companion Grass	Percent Companion Grass (PLS) 5 — Date of Observation 1969 Aug. 24	5 — 1969 Sept. 7	5 — 1969 Sept. 27	5 — 1969 Oct. 18	10 — 1969 Aug. 24	10 — 1969 Sept. 7	10 — 1969 Sept. 27	10 — 1969 Oct. 18	20 — 1969 Aug. 24	20 — 1969 Sept. 7	20 — 1969 Sept. 27	20 — 1969 Oct. 18
	Percent ground cover											
	Clipped to a 1-inch height											
None*	48.3	57.7	66.7	72.0	----	----	----	----	----	----	----	----
Redtop	59.7	63.3	83.0	83.0	83.3	74.3	85.7	84.3	80.0	76.3	84.7	87.7
C. R. Fescue	55.0	60.7	78.7	73.7	61.0	63.3	76.0	79.0	62.7	71.7	77.3	78.0
A. Ryegrass	83.7	60.0	78.0	83.3	77.0	49.0	73.3	85.0	78.3	52.7	80.0	83.7
Pelo	80.0	65.3	78.0	83.0	83.3	63.3	80.0	85.0	84.7	61.0	70.3	86.3
NK-100	83.3	63.3	73.3	84.7	82.7	63.3	76.0	83.7	83.0	57.7	70.0	85.3
	Clipped to a 2-inch height											
None*	77.0	85.0	82.7	85.0	----	----	----	----	----	----	----	----
Redtop	85.3	86.0	89.0	89.7	83.0	84.7	90.0	89.7	86.3	84.7	89.3	89.3
C. R. Fescue	80.7	84.7	87.3	89.3	76.7	81.0	85.3	86.3	81.0	83.7	87.3	88.3
A. Ryegrass	84.0	65.0	88.0	81.3	81.3	70.7	86.0	86.0	75.0	69.3	84.3	86.0
Pelo	73.7	74.7	88.0	89.0	80.7	73.3	86.0	88.0	78.0	74.7	85.3	88.7
NK-100	81.7	80.0	87.7	88.3	83.3	77.3	86.3	88.3	82.0	70.7	84.0	87.0

LSD (.05) 9.3, applicable to differences between two date means at the same cutting and mixture.

LSD (.05) 13.2, applicable to differences between two mixture means at the same cutting and date.

LSD (.05) 15.1, applicable to differences between two cutting means at the same mixture and date.

†Bluegrass alone.

suffered a significant loss of stand between the fifth and eighth weeks; whereas under high clipping there was only a slight reduction in cover. It appears that plot coverage was generally favored by high clipping.

Generally, ground coverage at four weeks was better with mixtures than with bluegrass alone. All mixtures provided slightly more coverage than pure bluegrass at low clipping (Table XI). When clipped high,pure bluegrass provided about as much cover as any mixture during the season.

Turf Quality

Fall Seeding

Collectively, the quality of turf significantly decreased with an increase in percentage of ryegrass in the mixtures, but quality of mixtures containing creeping red fescue was not generally affected by rate of seeding (Table XII).

There was a general increase in the quality of the fall seeded turf as time progressed. However, the increase in quality of pure bluegrass turf or mixtures with redtop and creeping red fescue was not significant.

The qualtiy of Pelo mixtures was usually slightly superior to those of NK-100, especially at highest seeding rates. Turf quality of all other mixtures was significantly better than for those mixtures containing annual ryegrass.

Companion grasses did not appear to significantly improve the turf quality over pure bluegrass at any time; in fact, pure bluegrass

Table XII. The influence of companion grasses seeded with Kentucky bluegrass in fall seedings (Sept. 1968), combined for two clipping heights, on turf quality.*

Companion Grass	Percent Companion Grass (PLS)																	
	5						10						20					
	Date of Observation																	
	1969						1969						1969					
	Feb.	May	June	Aug.	Sept.	Oct.	Feb.	May	June	Aug.	Sept.	Oct.	Feb.	May	June	Aug	Sept.	Oct.
	Turf quality																	
None†	5.7	5.7	6.9	7.3	6.9	7.9	---	---	---	---	---	---	---	---	---	---	---	---
Redtop	5.8	5.8	6.8	7.3	7.2	8.1	5.8	6.0	6.5	7.6	7.2	8.0	5.2	6.0	6.9	7.4	7.1	8.1
C. R. Fescue	5.5	5.8	6.8	6.8	6.8	8.3	5.5	5.8	6.7	7.1	6.6	8.1	5.0	5.7	6.7	6.9	6.7	8.0
A. Ryegrass	2.7	2.8	2.8	6.3	6.0	7.4	2.3	2.8	2.2	5.9	5.1	6.8	1.7	1.7	1.5	4.1	3.8	5.8
Pelo	3.8	6.5	6.5	6.1	6.0	6.9	3.8	6.5	6.3	5.3	5.7	7.1	3.2	6.2	6.0	5.0	5.8	6.9
NK-100	3.7	6.3	6.0	6.0	6.0	6.7	3.2	5.8	5.4	5.6	6.0	6.9	2.8	5.8	5.1	5.1	5.3	6.3

LSD (.05) 0.8, applicable to differences between two date means at the same mixture.

LSD (.05) 0.8, applicable to differences between two mixture means on the same date.

*Turf quality includes the combined effects of color, uniformity in texture, ground cover, disease, and mowability. Ratings were 1 to 10, 10 being the best.

†Bluegrass alone.

turf was significantly superior to all ryegrass mixtures at all times, except May and June 1969 (Table XII).

Spring Seeding

Six weeks (June 24) after the May 1969 seeding, turfgrass quality was generally inversely related to the seeding rate of the ryegrasses, while the highest seeding rate of redtop and creeping red fescue tended to provide better quality than the lowest (Table XIII).

The highest seeding of redtop or creeping red fescue tended to improve quality over pure bluegrass, while the lower two rates did not. Also, the mixtures composed of perennial ryegrass provided a slightly better quality than the bluegrass blend at six weeks, but all mixtures with annual ryegrass were inferior to all other mixtures and pure bluegrass. The clipping heights had similar effects on turf quality of mixtures during most of the season, but at the beginning of the fall season (Table XIV), the high clipping tended to give a slightly better quality for all mixtures.

By August 1969, the quality of mixtures containing redtop or creeping red fescue were about the same as for the Kentucky bluegrass blend. Quality of all mixtures, including the standard bluegrass turf, tended to deteriorate after August (Table XIII).

In October 1969, the turf quality of pure bluegrass and mixtures including redtop or creeping red fescue were similar (Table XIII). The turf quality of mixtures containing perennial ryegrass was significantly inferior to bluegrass, but definitely superior to mixtures with annual ryegrass.

Table XIII. The influence of companion grasses seeded with Kentucky bluegrass in spring seedings (May 1969), combined for two clipping heights, on turf quality.*

Companion Grasses	Percent Companion Grass (PLS)																	
	5						10						20					
	Date of Observation																	
	1969						1969						1969					
	June 24	July 13	Aug. 2	Aug. 30	Sept. 27	Oct. 18	June 24	July 13	Aug. 2	Aug. 30	Sept. 27	Oct. 18	June 24	July 13	Aug. 2	Aug. 30	Sept. 27	Oct. 18
	Turf quality																	
None†	3.9	5.5	6.5	5.9	5.2	5.3	---	---	---	---	---	---	---	---	---	---	---	---
Redtop	3.8	4.3	6.2	6.1	5.5	5.2	3.3	4.3	5.9	5.6	5.3	4.7	4.8	5.0	6.6	6.2	5.7	5.0
C. R. Fescue	3.4	5.0	6.6	5.8	5.1	5.1	2.4	3.8	5.6	5.6	5.3	5.3	4.3	5.7	6.9	6.3	5.6	5.0
A. Ryegrass	2.6	1.5	2.9	3.4	2.3	1.4	2.3	1.2	1.5	2.1	1.6	1.3	1.8	1.0	1.0	1.0	1.7	1.0
Pelo	4.0	4.0	5.6	4.7	4.9	4.0	4.6	3.0	3.9	4.2	4.3	3.8	5.8	2.2	2.7	3.3	3.8	3.8
NK-100	4.7	3.3	4.3	4.6	3.9	3.5	5.0	1.8	3.8	4.3	3.7	3.3	4.2	1.2	1.7	2.5	3.7	3.4

LSD (.05) 1.0, applicable to differences between two dates for determination of quality at the same mixture.

LSD (.05) 1.2, applicable to differences between two mixtures on the same date of determination.

*Turf quality includes the combined effects of color, uniformity in texture, ground cover, disease, and mowability. Ratings were 1 to 10, 10 being the best.

†Bluegrass alone.

Table XIV. The influence of clipping heights and age on turf quality* of spring seeded (May 1969) Kentucky bluegrass mixtures (combined for seeding rates of companion grasses).

Date of Observation	Clipping heights	
	1 in.	2 in.
	Turf quality	
June 24, 1969	4.1	3.5
July 13, 1969	3.4	3.2
August 2, 1969	4.5	4.5
August 30, 1969	4.2	4.7
Sept. 27, 1969	3.9	4.5
October 18, 1969	3.4	4.3

LSD (.05) 0.4, applicable to differences between two dates at the same cutting height.

LSD (.05) 1.1, applicable to differences between two cutting heights at the same date.

*Turf quality includes the combined effects of color, uniformity in texture, ground cover, disease, and mowability. Ratings were 1 to 10, 10 being the best.

Summer Seeding

Turf quality as related to seeding rates of companion grasses was quite variable, but the best turf after seven weeks (Sept. 7) was that which contained 5% companion grass (Table XV), with the exception of annual ryegrass. After thirteen weeks (Oct. 18), the best turf quality generally occurred with the higher rates of seeding the companion grasses.

Seven and thirteen weeks after seeding, turf quality of mixtures containing redtop or creeping red fescue and the Kentucky bluegrass blend was better at high clipping than at low. Mixtures including perennial ryegrass had significantly better turf at two-inch clipping at seven weeks, but after thirteen weeks the low clipping tended to have promoted the best turf.

The quality of all bluegrass-ryegrass mixtures, especially those containing annual ryegrass, was significantly inferior to any others at both clipping heights.

After thirteen weeks, mixtures containing 10 and 20% creeping red fescue or redtop had better quality than pure bluegrass clipped at one inch. At high clipping, the quality of mixtures with redtop was similar to pure bluegrass, but mixtures containing creeping red fescue were superior to either.

Low clipping, relative to high, seemed to be more harmful to quality of pure bluegrass, mixtures containing redtop, or creeping red fescue than to the ryegrass mixtures.

Table XV. The influence of companion grasses seeded with Kentucky bluegrass in summer seedings (July 1969) and clipping heights on turf quality.*

Companion Grass	Percent Companion Grass (PLS)								
	5			10			20		
	Dates of Observation								
	1969			1969			1969		
	Sept. 7	Sept. 27	Oct. 18	Sept. 7	Sept. 27	Oct. 18	Sept. 7	Sept. 27	Oct. 18
	Turf Quality								
	Clipped to a 1-inch height								
None†	3.7	4.2	4.3	---	---	---	---	---	---
Redtop	4.2	4.2	4.4	4.0	5.3	4.8	3.8	6.3	5.8
C. R. Fescue	3.8	4.6	4.5	4.1	4.5	5.2	3.9	4.3	4.8
A. Ryegrass	2.2	3.3	3.0	1.7	3.2	3.2	1.7	3.3	3.2
Pelo	2.3	4.3	4.0	1.8	4.2	4.7	2.0	4.0	5.5
NK-100	1.7	4.0	3.8	1.8	3.9	4.0	1.3	3.8	4.6
	Clipped to a 2-inch height								
None†	6.3	5.2	6.1	---	---	---	---	---	---
Redtop	5.5	6.3	5.8	5.5	6.7	6.1	5.3	6.9	5.9
C. R. Fescue	6.5	5.2	7.5	5.5	4.8	6.8	6.5	6.3	7.2
A. Ryegrass	2.2	3.0	2.8	3.3	4.0	3.3	3.0	3.3	3.2
Pelo	3.7	3.8	3.9	3.7	4.0	4.4	3.8	4.0	4.3
NK-100	4.2	3.8	3.8	3.7	3.6	4.1	3.3	4.2	4.2

LSD (.05) 1.0, applicable to differences between two dates at the same cutting height and mixture.

LSD (.05) 0.9, applicable to differences between two mixtures at the same cutting and on the same date.

LSD (.05) 1.1, applicable to differences between two cuttings for the same mixture and on the same date.

*Turf quality includes the combined effects of color, uniformity in texture, ground cover, disease, and mowability. Ratings were 1 to 10, 10 being the best.

†Bluegrass alone.

Seedling Stage Relationships

Vigor of the turf plants as measured by height (Table XVI) indicated that annual ryegrass was the most vigorous in all three seeding seasons, followed by NK-100 and Pelo. Vigor of creeping red fescue and redtop was similar to bluegrass. The ryegrasses seemed to be more vigorous relative to bluegrass in the fall and summer seedings than in the spring seeding. As the rate of seeding the ryegrasses increased, so did the height of plants.

Results of 4- to 5-week-old Kentucky bluegrass seedlings from the fall seeded mixtures revealed that bluegrass plants were significantly lighter when grown in mixtures with annual and perennial ryegrass (Table XVII). The bluegrass in mixtures of annual ryegrass was etiolated, but only the high rates of seeding NK-100 and Pelo tended to cause stem elongation.

The height and weight of bluegrass in mixtures with redtop or creeping red fescue were not significantly affected.

Sod Studies

Fall

Kentucky bluegrass sod (one year of age) maintained at two-inch clipping height was over two-fold stronger than the best sod containing the perennial ryegrasses, but only 12 and 23% stronger, respectively, than sod containing creeping red fescue or redtop (Table XVIII). The trend was toward weaker sod with increased percentage of ryegrass in the mixture. Sod strength appeared to increase with increased composition of creeping red fescue but varied with redtop composition.

Table XVI. The average height of the turf seedlings three to four weeks after spring, summer, and fall seedings of companion grasses with Kentucky bluegrass.

Companion Grass	Percent Companion Grass (PLS)								
	5			10			20		
	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer
	Height (inches)								
None*	1.1	0.9	1.0	---	---	---	---	---	---
Redtop	1.6	0.9	1.0	1.7	0.9	1.2	1.7	1.1	1.5
C. R. Fescue	1.5	0.7	0.9	1.4	0.9	0.9	1.4	1.0	1.0
A. Ryegrass	5.2	2.8	4.1	6.6	3.5	5.2	8.5	4.8	6.5
Pelo	2.9	1.6	2.4	3.1	1.9	3.5	4.0	2.3	3.6
NK-100	3.5	1.9	3.0	3.8	2.2	3.7	4.9	2.9	4.0

LSD (.05) 2.1, applicable to differences between two mixtures in the fall season.

LSD (.05) 2.0, applicable to differences between two mixtures in the spring season.

LSD (.05) 2.4, applicable to differences between two mixtures in the summer season.

*Bluegrass alone.

Table XVII. Height and weight of Kentucky bluegrass 4 to 5 weeks after fall seeding with various companion grasses.

Companion Grass	Percent Companion Grass (PLS)					
	5	10	20	5	10	20
	Weight (mg)			Height (cm)		
None*	62.4	----	----	2.5	---	---
Redtop	78.6	67.1	65.5	2.5	2.5	2.3
C. R. Fescue	58.6	56.0	66.9	2.8	2.5	2.1
A. Ryegrass	17.5	12.6	8.2	3.0	3.7	4.1
Pelo	23.4	20.1	17.8	2.5	2.4	2.8
NK-100	23.5	20.5	14.2	2.6	2.7	2.8
LSD (.05)		11.9 mg			0.6 cm	

*Bluegrass alone.

Table XVIII. Sod strength* of one-year-old fall seeded (Sept. 1968) Kentucky bluegrass-companion grass mixtures clipped to a 2-inch height.

Companion Grass	Percent Companion Grass (PLS)		
	5	10	20
	Sod strength, lbs.*		
None†	41.7	----	----
Redtop	34.0	28.3	32.3
C. R. Fescue	23.0	35.0	37.0
A. Ryegrass	21.3	13.5	5.7
Pelo	18.2	12.8	11.7
NK-100	18.3	17.0	10.7
LSD (.05)	8.7		

*Pounds required to break a strip of sod one foot wide and 1.5 inches thick.

†Bluegrass alone.

Low clipping did not significantly affect sod strength of the mixtures seeded with 5% companion grass (Table XIX), although high clipping tended to be best. Sod strength of pure bluegrass was reduced by 96% due to low clipping, whereas mixes of redtop and creeping fescue were weakened by approximately 21%. The sod strength of mixtures with Pelo and NK-100 was 53 and 18% less, respectively, at low than at high clipping.

Although the rooting strength of sod clipped at two inches did not differ significantly after a knitting period of six weeks, the mixtures tended to have more rooting strength than the bluegrass blend. The mixtures with perennial ryegrass had 28% more rooting strength than the pure bluegrass sod, while mixtures containing redtop, annual ryegrass, and creeping red fescue were 12, 11, and 5% stronger, respectively, than pure bluegrass (Table XX).

Root strength of mixtures with 5% companion grasses was not significantly affected by clipping heights, although turf clipped at two inches averaged 13% stronger than that clipped to one inch (Table XIX).

Spring

Although none of the spring seeded mixtures improved sod strength over pure Kentucky bluegrass (Table XXI) when clipped at two inches, the average of the companion grasses (excluding annual ryegrass) increased sod strength by approximately 6%. However, the mixtures containing 5 and 20% annual ryegrass formed an average of 21% and 25% respectively, weaker sod than pure bluegrass.

Table XIX. Sod* and root† strengths of one-year-old fall seeded (Sept. 1968) Kentucky bluegrass-companion grass mixtures clipped to 1- and 2-inch heights.

Companion Grass‡	Clipping Heights					
	1 in.	2 in.	Mean	1 in.	2 in.	Mean
	Sod strength, lbs.*			Root strength, lbs.†		
None§	21.2	41.7	31.4	157	173	165
Redtop	27.8	34.0	30.9	145	194	170
C. R. Fescue	30.7	37.0	33.8	161	183	172
A. Ryegrass	19.7	21.3	20.5	190	199	194
Pelo	12.0	18.3	15.1	193	213	203
NK-100	15.5	18.3	16.9	185	210	197
	21.1	28.4		172	195	
LSD (.05)	N.S.		9.2	N.S.		N.S.

*Pounds required to break a sod one foot wide and 1.5 inches thick.

†Pounds required to lift a flat of sod (198 in^2) after a 6-week rooting period.

‡The companion grasses were seeded at 5% (PLS) rate, except creeping red fescue, which was 20%.

§Bluegrass alone.

Table XX. Root strength* of one-year-old fall seeded (Sept. 1968) Kentucky bluegrass-companion grass mixtures clipped to a 2-inch height.

Companion Grass	Percent Companion Grass (PLS)		
	5	10	20
	Root strength, lbs.*		
None†	173.3	-----	-----
Redtop	193.9	194.5	193.7
C. R. Fescue	177.4	183.2	182.9
A. Ryegrass	198.7	173.1	205.9
Pelo	213.0	244.9	218.0
NK-100	209.8	215.9	234.7
LSD (.05)	N.S.		

*Pounds required to lift a flat of sod (198 in^2) after a 6-week rooting period.

†Bluegrass alone.

Table XXI. Sod strength* of one-year-old spring seeded (May 1969) Kentucky bluegrass-companion grass mixtures clipped to a 2-inch height.

Companion Grass	Percent Companion Grass (PLS)		
	5	10	20
	Sod strength, lbs.*		
None†	61.0	----	----
Redtop	68.3	64.0	64.0
C. R. Fescue	61.7	74.0	64.3
A. Ryegrass	50.3	40.7	48.7
Pelo	61.7	71.0	66.0
NK-100	65.7	63.0	53.0
LSD (.05) 15.1			

*Pounds required to break a sod one foot wide and 1.5 inches thick.

†Bluegrass alone.

Although clipping did not significantly affect sod strength of the spring seeded mixtures containing pure bluegrass or 5% companion grasses (Table XXII), the high clipped turf was 27% stronger than that of a low clipped. Low clipping appeared to affect mixtures with creeping red fescue least and those with annual ryegrass and NK-100 most.

When averaged for all mixtures, the addition of redtop or creeping red fescue did not increase the root strength over pure bluegrass in the spring seeding; whereas annual, Pelo, and NK-100 ryegrasses increased the root strength by 30, 40, and 12%, respectively (Table XXIII). The only mixtures that significantly increased root strength over pure bluegrass were the 10 and 20% seedings of Pelo and the mixture containing 20% annual ryegrass. Root strength of sod containing mixtures with redtop and creeping red fescue tended to increase with increased seeding rate of the companion grass.

Low clipping tended to increase root strength of the 5% bluegrass-companion grass mixtures (Table XXII), over high clipping, but not for pure Kentucky bluegrass.

Incubation Study

The percent germination of Kentucky bluegrass (Table XXIV) was not significantly influenced by the incubation with annual or NK-100 ryegrass; however, 13 days after the tests were initiated, the percent germination of bluegrass in association with annual and NK-100 ryegrass was 28 and 39% better than control bluegrass.

The root length of Kentucky bluegrass (Table XXIV) did not vary significantly when grown (3 weeks) in association with the ryegrasses. On the 13th day the roots of Kentucky bluegrass in association with

Table XXII. Sod* and root† strengths of one-year-old spring seeded (May 1969) Kentucky bluegrass-companion grass mixtures clipped to 1- and 2-inch heights.

Companion Grass Seeded at 5% PLS	Clipping Heights					
	1 in.	2 in.	Mean	1 in.	2 in.	Mean
	Sod strength, lbs.*			Root strength, lbs.†		
None‡	46.3	61.0	53.7	62.2	66.5	64.3
Redtop	54.7	68.3	61.5	71.9	57.5	64.7
C. R. Fescue	59.3	61.7	60.5	75.4	59.7	67.5
A. Ryegrass	33.0	50.3	41.7	92.5	84.1	88.3
Pelo	46.3	61.7	54.0	86.5	71.4	78.9
	48.7	65.7	57.2	71.5	57.4	64.5
	48.1	61.1		76.7	66.1	
LSD (.05)	N.S.		11.2	N.S.		16.3

*Pounds required to break a sod one foot wide and 1.5 inches thick.

†Pounds required to lift a flat of sod 198 $in.^2$ after a 4-week rooting period.

‡Bluegrass alone.

Table XXIII. Root strength* of one-year-old spring seeded (May 1969) Kentucky bluegrass-companion grass mixtures clipped to a 2-inch height.

Companion Grass	Percent Companion Grass (PLS)		
	5	10	20
	Root strength, lbs.*		
None†	66.5	-----	-----
Redtop	57.5	68.1	79.3
C. R. Fescue	59.7	69.1	76.5
A. Ryegrass	84.1	59.8	116.6
Pelo	71.4	110.0	97.6
NK-100	57.4	91.8	74.0
LSD (.05) 27.3			

*Pounds required to lift a flat of sod (198 in^2) after a 4-week rooting period.

†Bluegrass alone.

Table XXIV. The effects of ryegrass seed and seedling association on germination, root length, and shoot length of Kentucky bluegrass.

No Seeds		Days after Seeding								
Bluegrass	Other	13	19	21	13	19	21	13	19	21
		Germination (%)			Root length (mm)			Shoot length (mm)		
100	0	39.0	62.0	74.0	2.9	7.8	10.9	1.5	10.2	14.2
60	30 A.R.*	50.8	70.8	77.0	4.9	9.0	11.3	4.7	9.6	13.0
60	30 N.K.†	55.0	70.0	74.5	4.6	9.4	12.1	3.7	10.3	14.9
50	40 A.R.	49.5	64.5	73.0	5.4	9.4	11.0	4.6	10.9	13.4
50	40 N.K.	53.5	72.5	79.5	4.4	7.4	11.3	3.9	8.7	12.7
F-value, N.S.										

*A.R. represents annual ryegrass.

†N.K. represents NK-100 perennial ryegrass.

NK-100 and annual ryegrass were about 55 and 78% longer than the control. After 21 days the length of bluegrass roots was similar for all treatments.

Although bluegrass shoot length tended to be longer on the 13th day when in association with the ryegrass, they were not significantly affected (Table XXIV).

Root Associations in Soil Media

Kentucky bluegrass top growth was not significantly influenced by the presence of annual or NK-100 ryegrass roots (Table XXV). Where the root systems of annual ryegrass and bluegrass were separated, the bluegrass foliage yield was 10% greater than when their roots were allowed to grow in the same area. But when the root systems of NK-100 and bluegrass were in contact, the yield of bluegrass foliage was 36% larger than where the two root systems were separated.

Table XXV. The influence of ryegrass root systems on Kentucky bluegrass topgrowth.

Treatment*		Average Daily Top Weight
		mg
Ryegrass	Roots separated	358
	Roots not separated	324
Ky. bluegrass (100%)		422
Perennial Ryegrass	Roots separated	364
	Roots not separated	496
		F-value, N.S.

*Kentucky bluegrass was seeded in one-half of each container with the ryegrass in the other one-half.

DISCUSSION

Companion grasses are often used in turf seedings to provide a ground cover quickly and as insurance against failures because of pests or poor adaptation of some species (Blaser, 1964; Davis, 1967). Aggressive companion seedlings often eliminate many slower growing seedlings of the desirable grasses, and the subsequent lack of persistence of many companion grasses may cause bare areas, variable color and texture, and pollution from soil erosion. In mixed plant communities with dense stands, certain species tend to dominate the sward through plant succession. Plant succession has been attributed to two general categories: (1) natural plant growth inhibitors, and (2) competition attributed to morphological and physiological interrelationships.

Some researchers have suggested that natural plant growth inhibitors play a role in plant competition (Ahlgren and Aamodt, 1939; Osvald, 1949). However, results in this thesis from incubating bluegrass seed in association with annual and perennial ryegrasses indicated that there were minor effects on bluegrass germination and root and shoot length. Also, there was no reduction of bluegrass top growth when its roots grew in association with annual and NK-100 ryegrass in soil medias. The slightly beneficial stimulation of young bluegrass in the incubation study could have been attributed to excreted sugars (Brown et al., 1949) of ryegrass seeds or seedlings. Since there was no evidence of harmful inhibitory substances when seeds were incubated together, it is very unlikely that such inhibitors could be a factor in

field conditions where there are dilution effects.

In these investigations the botanical shift among the turf mixtures during establishment was apparently caused by morphological and physiological factors and their interplay. It is generally conceded that the differential responses among herbaceous species to imposed and natural environment are major factors in plant succession (Blaser et al., 1952; Donald, 1963).

Of the companion grasses studied, annual ryegrass was the most competitive during the seedling stage toward Kentucky bluegrass becuase of its quick germination and rapid growth. The improved perennial ryegrasses (NK-100 and Pelo) germinated as quickly as annual ryegrass, but they were less aggressive because of less seedling vigor. The fast growth of ryegrass seedlings has been attributed to large caryopsis in seeds and genetic factors (Blaser et al., 1952).

Kentucky bluegrass seeds are small, and according to Daniel (1958), they have enough carbohydrate reserves to grow plants 1/2 to 3/4 inch high; thereafter, survival and growth of the seedlings depends on photosynthates. Bluegrass seedling weights from the fall-seeded mixtures with ryegrasses, at 4 to 5 weeks of age, were depressed and the foliage was etiolated, especially in the mixtures with annual ryegrass. The etiolation was more severe with added increments of ryegrass because of more shading with the higher ryegrass populations. Competition for light is recognized as a primary competitive factor in plant communities (Donald, 1963; Blaser et al., 1952). Nutrients and soil moisture were not likely competitive factors in this investigation because of liberal fertilization and irrigation during seedling

establishment.

Redtop and creeping red fescue were mild competitors, as they did not affect the weight or height of Kentucky bluegrass seedlings. Seedlings of these two species were similar to bluegrass in morphology and growth rate, thereby minimizing competition for light. Mixtures with redtop and creeping red fescue consistently had more bluegrass than the ryegrass-bluegrass mixtures; however, these two companion grasses did not generally improve ground cover and turf quality during early establishment as compared to bluegrass alone.

After one year there was generally more bluegrass in mixtures with redtop, creeping red fescue, and annual ryegrass than in mixtures with perennial ryegrass, which was a persistent competitor, especially with high clipping. Redtop and creeping red fescue were not aggressive after a year, and most of the annual ryegrass was killed by the temperature stresses (mainly winter) which allowed bluegrass to encroach readily.

Differential seedling populations also influence survival and plant succession (Donald, 1963). With constant rates of bluegrass, increasing the components of any companion grass generally reduced the bluegrass population because this augmented competition, but ground cover was generally improved. The added increments of redtop or creeping red fescue did not cause severe competition to bluegrass; however, annual and perennial ryegrasses almost exterminated the bluegrass seedlings during development. This severe competition caused a later decline in turf quality. Such declines in turf quality were partly attributed to reduced bluegrass populations and slow encroachment

because of dense stands of ryegrass. It is not known how NK-100 and Pelo would respond at a low seeding rate, but if they maintained their persistence and narrow, short stems and multiple tillers as reported by Kaerwer (1968), they could be effectively used at a low percentage in mixtures on lawns, playgrounds, and golf courses to provide ground cover and reduce soil erosion.

It has been a common practice to compound seed mixtures on a percent weight basis. In this research the individual companion grasses were included on the basis of 5, 10, and 20% pure live seed (PLS). If the ryegrass had been seeded at 5% weight basis, this would have corresponded to 1% PLS, which would have been about 36 PLS/ft.^{2}. Thus, relative to the weight basis of making seed mixtures, too much ryegrass and too little redtop seed was used (Table 1).

Because of the large differences in seed size, coupled with inherent differences among species in viability, germination, emergence, survival, and aggressiveness of seedlings, it appears that seed mixtures should be designed to obtain designated populations of companion and other grass seedlings. For example, when considering the aforementioned factors, it seems evident that competition from 180, 360, and 720 seedlings/ft.^{2} for the 5, 10, and 20% PLS, respectively, would have been too severe, even at 5% PLS. When considering emergence factors and morphological development of seedlings, it appears that the companion grass components should have been varied with species. This contention is based on the fact that the higher seeding rates of creeping red fescue and redtop did not generally affect turf quality and bluegrass encroachment significantly.

The fall (Sept. 7) seeding generally gave the best bluegrass populations during the seedling stage and after one year, and summer seedings generally gave the poorest. Apparently soil and air temperatures during and after fall seeding (Fig. 1) were most favorable for bluegrass stands and seedling survival relative to companion grasses. The poor bluegrass stands in the summer seedings were attributed to poor emergence and slow seedling growth of bluegrass, relative to companion grasses, because of high summer temperatures. However, after one year there was no difference in the amount of bluegrass in spring and summer seeded mixtures because companion grasses tended to be more persistent after the spring seeding.

Mixtures with annual ryegrass were more persistent (after one year) when seeded in the spring and summer than in the fall, because these mixtures had reverted to 100% bluegrass due to the winter freezing and thawing (1968-69) that occurred immediately after fall seeding.

Mixtures with the perennial ryegrasses were most persistent and had the least bluegrass when summer seeded because they were well established before the summer stress (heat) which occurred 10-12 months after seeding. However, fall and spring seeded mixtures with the perennial ryegrasses were not as persistent at 1 in., as bluegrass did encroach.

The spring seeding favored creeping red fescue in its competitive relationship toward Kentucky bluegrass more than in the other seeding seasons, probably because creeping red fescue has lower optimum germination temperatures than bluegrass. There was not a complete shift to a bluegrass sod at any rate of seeding creeping red fescue (Davis, 1958); in fact, creeping red fescue tended to increase in the turf,

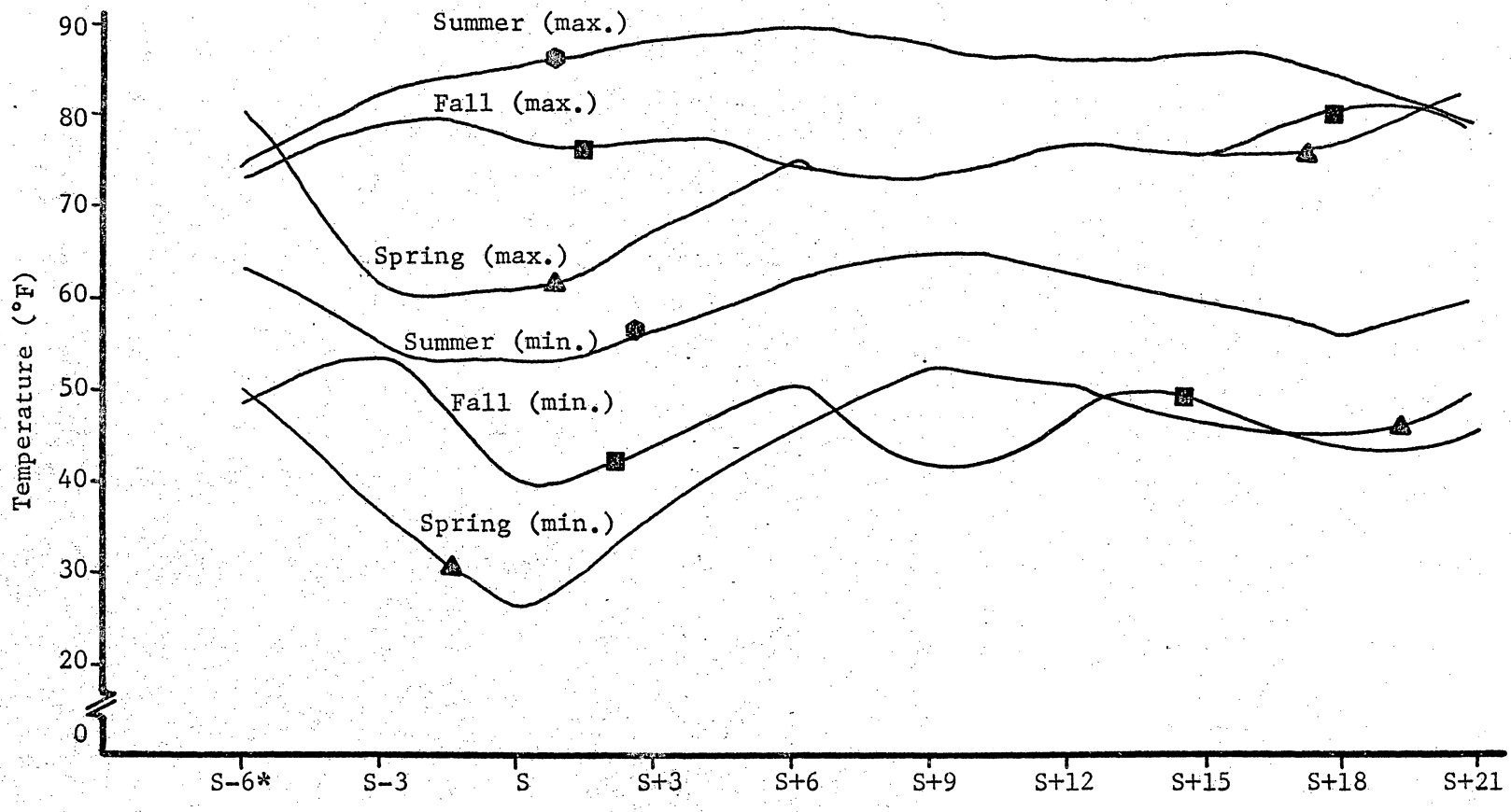

Fig. 1. The relationship between air temperatures and time of seeding several turfgrass mixtures in three seasons.

*S± is the number of days before or after seeding date (S) (average temperature for 3 days).

especially during the winter and early spring of each seeding. This was attributed to the earlier start of creeping red fescue in the spring than Merion bluegrass (Davis, 1967), and its more erect growth, allowing a greater percentage of stems and tillers to be observed relative to bluegrass.

Redtop exhibited its most competitive influence toward bluegrass in the summer seeding, at six weeks, primarily because of its tolerance (Musser, 1962) to temperature extremes and Kentucky bluegrass's less aggressive nature during late summer. The change from about 40% bluegrass at six weeks after summer seeding to 75% bluegrass at one year was due to the increase in bluegrass rhizomes and tillers during the spring and early summer of 1970 (9 to 12 months after seeding). Redtop was least competitive as a seedling in the spring seeding, but it became more aggressive with age in the spring seeding because of its tolerance to summer temperatures, relative to bluegrass.

High clipping left more leaf area on the plants; therefore, ground cover tended to be better than for low clipping, and turf quality of high clipped turf was generally best for mixtures containing redtop or creeping red fescue or the bluegrass blend. However, turf quality of the perennial ryegrasses was best at low clipping because leaf shredding was greatly reduced.

Low clipping generally favored Kentucky bluegrass in its competitive relationship with the companion grasses (Juska et al., 1956; Davis, 1958; Schmidt and Blaser, 1967). The bluegrass composition was altered least in mixtures with redtop and most in those of the perennial ryegrasses because of their morphological differences.

Apparently the perennial ryegrasses cannot tolerate low clipping during the summer months because bluegrass tended to encroach quite readily in the summer after fall and spring seedings. However, when the bluegrass composition was determined in May 1970 (sod one year after seeding), it was evident that there was a decrease in Ky. bluegrass population from the previous fall under low clipping. The bluegrass percentage did not change from the fall at high clipping because the perennial ryegrasses furnished some insulation, possibly making bluegrass more resistant to winter injury. The transition to larger percentage bluegrass at low clipping did not adversely affect the cover and quality of the turf.

The appearance, quality, and persistence of a turf is the ultimate test of a seed mixture. Results reported here indicate that there was no advantage of using companion grasses with bluegrass except for quick ground cover. After 3 to 6 months of good growing conditions, the bluegrass blend generally gave as good a ground cover and turf quality as any mixture with a companion grass. Turf quality of bluegrass-annual ryegrass mixtures was unacceptable because of its sparse and clumpy stand, except for one-year-old fall seedings. The turf quality of mixtures with perennial ryegrasses was inferior to bluegrass alone because of leaf shredding; however, perennial ryegrass, because of persistence and finer texture, gave a better turf than mixtures with annual ryegrass. Mixtures with redtop and creeping red fescue did not give an advantage in cover or quality over pure bluegrass because of morphological similarities.

Pure Kentucky bluegrass turf was tightly knitted and had the strongest sod, since sod strength depends on rhizome and root development (Beard and Rieke, 1969). However, the short rhizomes of the companion grasses and the high percentage of bluegrass in the turf of mixtures containing redtop and creeping red fescue possibly helped the handling characteristics and strength. The mixtures with perennial ryegrass lacked rhizomes and knitted tillers, since there was little bluegrass in the turf; thus they provided the weakest sod. Although mixtures with annual ryegrass had reverted to pure bluegrass, the turf was loose, thin, and unsuitable for handling.

Sod strength and rooting ability were best for mixtures clipped at two inches, because low clipping evidently reduced rhizomes, tillers, and root development (Juska and Hanson, 1961; Loberstein and Daniel, 1962).

Although the sod strength of mixtures with perennial ryegrass was poorest, their root strength was superior to other mixtures. Almost all mixtures tended to increase root strength over pure bluegrass, and this should be considered when preparing seedings for sod production. The improved rooting ability of the mixtures could be effectively utilized when sod is used on slopes, such as highway embankments.

The only apparent differences between the fall and spring seeding seasons was that pure Kentucky bluegrass sod strength from spring seeded turf was not better than other mixtures, except annual ryegrass. Sod strength of spring seeded mixtures containing perennial ryegrass was better, relative to pure bluegrass sod, than in fall seeding.

SUMMARY AND CONCLUSIONS

An experiment was conducted to investigate the rapidity of turf development and subsequent turf quality of various aggressive grasses seeded at three rates with Kentucky bluegrass in fall, spring, and summer seedings and clipped at two cutting heights. Irrigation was provided during seedling establishment and thereafter when needed. Botanical composition, ground cover, and turf quality were determined periodically. Sod strength and rooting ability of the mixtures were measured. Experiments were conducted to find if plant growth inhibitors from ryegrass influenced bluegrass.

Annual ryegrass as a companion grass with bluegrass did not improve the initial cover over NK-100 or Pelo perennial ryegrasses, and aesthetic values of turf with annual ryegrass were poor. Annual and perennial ryegrasses were very competitive toward Kentucky bluegrass due to physiological and morphological responses, because there was no evidence of inhibitory exudations from ryegrass.

Although one year after fall seeding mixtures of annual ryegrass there was 100% bluegrass in the plots (cover 80-88%), the turf quality and ground cover throughout the winter and spring after seeding were entirely unacceptable, because of lack of persistence and thin, clumpy turf. Annual ryegrass is not tolerant of temperature stresses, especially in early ontogeny.

Mixtures of bluegrass-perennial ryegrass (Pelo and NK-100) provided an excellent ground cover soon after seeding, although turf quality was generally inferior to bluegrass alone, but better than mixtures with annual ryegrass because of the relative uniformity in texture, color,

and persistence. Leaf tip shredding of the perennial ryegrasses, especially at two-inch clipping, was objectionable.

The two perennial ryegrasses were winter hardy, but they appeared less tolerant of summer environments, especially at the one-inch clipping. The latter could be a disadvantage under heavy turf useage, or an advantage with proper management, in shifting to a bluegrass turf.

Creeping red fescue and redtop were the least competitive toward bluegrass encroachment, and they generally did not improve the initial cover over the bluegrass blend. These companion grasses with bluegrass gave a turf quality similar to the bluegrass blend throughout the study. Mixtures of creeping red fescue tended to be better than redtop because of finer texture and a more uniform color. Redtop tended to become noticeable with age.

Bluegrass alone generally produced a good turf the first year after seeding.

Added increments of companion grasses usually produced quicker ground cover.

The initial turf quality during establishment was usually inversely related to the seeding rates of the ryegrasses and directly related to the seeding rates of redtop or creeping red fescue. With time, the seeding rates of companion grasses were less influential, especially with redtop and creeping red fescue.

Increased seeding rates of companion grasses generally reduced the percentage of bluegrass in the mixtures. There was no advantage to seeding more than 5% PLS of any of the companion grasses with bluegrass.

The fall seeding season was the best for establishing bluegrass, as there was significantly larger percentage bluegrass at six weeks and after one year. Although there was significantly more bluegrass in spring than in summer seedings at six weeks, there were no significant differences at one year. This was attributed to more encroachment of bluegrass in the summer than in the spring seeding, as the companion grasses tended to be slightly more persistent in the spring seeding than for the summer seedings.

High clipping left more leaf area, which gave a better ground cover than for the low clipping. The high clipping usually resulted in the best turf quality of bluegrass alone and in mixtures with redtop and creeping red fescue because of a desirable dense turf with a good color. Turf quality was initially best for high clipping of the ryegrasses because the low clipping removed large amounts of leaf area until the plants "adjusted" to clipping. On the other hand, low clipping reduced leaf shredding of the perennial ryegrasses.

Generally, low clipping favored bluegrass encroachment because the companion grasses were not persistent at one-inch clipping, but there was also significant interactions between clipping heights and date of seeding, and clipping heights and companion grasses.

Pure Kentucky bluegrass tended to have the best sod strength and the poorest rooting ability, whereas the reverse was true for bluegrass-perennial ryegrass mixtures. NK-100 and Pelo ryegrasses may have a place in the sod industry because they have better rooting ability than bluegrass. Such sod may be effectively used on areas where erosion is a severe problem, as with highway embankments.

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THE EFFECTS ON RAPID ESTABLISHMENT AND SUBSEQUENT TURF QUALITY OF AGGRESSIVE GRASSES SEEDED WITH POA PRATENSIS L.

James T. Green, Jr.

Abstract

Field experiments were established on September 7, 1968, and May 13 and July 16, 1969, by seeding three rates (on pure live seed basis [PLS]) of several companion grasses with a constant rate of Kentucky bluegrass (Poa pratensis L.). Mixtures were irrigated and clipped to 1- and 2-in. sod residues. Objectives were to determine which mixture or mixtures could provide rapid initial establishment with subsequent high quality, permanent turf. The improved perennial ryegrasses (Lolium perenne L.) (NK-100 and Pelo) were no more competitive in the seedling stage toward Kentucky bluegrass (Poa pratensis L.) than annual ryegrass (Lolium multiflorum L.), but they provided as rapid initial cover. However, their persistence provides a means for bluegrass encroachment during the seedling year. Seedling competition was not due to any excretions from ryegrass seeds or seedlings. Turf quality of the improved perennials was superior to annual ryegrass, but slightly lower than pure bluegrass, because of frayed leaf tips. Redtop (Agrostis alba L.) and creeping red fescue (Festuca rubra L.) were less competitive to bluegrass than the ryegrasses, but they provided little advantage in ground cover; however, turf quality was similar to pure bluegrass.

It was concluded that mixtures should be designed to obtain designated populations of companion and other seedlings that are needed for sufficient initial cover. The 5% PLS in this study was higher than normally recommended on a weight basis; therefore there was no advantage from higher seeding rates.

Fall seeded mixtures generally contained the most Kentucky bluegrass, and the summer seedings had the least.

Low clipping reduced competition from companion grasses, especially the improved perennial ryegrasses, which allowed a uniform transition toward bluegrass dominance with turf of average quality.

Sod strength was best for the pure bluegrass turf, but root development of the improved perennial ryegrasses was best.